What's New in Python

Release 3.7.0

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This article explains the new features in Python 3.7, compared to 3.6. Python 3.7 was released on June 27, 2018. For full details, see the changelog.

1 Summary – Release Highlights

New syntax features:

- *PEP 563*, postponed evaluation of type annotations.

Backwards incompatible syntax changes:

- `async` and `await` are now reserved keywords.

New library modules:

- `contextvars`: *PEP 567 – Context Variables*
- `dataclasses`: *PEP 557 – Data Classes*
- *importlib.resources*

New built-in features:

- *PEP 553*, the new `breakpoint()` function.

Python data model improvements:

- *PEP 562*, customization of access to module attributes.
- *PEP 560*, core support for typing module and generic types.
- the insertion-order preservation nature of dict objects has been declared to be an official part of the Python language spec.

Significant improvements in the standard library:

- The `asyncio` module has received new features, significant *usability and performance improvements*.
- The `time` module gained support for *functions with nanosecond resolution*.

CPython implementation improvements:

- Avoiding the use of ASCII as a default text encoding:
  - *PEP 538*, legacy C locale coercion
  - *PEP 540*, forced UTF-8 runtime mode
- *PEP 552*, deterministic .pycs
- *the new development runtime mode*
- *PEP 565*, improved `DeprecationWarning` handling

C API improvements:

- *PEP 539*, new C API for thread-local storage

Documentation improvements:

- *PEP 545*, Python documentation translations
- New documentation translations: Japanese, French, and Korean.

This release features notable performance improvements in many areas. The *Optimizations* section lists them in detail.

For a list of changes that may affect compatibility with previous Python releases please refer to the *Porting to Python 3.7* section.

2 New Features

2.1 PEP 563: Postponed Evaluation of Annotations

The advent of type hints in Python uncovered two glaring usability issues with the functionality of annotations added in **PEP 3107** and refined further in **PEP 526**:

- annotations could only use names which were already available in the current scope, in other words they didn't support forward references of any kind; and
- annotating source code had adverse effects on startup time of Python programs.

Both of these issues are fixed by postponing the evaluation of annotations. Instead of compiling code which executes expressions in annotations at their definition time, the compiler stores the annotation in a string form equivalent to the AST of the expression in question. If needed, annotations can be resolved at runtime using `typing.get_type_hints()`. In the common case where this is not required, the annotations are cheaper to store (since short strings are interned by the interpreter) and make startup time faster.

Usability-wise, annotations now support forward references, making the following syntax valid:

```
class C:
    @classmethod
    def from_string(cls, source: str) -> C:
        ...

    def validate_b(self, obj: B) -> bool:
        ...

class B:
    ...
```

Since this change breaks compatibility, the new behavior needs to be enabled on a per-module basis in Python 3.7 using a `__future__` import:

```
from __future__ import annotations
```

It will become the default in Python 4.0.

See also:

PEP 563 – **Postponed evaluation of annotations** PEP written and implemented by Łukasz Langa.

2.2 PEP 538: Legacy C Locale Coercion

An ongoing challenge within the Python 3 series has been determining a sensible default strategy for handling the "7-bit ASCII" text encoding assumption currently implied by the use of the default C or POSIX locale on non-Windows platforms.

PEP 538 updates the default interpreter command line interface to automatically coerce that locale to an available UTF-8 based locale as described in the documentation of the new `PYTHONCOERCECLOCALE` environment variable. Automatically setting `LC_CTYPE` this way means that both the core interpreter and locale-aware C extensions (such as `readline`) will assume the use of UTF-8 as the default text encoding, rather than ASCII.

The platform support definition in **PEP 11** has also been updated to limit full text handling support to suitably configured non-ASCII based locales.

As part of this change, the default error handler for `stdin` and `stdout` is now `surrogateescape` (rather than `strict`) when using any of the defined coercion target locales (currently `C.UTF-8`, `C.utf8`, and `UTF-8`). The default error handler for `stderr` continues to be `backslashreplace`, regardless of locale.

Locale coercion is silent by default, but to assist in debugging potentially locale related integration problems, explicit warnings (emitted directly on `stderr`) can be requested by setting `PYTHONCOERCECLOCALE=warn`. This setting will also cause the Python runtime to emit a warning if the legacy C locale remains active when the core interpreter is initialized.

While **PEP 538**'s locale coercion has the benefit of also affecting extension modules (such as GNU `readline`), as well as child processes (including those running non-Python applications and older versions of Python), it has the downside of requiring that a suitable target locale be present on the running system. To better handle the case where no suitable target locale is available (as occurs on RHEL/CentOS 7, for example), Python 3.7 also implements *PEP 540: Forced UTF-8 Runtime Mode*.

See also:

PEP 538 – **Coercing the legacy C locale to a UTF-8 based locale** PEP written and implemented by Nick Coghlan.

2.3 PEP 540: Forced UTF-8 Runtime Mode

The new `-X utf8` command line option and `PYTHONUTF8` environment variable can be used to enable the CPython *UTF-8 mode*.

When in UTF-8 mode, CPython ignores the locale settings, and uses the UTF-8 encoding by default. The error handlers for `sys.stdin` and `sys.stdout` streams are set to `surrogateescape`.

The forced UTF-8 mode can be used to change the text handling behavior in an embedded Python interpreter without changing the locale settings of an embedding application.

While **PEP 540**'s UTF-8 mode has the benefit of working regardless of which locales are available on the running system, it has the downside of having no effect on extension modules (such as GNU `readline`), child processes running non-Python applications, and child processes running older versions of Python. To reduce the risk of corrupting text data when communicating with such components, Python 3.7 also implements *PEP 540: Forced UTF-8 Runtime Mode*).

The UTF-8 mode is enabled by default when the locale is `C` or `POSIX`, and the **PEP 538** locale coercion feature fails to change it to a UTF-8 based alternative (whether that failure is due to `PYTHONCOERCECLOCALE=0` being set, `LC_ALL` being set, or the lack of a suitable target locale).

See also:

PEP 540 – **Add a new UTF-8 mode** PEP written and implemented by Victor Stinner

2.4 PEP 553: Built-in `breakpoint()`

Python 3.7 includes the new built-in `breakpoint()` function as an easy and consistent way to enter the Python debugger.

Built-in `breakpoint()` calls `sys.breakpointhook()`. By default, the latter imports `pdb` and then calls `pdb.set_trace()`, but by binding `sys.breakpointhook()` to the function of your choosing, `breakpoint()` can enter any debugger. Additionally, the environment variable `PYTHONBREAKPOINT` can be set to the callable of your debugger of choice. Set `PYTHONBREAKPOINT=0` to completely disable built-in `breakpoint()`.

See also:

PEP 553 – **Built-in breakpoint()** PEP written and implemented by Barry Warsaw

2.5 PEP 539: New C API for Thread-Local Storage

While Python provides a C API for thread-local storage support; the existing Thread Local Storage (TLS) API has used `int` to represent TLS keys across all platforms. This has not generally been a problem for officially-support platforms, but that is neither POSIX-compliant, nor portable in any practical sense.

PEP 539 changes this by providing a new Thread Specific Storage (TSS) API to CPython which supersedes use of the existing TLS API within the CPython interpreter, while deprecating the existing API. The TSS API uses a new type `Py_tss_t` instead of `int` to represent TSS keys–an opaque type the definition of which may depend on the underlying TLS implementation. Therefore, this will allow to build CPython on platforms where the native TLS key is defined in a way that cannot be safely cast to `int`.

Note that on platforms where the native TLS key is defined in a way that cannot be safely cast to `int`, all functions of the existing TLS API will be no-op and immediately return failure. This indicates clearly that the old API is not supported on platforms where it cannot be used reliably, and that no effort will be made to add such support.

See also:

PEP 539 – **A New C-API for Thread-Local Storage in CPython** PEP written by Erik M. Bray; implementation by Masayuki Yamamoto.

2.6 PEP 562: Customization of Access to Module Attributes

Python 3.7 allows defining `__getattr__()` on modules and will call it whenever a module attribute is otherwise not found. Defining `__dir__()` on modules is now also allowed.

A typical example of where this may be useful is module attribute deprecation and lazy loading.

See also:

PEP 562 – **Module `__getattr__` and `__dir__`** PEP written and implemented by Ivan Levkivskyi

2.7 PEP 564: New Time Functions With Nanosecond Resolution

The resolution of clocks in modern systems can exceed the limited precision of a floating point number returned by the `time.time()` function and its variants. To avoid loss of precision, **PEP 564** adds six new "nanosecond" variants of the existing timer functions to the `time` module:

- `time.clock_gettime_ns()`
- `time.clock_settime_ns()`
- `time.monotonic_ns()`
- `time.perf_counter_ns()`
- `time.process_time_ns()`
- `time.time_ns()`

The new functions return the number of nanoseconds as an integer value.

Measurements show that on Linux and Windows the resolution of `time.time_ns()` is approximately 3 times better than that of `time.time()`.

See also:

PEP 564 – **Add new time functions with nanosecond resolution** PEP written and implemented by Victor Stinner

2.8 PEP 565: Show DeprecationWarning in `__main__`

The default handling of `DeprecationWarning` has been changed such that these warnings are once more shown by default, but only when the code triggering them is running directly in the `__main__` module. As a result, developers of single file scripts and those using Python interactively should once again start seeing deprecation warnings for the APIs they use, but deprecation warnings triggered by imported application, library and framework modules will continue to be hidden by default.

As a result of this change, the standard library now allows developers to choose between three different deprecation warning behaviours:

- `FutureWarning`: always displayed by default, recommended for warnings intended to be seen by application end users (e.g. for deprecated application configuration settings).
- `DeprecationWarning`: displayed by default only in `__main__` and when running tests, recommended for warnings intended to be seen by other Python developers where a version upgrade may result in changed behaviour or an error.
- `PendingDeprecationWarning`: displayed by default only when running tests, intended for cases where a future version upgrade will change the warning category to `DeprecationWarning` or `FutureWarning`.

Previously both `DeprecationWarning` and `PendingDeprecationWarning` were only visible when running tests, which meant that developers primarily writing single file scripts or using Python interactively could be surprised by breaking changes in the APIs they used.

See also:

PEP 565 – **Show DeprecationWarning in `__main__`** PEP written and implemented by Nick Coghlan

2.9 PEP 560: Core Support for `typing` module and Generic Types

Initially **PEP 484** was designed in such way that it would not introduce *any* changes to the core CPython interpreter. Now type hints and the `typing` module are extensively used by the community, so this restriction is removed. The PEP introduces two special methods `__class_getitem__()` and `__mro_entries__`, these methods are now used by most classes and special constructs in `typing`. As a result, the speed of various operations with types increased up to 7 times, the generic types can be used without metaclass conflicts, and several long standing bugs in `typing` module are fixed.

See also:

PEP 560 – **Core support for typing module and generic types** PEP written and implemented by Ivan Levkivskyi

2.10 PEP 552: Hash-based .pyc Files

Python has traditionally checked the up-to-dateness of bytecode cache files (i.e., `.pyc` files) by comparing the source metadata (last-modified timestamp and size) with source metadata saved in the cache file header when it was generated. While effective, this invalidation method has its drawbacks. When filesystem timestamps are too coarse, Python can miss source updates, leading to user confusion. Additionally, having a timestamp in the cache file is problematic for build reproduciblity and content-based build systems.

PEP 552 extends the pyc format to allow the hash of the source file to be used for invalidation instead of the source timestamp. Such `.pyc` files are called "hash-based". By default, Python still uses timestamp-based invalidation and does not generate hash-based `.pyc` files at runtime. Hash-based `.pyc` files may be generated with `py_compile` or `compileall`.

Hash-based `.pyc` files come in two variants: checked and unchecked. Python validates checked hash-based `.pyc` files against the corresponding source files at runtime but doesn't do so for unchecked hash-based pycs.

Unchecked hash-based `.pyc` files are a useful performance optimization for environments where a system external to Python (e.g., the build system) is responsible for keeping `.pyc` files up-to-date.

See pyc-invalidation for more information.

See also:

PEP 552 – **Deterministic pycs** PEP written and implemented by Benjamin Peterson

2.11 PEP 545: Python Documentation Translations

PEP 545 describes the process of creating and maintaining Python documentation translations.

Three new translations have been added:

- Japanese: https://docs.python.org/ja/
- French: https://docs.python.org/fr/
- Korean: https://docs.python.org/ko/

See also:

PEP 545 – **Python Documentation Translations** PEP written and implemented by Julien Palard, Inada Naoki, and Victor Stinner.

2.12 Development Runtime Mode: -X dev

The new `-X dev` command line option or the new `PYTHONDEVMODE` environment variable can be used to enable CPython's *development mode*. When in development mode, CPython performs additional runtime checks that are too expensive to be enabled by default. See `-X dev` documentation for the full description of the effects of this mode.

3 Other Language Changes

- More than 255 arguments can now be passed to a function, and a function can now have more than 255 parameters. (Contributed by Serhiy Storchaka in bpo-12844 and bpo-18896.)
- `bytes.fromhex()` and `bytearray.fromhex()` now ignore all ASCII whitespace, not only spaces. (Contributed by Robert Xiao in bpo-28927.)
- `str`, `bytes`, and `bytearray` gained support for the new `isascii()` method, which can be used to test if a string or bytes contain only the ASCII characters. (Contributed by INADA Naoki in bpo-32677.)
- `ImportError` now displays module name and module `__file__` path when `from ... import ...` fails. (Contributed by Matthias Bussonnier in bpo-29546.)
- Circular imports involving absolute imports with binding a submodule to a name are now supported. (Contributed by Serhiy Storchaka in bpo-30024.)
- `object.__format__(x, '')` is now equivalent to `str(x)` rather than `format(str(self), '')`. (Contributed by Serhiy Storchaka in bpo-28974.)
- In order to better support dynamic creation of stack traces, `types.TracebackType` can now be instantiated from Python code, and the `tb_next` attribute on tracebacks is now writable. (Contributed by Nathaniel J. Smith in bpo-30579.)
- When using the `-m` switch, `sys.path[0]` is now eagerly expanded to the full starting directory path, rather than being left as the empty directory (which allows imports from the *current* working directory at the time when an import occurs) (Contributed by Nick Coghlan in bpo-33053.)

- The new `-X importtime` option or the `PYTHONPROFILEIMPORTTIME` environment variable can be used to show the timing of each module import. (Contributed by Victor Stinner in bpo-31415.)

4 New Modules

4.1 contextvars

The new `contextvars` module and a set of new C APIs introduce support for *context variables*. Context variables are conceptually similar to thread-local variables. Unlike TLS, context variables support asynchronous code correctly.

The `asyncio` and `decimal` modules have been updated to use and support context variables out of the box. Particularly the active decimal context is now stored in a context variable, which allows decimal operations to work with the correct context in asynchronous code.

See also:

PEP 567 – **Context Variables** PEP written and implemented by Yury Selivanov

4.2 dataclasses

The new `dataclass()` decorator provides a way to declare *data classes*. A data class describes its attributes using class variable annotations. Its constructor and other magic methods, such as `__repr__()`, `__eq__()`, and `__hash__()` are generated automatically.

Example:

```
@dataclass
class Point:
    x: float
    y: float
    z: float = 0.0

p = Point(1.5, 2.5)
print(p)   # produces "Point(x=1.5, y=2.5, z=0.0)"
```

See also:

PEP 557 – **Data Classes** PEP written and implemented by Eric V. Smith

4.3 importlib.resources

The new `importlib.resources` module provides several new APIs and one new ABC for access to, opening, and reading *resources* inside packages. Resources are roughly similar to files inside packages, but they needn't be actual files on the physical file system. Module loaders can provide a `get_resource_reader()` function which returns a `importlib.abc.ResourceReader` instance to support this new API. Built-in file path loaders and zip file loaders both support this.

Contributed by Barry Warsaw and Brett Cannon in bpo-32248.

See also:

importlib_resources – a PyPI backport for earlier Python versions.

5 Improved Modules

5.1 argparse

The new `ArgumentParser.parse_intermixed_args()` method allows intermixing options and positional arguments. (Contributed by paul.j3 in bpo-14191.)

5.2 asyncio

The `asyncio` module has received many new features, usability and *performance improvements*. Notable changes include:

- The new provisional `asyncio.run()` function can be used to run a coroutine from synchronous code by automatically creating and destroying the event loop. (Contributed by Yury Selivanov in bpo-32314.)
- asyncio gained support for `contextvars`. `loop.call_soon()`, `loop.call_soon_threadsafe()`, `loop.call_later()`, `loop.call_at()`, and `Future.add_done_callback()` have a new optional keyword-only *context* parameter. `Tasks` now track their context automatically. See **PEP 567** for more details. (Contributed by Yury Selivanov in bpo-32436.)
- The new `asyncio.create_task()` function has been added as a shortcut to `asyncio.get_event_loop().create_task()`. (Contributed by Andrew Svetlov in bpo-32311.)
- The new `loop.start_tls()` method can be used to upgrade an existing connection to TLS. (Contributed by Yury Selivanov in bpo-23749.)
- The new `loop.sock_recv_into()` method allows reading data from a socket directly into a provided buffer making it possible to reduce data copies. (Contributed by Antoine Pitrou in bpo-31819.)
- The new `asyncio.current_task()` function returns the currently running `Task` instance, and the new `asyncio.all_tasks()` function returns a set of all existing `Task` instances in a given loop. The `Task.current_task()` and `Task.all_tasks()` methods have been deprecated. (Contributed by Andrew Svetlov in bpo-32250.)
- The new *provisional* `BufferedProtocol` class allows implementing streaming protocols with manual control over the receive buffer. (Contributed by Yury Selivanov in bpo-32251.)
- The new `asyncio.get_running_loop()` function returns the currently running loop, and raises a `RuntimeError` if no loop is running. This is in contrast with `asyncio.get_event_loop()`, which will *create* a new event loop if none is running. (Contributed by Yury Selivanov in bpo-32269.)
- The new `StreamWriter.wait_closed()` coroutine method allows waiting until the stream writer is closed. The new `StreamWriter.is_closing()` method can be used to determine if the writer is closing. (Contributed by Andrew Svetlov in bpo-32391.)
- The new `loop.sock_sendfile()` coroutine method allows sending files using `os.sendfile` when possible. (Contributed by Andrew Svetlov in bpo-32410.)
- The new `Task.get_loop()` and `Future.get_loop()` methods return the instance of the loop on which a task or a future were created. `Server.get_loop()` allows doing the same for `asyncio.Server` objects. (Contributed by Yury Selivanov in bpo-32415 and Srinivas Reddy Thatiparthy in bpo-32418.)
- It is now possible to control how instances of `asyncio.Server` begin serving. Previously, the server would start serving immediately when created. The new *start_serving* keyword argument to `loop.create_server()` and `loop.create_unix_server()`, as well as `Server.start_serving()`, and `Server.serve_forever()` can be used to decouple server instantiation and serving. The new `Server.is_serving()` method returns `True` if the server is serving. `Server` objects are now asynchronous context managers:

```
srv = await loop.create_server(...)

async with srv:
    # some code

# At this point, srv is closed and no longer accepts new connections.
```

(Contributed by Yury Selivanov in bpo-32662.)

- Callback objects returned by `loop.call_later()` gained the new `when()` method which returns an absolute scheduled callback timestamp. (Contributed by Andrew Svetlov in bpo-32741.)
- The `loop.create_datagram_endpoint()` method gained support for Unix sockets. (Contributed by Quentin Dawans in bpo-31245.)
- The `asyncio.open_connection()`, `asyncio.start_server()` functions, `loop.create_connection()`, `loop.create_server()`, `loop.create_accepted_socket()` methods and their corresponding UNIX socket variants now accept the *ssl_handshake_timeout* keyword argument. (Contributed by Neil Aspinall in bpo-29970.)
- The new `Handle.cancelled()` method returns `True` if the callback was cancelled. (Contributed by Marat Sharafutdinov in bpo-31943.)
- The asyncio source has been converted to use the `async`/`await` syntax. (Contributed by Andrew Svetlov in bpo-32193.)
- The new `ReadTransport.is_reading()` method can be used to determine the reading state of the transport. Additionally, calls to `ReadTransport.resume_reading()` and `ReadTransport.pause_reading()` are now idempotent. (Contributed by Yury Selivanov in bpo-32356.)
- Loop methods which accept socket paths now support passing path-like objects. (Contributed by Yury Selivanov in bpo-32066.)
- In `asyncio` TCP sockets on Linux are now created with `TCP_NODELAY` flag set by default. (Contributed by Yury Selivanov and Victor Stinner in bpo-27456.)
- Exceptions occurring in cancelled tasks are no longer logged. (Contributed by Yury Selivanov in bpo-30508.)
- New `WindowsSelectorEventLoopPolicy` and `WindowsProactorEventLoopPolicy` classes. (Contributed by Yury Selivanov in bpo-33792.)

Several `asyncio` APIs have been *deprecated*.

5.3 binascii

The `b2a_uu()` function now accepts an optional *backtick* keyword argument. When it's true, zeros are represented by `'`'` instead of spaces. (Contributed by Xiang Zhang in bpo-30103.)

5.4 calendar

The `HTMLCalendar` class has new class attributes which ease the customization of CSS classes in the produced HTML calendar. (Contributed by Oz Tiram in bpo-30095.)

5.5 collections

`collections.namedtuple()` now supports default values. (Contributed by Raymond Hettinger in bpo-32320.)

5.6 compileall

`compileall.compile_dir()` learned the new *invalidation_mode* parameter, which can be used to enable *hash-based .pyc invalidation*. The invalidation mode can also be specified on the command line using the new `--invalidation-mode` argument. (Contributed by Benjamin Peterson in bpo-31650.)

5.7 concurrent.futures

`ProcessPoolExecutor` and `ThreadPoolExecutor` now support the new *initializer* and *initargs* constructor arguments. (Contributed by Antoine Pitrou in bpo-21423.)

The `ProcessPoolExecutor` can now take the multiprocessing context via the new *mp_context* argument. (Contributed by Thomas Moreau in bpo-31540.)

5.8 contextlib

The new `nullcontext()` is a simpler and faster no-op context manager than `ExitStack`. (Contributed by Jesse-Bakker in bpo-10049.)

The new `asynccontextmanager()`, `AbstractAsyncContextManager`, and `AsyncExitStack` have been added to complement their synchronous counterparts. (Contributed by Jelle Zijlstra in bpo-29679 and bpo-30241, and by Alexander Mohr and Ilya Kulakov in bpo-29302.)

5.9 cProfile

The `cProfile` command line now accepts `-m module_name` as an alternative to script path. (Contributed by Sanyam Khurana in bpo-21862.)

5.10 crypt

The `crypt` module now supports the Blowfish hashing method. (Contributed by Serhiy Storchaka in bpo-31664.)

The `mksalt()` function now allows specifying the number of rounds for hashing. (Contributed by Serhiy Storchaka in bpo-31702.)

5.11 datetime

The new `datetime.fromisoformat()` method constructs a `datetime` object from a string in one of the formats output by `datetime.isoformat()`. (Contributed by Paul Ganssle in bpo-15873.)

The `tzinfo` class now supports sub-minute offsets. (Contributed by Alexander Belopolsky in bpo-5288.)

5.12 dbm

`dbm.dumb` now supports reading read-only files and no longer writes the index file when it is not changed.

5.13 decimal

The `decimal` module now uses *context variables* to store the decimal context. (Contributed by Yury Selivanov in bpo-32630.)

5.14 dis

The `dis()` function is now able to disassemble nested code objects (the code of comprehensions, generator expressions and nested functions, and the code used for building nested classes). The maximum depth of disassembly recursion is controlled by the new *depth* parameter. (Contributed by Serhiy Storchaka in bpo-11822.)

5.15 distutils

`README.rst` is now included in the list of distutils standard READMEs and therefore included in source distributions. (Contributed by Ryan Gonzalez in bpo-11913.)

5.16 enum

The `Enum` learned the new `_ignore_` class property, which allows listing the names of properties which should not become enum members. (Contributed by Ethan Furman in bpo-31801.)

In Python 3.8, attempting to check for non-Enum objects in `Enum` classes will raise a `TypeError` (e.g. `1 in Color`); similarly, attempting to check for non-Flag objects in a `Flag` member will raise `TypeError` (e.g. `1 in Perm.RW`); currently, both operations return `False` instead and are deprecated. (Contributed by Ethan Furman in bpo-33217.)

5.17 functools

`functools.singledispatch()` now supports registering implementations using type annotations. (Contributed by Łukasz Langa in bpo-32227.)

5.18 gc

The new `gc.freeze()` function allows freezing all objects tracked by the garbage collector and excluding them from future collections. This can be used before a POSIX `fork()` call to make the GC copy-on-write friendly or to speed up collection. The new `gc.unfreeze()` functions reverses this operation. Additionally, `gc.get_freeze_count()` can be used to obtain the number of frozen objects. (Contributed by Li Zekun in bpo-31558.)

5.19 hmac

The `hmac` module now has an optimized one-shot `digest()` function, which is up to three times faster than `HMAC()`. (Contributed by Christian Heimes in bpo-32433.)

5.20 http.client

`HTTPConnection` and `HTTPSConnection` now support the new *blocksize* argument for improved upload throughput. (Contributed by Nir Soffer in bpo-31945.)

5.21 http.server

`SimpleHTTPRequestHandler` now supports the HTTP `If-Modified-Since` header. The server returns the 304 response status if the target file was not modified after the time specified in the header. (Contributed by Pierre Quentel in bpo-29654.)

`SimpleHTTPRequestHandler` accepts the new *directory* argument, in addition to the new `--directory` command line argument. With this parameter, the server serves the specified directory, by default it uses the current working directory. (Contributed by Stéphane Wirtel and Julien Palard in bpo-28707.)

The new `ThreadingHTTPServer` class uses threads to handle requests using `ThreadingMixin`. It is used when `http.server` is run with `-m`. (Contributed by Julien Palard in bpo-31639.)

5.22 idlelib and IDLE

Multiple fixes for autocompletion. (Contributed by Louie Lu in bpo-15786.)

Module Browser (on the File menu, formerly called Class Browser), now displays nested functions and classes in addition to top-level functions and classes. (Contributed by Guilherme Polo, Cheryl Sabella, and Terry Jan Reedy in bpo-1612262.)

The Settings dialog (Options, Configure IDLE) has been partly rewritten to improve both appearance and function. (Contributed by Cheryl Sabella and Terry Jan Reedy in multiple issues.)

The font sample now includes a selection of non-Latin characters so that users can better see the effect of selecting a particular font. (Contributed by Terry Jan Reedy in bpo-13802.) The sample can be edited to include other characters. (Contributed by Serhiy Storchaka in bpo-31860.)

The IDLE features formerly implemented as extensions have been reimplemented as normal features. Their settings have been moved from the Extensions tab to other dialog tabs. (Contributed by Charles Wohlganger and Terry Jan Reedy in bpo-27099.)

Editor code context option revised. Box displays all context lines up to maxlines. Clicking on a context line jumps the editor to that line. Context colors for custom themes is added to Highlights tab of Settings dialog. (Contributed by Cheryl Sabella and Terry Jan Reedy in bpo-33642, bpo-33768, and bpo-33679,

On Windows, a new API call tells Windows that tk scales for DPI. On Windows 8.1+ or 10, with DPI compatibility properties of the Python binary unchanged, and a monitor resolution greater than 96 DPI, this should make text and lines sharper. It should otherwise have no effect. (Contributed by Terry Jan Reedy in bpo-33656).

The changes above have been backported to 3.6 maintenance releases.

5.23 importlib

The `importlib.abc.ResourceReader` ABC was introduced to support the loading of resources from packages. See also *importlib.resources*. (Contributed by Barry Warsaw, Brett Cannon in bpo-32248.)

`importlib.reload()` now raises `ModuleNotFoundError` if the module lacks a spec. (Contributed by Garvit Khatri in bpo-29851.)

`importlib.find_spec()` now raises `ModuleNotFoundError` instead of `AttributeError` if the specified parent module is not a package (i.e. lacks a `__path__` attribute). (Contributed by Milan Oberkirch in bpo-30436.)

The new `importlib.source_hash()` can be used to compute the hash of the passed source. A *hash-based .pyc file* embeds the value returned by this function.

5.24 io

The new `TextIOWrapper.reconfigure()` method can be used to reconfigure the text stream with the new settings. (Contributed by Antoine Pitrou in bpo-30526 and INADA Naoki in bpo-15216.)

5.25 ipaddress

The new `subnet_of()` and `supernet_of()` methods of `ipaddress.IPv6Network` and `ipaddress.IPv4Network` can be used for network containment tests. (Contributed by Michel Albert and Cheryl Sabella in bpo-20825.)

5.26 itertools

`itertools.islice()` now accepts `integer-like objects` as start, stop, and slice arguments. (Contributed by Will Roberts in bpo-30537.)

5.27 locale

The new *monetary* argument to `locale.format_string()` can be used to make the conversion use monetary thousands separators and grouping strings. (Contributed by Garvit in bpo-10379.)

The `locale.getpreferredencoding()` function now always returns `'UTF-8'` on Android or when in the *forced UTF-8 mode*.

5.28 logging

`Logger` instances can now be pickled. (Contributed by Vinay Sajip in bpo-30520.)

The new `StreamHandler.setStream()` method can be used to replace the logger stream after handler creation. (Contributed by Vinay Sajip in bpo-30522.)

It is now possible to specify keyword arguments to handler constructors in configuration passed to `logging.config.fileConfig()`. (Contributed by Preston Landers in bpo-31080.)

5.29 math

The new `math.remainder()` function implements the IEEE 754-style remainder operation. (Contributed by Mark Dickinson in bpo-29962.)

5.30 mimetypes

The MIME type of .bmp has been changed from `'image/x-ms-bmp'` to `'image/bmp'`. (Contributed by Nitish Chandra in bpo-22589.)

5.31 msilib

The new `Database.Close()` method can be used to close the MSI database. (Contributed by Berker Peksag in bpo-20486.)

5.32 multiprocessing

The new `Process.close()` method explicitly closes the process object and releases all resources associated with it. `ValueError` is raised if the underlying process is still running. (Contributed by Antoine Pitrou in bpo-30596.)

The new `Process.kill()` method can be used to terminate the process using the `SIGKILL` signal on Unix. (Contributed by Vitor Pereira in bpo-30794.)

Non-daemonic threads created by `Process` are now joined on process exit. (Contributed by Antoine Pitrou in bpo-18966.)

5.33 os

`os.fwalk()` now accepts the *path* argument as `bytes`. (Contributed by Serhiy Storchaka in bpo-28682.)

`os.scandir()` gained support for file descriptors. (Contributed by Serhiy Storchaka in bpo-25996.)

The new `register_at_fork()` function allows registering Python callbacks to be executed at process fork. (Contributed by Antoine Pitrou in bpo-16500.)

Added `os.preadv()` (combine the functionality of `os.readv()` and `os.pread()`) and `os.pwritev()` functions (combine the functionality of `os.writev()` and `os.pwrite()`). (Contributed by Pablo Galindo in bpo-31368.)

The mode argument of `os.makedirs()` no longer affects the file permission bits of newly-created intermediate-level directories. (Contributed by Serhiy Storchaka in bpo-19930.)

`os.dup2()` now returns the new file descriptor. Previously, `None` was always returned. (Contributed by Benjamin Peterson in bpo-32441.)

The structure returned by `os.stat()` now contains the `st_fstype` attribute on Solaris and its derivatives. (Contributed by Jesús Cea Avión in bpo-32659.)

5.34 pathlib

The new `Path.is_mount()` method is now available on POSIX systems and can be used to determine whether a path is a mount point. (Contributed by Cooper Ry Lees in bpo-30897.)

5.35 pdb

`pdb.set_trace()` now takes an optional *header* keyword-only argument. If given, it is printed to the console just before debugging begins. (Contributed by Barry Warsaw in bpo-31389.)

`pdb` command line now accepts `-m module_name` as an alternative to script file. (Contributed by Mario Corchero in bpo-32206.)

5.36 py_compile

`py_compile.compile()` – and by extension, `compileall` – now respects the `SOURCE_DATE_EPOCH` environment variable by unconditionally creating `.pyc` files for hash-based validation. This allows for guaranteeing reproducible builds of `.pyc` files when they are created eagerly. (Contributed by Bernhard M. Wiedemann in bpo-29708.)

5.37 pydoc

The pydoc server can now bind to an arbitrary hostname specified by the new `-n` command-line argument. (Contributed by Feanil Patel in bpo-31128.)

5.38 queue

The new `SimpleQueue` class is an unbounded FIFO queue. (Contributed by Antoine Pitrou in bpo-14976.)

5.39 re

The flags `re.ASCII`, `re.LOCALE` and `re.UNICODE` can be set within the scope of a group. (Contributed by Serhiy Storchaka in bpo-31690.)

`re.split()` now supports splitting on a pattern like `r'\b'`, `'^$'` or `(?=-)` that matches an empty string. (Contributed by Serhiy Storchaka in bpo-25054.)

Regular expressions compiled with the `re.LOCALE` flag no longer depend on the locale at compile time. Locale settings are applied only when the compiled regular expression is used. (Contributed by Serhiy Storchaka in bpo-30215.)

`FutureWarning` is now emitted if a regular expression contains character set constructs that will change semantically in the future, such as nested sets and set operations. (Contributed by Serhiy Storchaka in bpo-30349.)

Compiled regular expression and match objects can now be copied using `copy.copy()` and `copy.deepcopy()`. (Contributed by Serhiy Storchaka in bpo-10076.)

5.40 signal

The new *warn_on_full_buffer* argument to the `signal.set_wakeup_fd()` function makes it possible to specify whether Python prints a warning on stderr when the wakeup buffer overflows. (Contributed by Nathaniel J. Smith in bpo-30050.)

5.41 socket

The new `socket.getblocking()` method returns `True` if the socket is in blocking mode and `False` otherwise. (Contributed by Yury Selivanov in bpo-32373.)

The new `socket.close()` function closes the passed socket file descriptor. This function should be used instead of `os.close()` for better compatibility across platforms. (Contributed by Christian Heimes in bpo-32454.)

The `socket` module now exposes the `socket.TCP_CONGESTION` (Linux 2.6.13), `socket.TCP_USER_TIMEOUT` (Linux 2.6.37), and `socket.TCP_NOTSENT_LOWAT` (Linux 3.12) constants. (Contributed by Omar Sandoval in bpo-26273 and Nathaniel J. Smith in bpo-29728.)

Support for `socket.AF_VSOCK` sockets has been added to allow communication between virtual machines and their hosts. (Contributed by Cathy Avery in bpo-27584.)

Sockets now auto-detect family, type and protocol from file descriptor by default. (Contributed by Christian Heimes in bpo-28134.)

5.42 socketserver

`socketserver.ThreadingMixIn.server_close()` now waits until all non-daemon threads complete. `socketserver.ForkingMixIn.server_close()` now waits until all child processes complete.

Add a new `socketserver.ForkingMixIn.block_on_close` class attribute to `socketserver.ForkingMixIn` and `socketserver.ThreadingMixIn` classes. Set the class attribute to `False` to get the pre-3.7 behaviour.

5.43 sqlite3

`sqlite3.Connection` now exposes the `backup()` method when the underlying SQLite library is at version 3.6.11 or higher. (Contributed by Lele Gaifax in bpo-27645.)

The *database* argument of `sqlite3.connect()` now accepts any path-like object, instead of just a string. (Contributed by Anders Lorentsen in bpo-31843.)

5.44 ssl

The `ssl` module now uses OpenSSL's builtin API instead of `match_hostname()` to check a host name or an IP address. Values are validated during TLS handshake. Any certificate validation error including failing the host name check now raises `SSLCertVerificationError` and aborts the handshake with a proper TLS Alert message. The new exception contains additional information. Host name validation can be customized with `SSLContext.host_flags`. (Contributed by Christian Heimes in bpo-31399.)

Note: The improved host name check requires a *libssl* implementation compatible with OpenSSL 1.0.2 or 1.1. Consequently, OpenSSL 0.9.8 and 1.0.1 are no longer supported. The ssl module is mostly compatible with LibreSSL 2.7.2 and newer.

The `ssl` module no longer sends IP addresses in SNI TLS extension. (Contributed by Christian Heimes in bpo-32185.)

`match_hostname()` no longer supports partial wildcards like `www*.example.org`. `SSLContext.host_flags` has partial wildcard matching disabled by default. (Contributed by Mandeep Singh in bpo-23033 and Christian Heimes in bpo-31399.)

The default cipher suite selection of the `ssl` module now uses a blacklist approach rather than a hard-coded whitelist. Python no longer re-enables ciphers that have been blocked by OpenSSL security updates. Default cipher suite selection can be configured at compile time. (Contributed by Christian Heimes in bpo-31429.)

Validation of server certificates containing internationalized domain names (IDNs) is now supported. As part of this change, the `SSLSocket.server_hostname` attribute now stores the expected hostname in A-label form (`"xn--pythn-mua.org"`), rather than the U-label form (`"pythön.org"`). (Contributed by Nathaniel J. Smith and Christian Heimes in bpo-28414.)

The `ssl` module has preliminary and experimental support for TLS 1.3 and OpenSSL 1.1.1. At the time of Python 3.7.0 release, OpenSSL 1.1.1 is still under development and TLS 1.3 hasn't been finalized yet. The TLS 1.3 handshake and protocol behaves slightly differently than TLS 1.2 and earlier, see ssl-tlsv1_3. (Contributed by Christian Heimes in bpo-32947, bpo-20995, bpo-29136, bpo-30622 and bpo-33618)

`SSLSocket` and `SSLObject` no longer have a public constructor. Direct instantiation was never a documented and supported feature. Instances must be created with `SSLContext` methods `wrap_socket()` and `wrap_bio()`. (Contributed by Christian Heimes in bpo-32951)

OpenSSL 1.1 APIs for setting the minimum and maximum TLS protocol version are available as `SSLContext.minimum_version` and `SSLContext.maximum_version`. Supported protocols are indicated by serveral new flags, such as `HAS_TLSv1_1`. (Contributed by Christian Heimes in bpo-32609.)

5.45 string

`string.Template` now lets you to optionally modify the regular expression pattern for braced placeholders and non-braced placeholders separately. (Contributed by Barry Warsaw in bpo-1198569.)

5.46 subprocess

The `subprocess.run()` function accepts the new *capture_output* keyword argument. When true, stdout and stderr will be captured. This is equivalent to passing `subprocess.PIPE` as *stdout* and *stderr* arguments. (Contributed by Bo Bayles in bpo-32102.)

The `subprocess.run` function and the `subprocess.Popen` constructor now accept the *text* keyword argument as an alias to *universal_newlines*. (Contributed by Andrew Clegg in bpo-31756.)

On Windows the default for *close_fds* was changed from `False` to `True` when redirecting the standard handles. It's now possible to set *close_fds* to true when redirecting the standard handles. See `subprocess.Popen`. This means that *close_fds* now defaults to `True` on all supported platforms. (Contributed by Segev Finer in bpo-19764.)

The subprocess module is now more graceful when handling `KeyboardInterrupt` during `subprocess.call()`, `subprocess.run()`, or in a `Popen` context manager. It now waits a short amount of time for the child to exit, before continuing the handling of the `KeyboardInterrupt` exception. (Contributed by Gregory P. Smith in bpo-25942.)

5.47 sys

The new `sys.breakpointhook()` hook function is called by the built-in `breakpoint()`. (Contributed by Barry Warsaw in bpo-31353.)

On Android, the new `sys.getandroidapilevel()` returns the build-time Android API version. (Contributed by Victor Stinner in bpo-28740.)

The new `sys.get_coroutine_origin_tracking_depth()` function returns the current coroutine origin tracking depth, as set by the new `sys.set_coroutine_origin_tracking_depth()`. `asyncio` has been converted to use this new API instead of the deprecated `sys.set_coroutine_wrapper()`. (Contributed by Nathaniel J. Smith in bpo-32591.)

5.48 time

PEP 564 adds six new functions with nanosecond resolution to the `time` module:

- `time.clock_gettime_ns()`
- `time.clock_settime_ns()`
- `time.monotonic_ns()`
- `time.perf_counter_ns()`
- `time.process_time_ns()`
- `time.time_ns()`

New clock identifiers have been added:

- `time.CLOCK_BOOTTIME` (Linux): Identical to `time.CLOCK_MONOTONIC`, except it also includes any time that the system is suspended.
- `time.CLOCK_PROF` (FreeBSD, NetBSD and OpenBSD): High-resolution per-process CPU timer.

- `time.CLOCK_UPTIME` (FreeBSD, OpenBSD): Time whose absolute value is the time the system has been running and not suspended, providing accurate uptime measurement.

The new `time.thread_time()` and `time.thread_time_ns()` functions can be used to get per-thread CPU time measurements. (Contributed by Antoine Pitrou in bpo-32025.)

The new `time.pthread_getcpuclockid()` function returns the clock ID of the thread-specific CPU-time clock.

5.49 tkinter

The new `tkinter.ttk.Spinbox` class is now available. (Contributed by Alan Moore in bpo-32585.)

5.50 tracemalloc

`tracemalloc.Traceback` behaves more like regular tracebacks, sorting the frames from oldest to most recent. `Traceback.format()` now accepts negative *limit*, truncating the result to the `abs(limit)` oldest frames. To get the old behaviour, use the new *most_recent_first* argument to `Traceback.format()`. (Contributed by Jesse Bakker in bpo-32121.)

5.51 types

The new `WrapperDescriptorType`, `MethodWrapperType`, `MethodDescriptorType`, and `ClassMethodDescriptorType` classes are now available. (Contributed by Manuel Krebber and Guido van Rossum in bpo-29377, and Serhiy Storchaka in bpo-32265.)

The new `types.resolve_bases()` function resolves MRO entries dynamically as specified by **PEP 560**. (Contributed by Ivan Levkivskyi in bpo-32717.)

5.52 unicodedata

The internal `unicodedata` database has been upgraded to use Unicode 11. (Contributed by Benjamin Peterson.)

5.53 unittest

The new `-k` command-line option allows filtering tests by a name substring or a Unix shell-like pattern. For example, `python -m unittest -k foo` runs `foo_tests.SomeTest.test_something`, `bar_tests.SomeTest.test_foo`, but not `bar_tests.FooTest.test_something`. (Contributed by Jonas Haag in bpo-32071.)

5.54 unittest.mock

The `sentinel` attributes now preserve their identity when they are `copied` or `pickled`. (Contributed by Serhiy Storchaka in bpo-20804.)

The new `seal()` function allows sealing `Mock` instances, which will disallow further creation of attribute mocks. The seal is applied recursively to all attributes that are themselves mocks. (Contributed by Mario Corchero in bpo-30541.)

5.55 urllib.parse

`urllib.parse.quote()` has been updated from **RFC 2396** to **RFC 3986**, adding `~` to the set of characters that are never quoted by default. (Contributed by Christian Theune and Ratnadeep Debnath in bpo-16285.)

5.56 uu

The `uu.encode()` function now accepts an optional *backtick* keyword argument. When it's true, zeros are represented by `'`'` instead of spaces. (Contributed by Xiang Zhang in bpo-30103.)

5.57 uuid

The new `UUID.is_safe` attribute relays information from the platform about whether generated UUIDs are generated with a multiprocessing-safe method. (Contributed by Barry Warsaw in bpo-22807.)

`uuid.getnode()` now prefers universally administered MAC addresses over locally administered MAC addresses. This makes a better guarantee for global uniqueness of UUIDs returned from `uuid.uuid1()`. If only locally administered MAC addresses are available, the first such one found is returned. (Contributed by Barry Warsaw in bpo-32107.)

5.58 warnings

The initialization of the default warnings filters has changed as follows:

- warnings enabled via command line options (including those for `-b` and the new CPython-specific `-X dev` option) are always passed to the warnings machinery via the `sys.warnoptions` attribute.
- warnings filters enabled via the command line or the environment now have the following order of precedence:
  - the `BytesWarning` filter for `-b` (or `-bb`)
  - any filters specified with the `-W` option
  - any filters specified with the `PYTHONWARNINGS` environment variable
  - any other CPython specific filters (e.g. the `default` filter added for the new `-X dev` mode)
  - any implicit filters defined directly by the warnings machinery
- in CPython debug builds, all warnings are now displayed by default (the implicit filter list is empty)

(Contributed by Nick Coghlan and Victor Stinner in bpo-20361, bpo-32043, and bpo-32230.)

Deprecation warnings are once again shown by default in single-file scripts and at the interactive prompt. See *PEP 565: Show DeprecationWarning in __main__* for details. (Contributed by Nick Coghlan in bpo-31975.)

5.59 xml.etree

ElementPath predicates in the `find()` methods can now compare text of the current node with `[. = "text"]`, not only text in children. Predicates also allow adding spaces for better readability. (Contributed by Stefan Behnel in bpo-31648.)

5.60 xmlrpc.server

`SimpleXMLRPCDispatcher.register_function` can now be used as a decorator. (Contributed by Xiang Zhang in bpo-7769.)

5.61 zipapp

Function `create_archive()` now accepts an optional *filter* argument to allow the user to select which files should be included in the archive. (Contributed by Irmen de Jong in bpo-31072.)

Function `create_archive()` now accepts an optional *compressed* argument to generate a compressed archive. A command line option `--compress` has also been added to support compression. (Contributed by Zhiming Wang in bpo-31638.)

5.62 zipfile

`ZipFile` now accepts the new *compresslevel* parameter to control the compression level. (Contributed by Bo Bayles in bpo-21417.)

Subdirectories in archives created by `ZipFile` are now stored in alphabetical order. (Contributed by Bernhard M. Wiedemann in bpo-30693.)

6 C API Changes

A new API for thread-local storage has been implemented. See *PEP 539: New C API for Thread-Local Storage* for an overview and thread-specific-storage-api for a complete reference. (Contributed by Masayuki Yamamoto in bpo-25658.)

The new *context variables* functionality exposes a number of new C APIs.

The new `PyImport_GetModule()` function returns the previously imported module with the given name. (Contributed by Eric Snow in bpo-28411.)

The new `Py_RETURN_RICHCOMPARE` macro eases writing rich comparison functions. (Contributed by Petr Victorin in bpo-23699.)

The new `Py_UNREACHABLE` macro can be used to mark unreachable code paths. (Contributed by Barry Warsaw in bpo-31338.)

The `tracemalloc` now exposes a C API through the new `PyTraceMalloc_Track()` and `PyTraceMalloc_Untrack()` functions. (Contributed by Victor Stinner in bpo-30054.)

The new `import__find__load__start()` and `import__find__load__done()` static markers can be used to trace module imports. (Contributed by Christian Heimes in bpo-31574.)

The fields `name` and `doc` of structures `PyMemberDef`, `PyGetSetDef`, `PyStructSequence_Field`, `PyStructSequence_Desc`, and `wrapperbase` are now of type `const char *` rather of `char *`. (Contributed by Serhiy Storchaka in bpo-28761.)

The result of `PyUnicode_AsUTF8AndSize()` and `PyUnicode_AsUTF8()` is now of type `const char *` rather of `char *`. (Contributed by Serhiy Storchaka in bpo-28769.)

The result of `PyMapping_Keys()`, `PyMapping_Values()` and `PyMapping_Items()` is now always a list, rather than a list or a tuple. (Contributed by Oren Milman in bpo-28280.)

Added functions `PySlice_Unpack()` and `PySlice_AdjustIndices()`. (Contributed by Serhiy Storchaka in bpo-27867.)

`PyOS_AfterFork()` is deprecated in favour of the new functions `PyOS_BeforeFork()`, `PyOS_AfterFork_Parent()` and `PyOS_AfterFork_Child()`. (Contributed by Antoine Pitrou in bpo-16500.)

The `PyExc_RecursionErrorInst` singleton that was part of the public API has been removed as its members being never cleared may cause a segfault during finalization of the interpreter. Contributed by Xavier de Gaye in bpo-22898 and bpo-30697.

Added C API support for timezones with timezone constructors `PyTimeZone_FromOffset()` and `PyTimeZone_FromOffsetAndName()`, and access to the UTC singleton with `PyDateTime_TimeZone_UTC`. Contributed by Paul Ganssle in bpo-10381.

The type of results of `PyThread_start_new_thread()` and `PyThread_get_thread_ident()`, and the *id* parameter of `PyThreadState_SetAsyncExc()` changed from `long` to `unsigned long`. (Contributed by Serhiy Storchaka in bpo-6532.)

`PyUnicode_AsWideCharString()` now raises a `ValueError` if the second argument is *NULL* and the `wchar_t*` string contains null characters. (Contributed by Serhiy Storchaka in bpo-30708.)

Changes to the startup sequence and the management of dynamic memory allocators mean that the long documented requirement to call `Py_Initialize()` before calling most C API functions is now relied on more heavily, and failing to abide by it may lead to segfaults in embedding applications. See the *Porting to Python 3.7* section in this document and the pre-init-safe section in the C API documentation for more details.

The new `PyInterpreterState_GetID()` returns the unique ID for a given interpreter. (Contributed by Eric Snow in bpo-29102.)

`Py_DecodeLocale()`, `Py_EncodeLocale()` now use the UTF-8 encoding when the *UTF-8 mode* is enabled. (Contributed by Victor Stinner in bpo-29240.)

`PyUnicode_DecodeLocaleAndSize()` and `PyUnicode_EncodeLocale()` now use the current locale encoding for `surrogateescape` error handler. (Contributed by Victor Stinner in bpo-29240.)

The *start* and *end* parameters of `PyUnicode_FindChar()` are now adjusted to behave like string slices. (Contributed by Xiang Zhang in bpo-28822.)

7 Build Changes

Support for building `--without-threads` has been removed. The `threading` module is now always available. (Contributed by Antoine Pitrou in bpo-31370.).

A full copy of libffi is no longer bundled for use when building the `_ctypes` module on non-OSX UNIX platforms. An installed copy of libffi is now required when building `_ctypes` on such platforms. (Contributed by Zachary Ware in bpo-27979.)

The Windows build process no longer depends on Subversion to pull in external sources, a Python script is used to download zipfiles from GitHub instead. If Python 3.6 is not found on the system (via `py -3.6`), NuGet is used to download a copy of 32-bit Python for this purpose. (Contributed by Zachary Ware in bpo-30450.)

The `ssl` module requires OpenSSL 1.0.2 or 1.1 compatible libssl. OpenSSL 1.0.1 has reached end of lifetime on 2016-12-31 and is no longer supported. LibreSSL is temporarily not supported as well. LibreSSL releases up to version 2.6.4 are missing required OpenSSL 1.0.2 APIs.

8 Optimizations

The overhead of calling many methods of various standard library classes implemented in C has been significantly reduced by porting more code to use the `METH_FASTCALL` convention. (Contributed by Victor Stinner

in bpo-29300, bpo-29507, bpo-29452, and bpo-29286.)

Various optimizations have reduced Python startup time by 10% on Linux and up to 30% on macOS. (Contributed by Victor Stinner, INADA Naoki in bpo-29585, and Ivan Levkivskyi in bpo-31333.)

Method calls are now up to 20% faster due to the bytecode changes which avoid creating bound method instances. (Contributed by Yury Selivanov and INADA Naoki in bpo-26110.)

The `asyncio` module received a number of notable optimizations for commonly used functions:

- The `asyncio.get_event_loop()` function has been reimplemented in C to make it up to 15 times faster. (Contributed by Yury Selivanov in bpo-32296.)
- `asyncio.Future` callback management has been optimized. (Contributed by Yury Selivanov in bpo-32348.)
- `asyncio.gather()` is now up to 15% faster. (Contributed by Yury Selivanov in bpo-32355.)
- `asyncio.sleep()` is now up to 2 times faster when the *delay* argument is zero or negative. (Contributed by Andrew Svetlov in bpo-32351.)
- The performance overhead of asyncio debug mode has been reduced. (Contributed by Antoine Pitrou in bpo-31970.)

As a result of *PEP 560 work*, the import time of `typing` has been reduced by a factor of 7, and many typing operations are now faster. (Contributed by Ivan Levkivskyi in bpo-32226.)

`sorted()` and `list.sort()` have been optimized for common cases to be up to 40-75% faster. (Contributed by Elliot Gorokhovsky in bpo-28685.)

`dict.copy()` is now up to 5.5 times faster. (Contributed by Yury Selivanov in bpo-31179.)

`hasattr()` and `getattr()` are now about 4 times faster when *name* is not found and *obj* does not override `object.__getattr__()` or `object.__getattribute__()`. (Contributed by INADA Naoki in bpo-32544.)

Searching for certain Unicode characters (like Ukrainian capital “ ”) in a string was up to 25 times slower than searching for other characters. It is now only 3 times slower in the worst case. (Contributed by Serhiy Storchaka in bpo-24821.)

The `collections.namedtuple()` factory has been reimplemented to make the creation of named tuples 4 to 6 times faster. (Contributed by Jelle Zijlstra with further improvements by INADA Naoki, Serhiy Storchaka, and Raymond Hettinger in bpo-28638.)

`date.fromordinal()` and `date.fromtimestamp()` are now up to 30% faster in the common case. (Contributed by Paul Ganssle in bpo-32403.)

The `os.fwalk()` function is now up to 2 times faster thanks to the use of `os.scandir()`. (Contributed by Serhiy Storchaka in bpo-25996.)

The speed of the `shutil.rmtree()` function has been improved by 20–40% thanks to the use of the `os.scandir()` function. (Contributed by Serhiy Storchaka in bpo-28564.)

Optimized case-insensitive matching and searching of `regular expressions`. Searching some patterns can now be up to 20 times faster. (Contributed by Serhiy Storchaka in bpo-30285.)

`re.compile()` now converts `flags` parameter to int object if it is `RegexFlag`. It is now as fast as Python 3.5, and faster than Python 3.6 by about 10% depending on the pattern. (Contributed by INADA Naoki in bpo-31671.)

The `modify()` methods of classes `selectors.EpollSelector`, `selectors.PollSelector` and `selectors.DevpollSelector` may be around 10% faster under heavy loads. (Contributed by Giampaolo Rodola' in bpo-30014)

Constant folding has been moved from the peephole optimizer to the new AST optimizer, which is able perform optimizations more consistently. (Contributed by Eugene Toder and INADA Naoki in bpo-29469 and bpo-11549.)

Most functions and methods in `abc` have been rewritten in C. This makes creation of abstract base classes, and calling `isinstance()` and `issubclass()` on them 1.5x faster. This also reduces Python start-up time by up to 10%. (Contributed by Ivan Levkivskyi and INADA Naoki in bpo-31333)

Significant speed improvements to alternate constructors for `datetime.date` and `datetime.datetime` by using fast-path constructors when not constructing subclasses. (Contributed by Paul Ganssle in bpo-32403)

The speed of comparison of `array.array` instances has been improved considerably in certain cases. It is now from 10x to 70x faster when comparing arrays holding values of the same integer type. (Contributed by Adrian Wielgosik in bpo-24700.)

The `math.erf()` and `math.erfc()` functions now use the (faster) C library implementation on most platforms. (Contributed by Serhiy Storchaka in bpo-26121.)

9 Other CPython Implementation Changes

- Trace hooks may now opt out of receiving the `line` and opt into receiving the `opcode` events from the interpreter by setting the corresponding new `f_trace_lines` and `f_trace_opcodes` attributes on the frame being traced. (Contributed by Nick Coghlan in bpo-31344.)
- Fixed some consistency problems with namespace package module attributes. Namespace module objects now have an `__file__` that is set to `None` (previously unset), and their `__spec__.origin` is also set to `None` (previously the string `"namespace"`). See bpo-32305. Also, the namespace module object's `__spec__.loader` is set to the same value as `__loader__` (previously, the former was set to `None`). See bpo-32303.
- The `locals()` dictionary now displays in the lexical order that variables were defined. Previously, the order was undefined. (Contributed by Raymond Hettinger in bpo-32690.)
- The `distutils upload` command no longer tries to change CR end-of-line characters to CRLF. This fixes a corruption issue with sdists that ended with a byte equivalent to CR. (Contributed by Bo Bayles in bpo-32304.)

10 Deprecated Python Behavior

Yield expressions (both `yield` and `yield from` clauses) are now deprecated in comprehensions and generator expressions (aside from the iterable expression in the leftmost `for` clause). This ensures that comprehensions always immediately return a container of the appropriate type (rather than potentially returning a generator iterator object), while generator expressions won't attempt to interleave their implicit output with the output from any explicit yield expressions. In Python 3.7, such expressions emit `DeprecationWarning` when compiled, in Python 3.8 this will be a `SyntaxError`. (Contributed by Serhiy Storchaka in bpo-10544.)

Returning a subclass of `complex` from `object.__complex__()` is deprecated and will be an error in future Python versions. This makes `__complex__()` consistent with `object.__int__()` and `object.__float__()`. (Contributed by Serhiy Storchaka in bpo-28894.)

11 Deprecated Python modules, functions and methods

11.1 aifc

`aifc.openfp()` has been deprecated and will be removed in Python 3.9. Use `aifc.open()` instead. (Contributed by Brian Curtin in bpo-31985.)

11.2 asyncio

Support for directly `await`-ing instances of `asyncio.Lock` and other asyncio synchronization primitives has been deprecated. An asynchronous context manager must be used in order to acquire and release the synchronization resource. See async-with-locks for more information. (Contributed by Andrew Svetlov in bpo-32253.)

The `asyncio.Task.current_task()` and `asyncio.Task.all_tasks()` methods have been deprecated. (Contributed by Andrew Svetlov in bpo-32250.)

11.3 collections

In Python 3.8, the abstract base classes in `collections.abc` will no longer be exposed in the regular `collections` module. This will help create a clearer distinction between the concrete classes and the abstract base classes. (Contributed by Serhiy Storchaka in bpo-25988.)

11.4 dbm

`dbm.dumb` now supports reading read-only files and no longer writes the index file when it is not changed. A deprecation warning is now emitted if the index file is missing and recreated in the `'r'` and `'w'` modes (this will be an error in future Python releases). (Contributed by Serhiy Storchaka in bpo-28847.)

11.5 enum

In Python 3.8, attempting to check for non-Enum objects in `Enum` classes will raise a `TypeError` (e.g. `1 in Color`); similarly, attempting to check for non-Flag objects in a `Flag` member will raise `TypeError` (e.g. `1 in Perm.RW`); currently, both operations return `False` instead. (Contributed by Ethan Furman in bpo-33217.)

11.6 gettext

Using non-integer value for selecting a plural form in `gettext` is now deprecated. It never correctly worked. (Contributed by Serhiy Storchaka in bpo-28692.)

11.7 importlib

Methods `MetaPathFinder.find_module()` (replaced by `MetaPathFinder.find_spec()`) and `PathEntryFinder.find_loader()` (replaced by `PathEntryFinder.find_spec()`) both deprecated in Python 3.4 now emit `DeprecationWarning`. (Contributed by Matthias Bussonnier in bpo-29576)

The `importlib.abc.ResourceLoader` ABC has been deprecated in favour of `importlib.abc.ResourceReader`.

11.8 locale

`locale.format()` has been deprecated, use `locale.format_string()` instead. (Contributed by Garvit in bpo-10379.)

11.9 macpath

The `macpath` is now deprecated and will be removed in Python 3.8. (Contributed by Chi Hsuan Yen in bpo-9850.)

11.10 threading

`dummy_threading` and `_dummy_thread` have been deprecated. It is no longer possible to build Python with threading disabled. Use `threading` instead. (Contributed by Antoine Pitrou in bpo-31370.)

11.11 socket

The silent argument value trunctation in `socket.htons()` and `socket.ntohs()` has been deprecated. In future versions of Python, if the passed argument is larger than 16 bits, an exception will be raised. (Contributed by Oren Milman in bpo-28332.)

11.12 ssl

`ssl.wrap_socket()` is deprecated. Use `ssl.SSLContext.wrap_socket()` instead. (Contributed by Christian Heimes in bpo-28124.)

11.13 sunau

`sunau.openfp()` has been deprecated and will be removed in Python 3.9. Use `sunau.open()` instead. (Contributed by Brian Curtin in bpo-31985.)

11.14 sys

Deprecated `sys.set_coroutine_wrapper()` and `sys.get_coroutine_wrapper()`.

The undocumented `sys.callstats()` function has been deprecated and will be removed in a future Python version. (Contributed by Victor Stinner in bpo-28799.)

11.15 wave

`wave.openfp()` has been deprecated and will be removed in Python 3.9. Use `wave.open()` instead. (Contributed by Brian Curtin in bpo-31985.)

12 Deprecated functions and types of the C API

Function `PySlice_GetIndicesEx()` is deprecated and replaced with a macro if `Py_LIMITED_API` is not set or set to a value in the range between `0x03050400` and `0x03060000` (not inclusive), or is `0x03060100` or higher. (Contributed by Serhiy Storchaka in bpo-27867.)

`PyOS_AfterFork()` has been deprecated. Use `PyOS_BeforeFork()`, `PyOS_AfterFork_Parent()` or `PyOS_AfterFork_Child()` instead. (Contributed by Antoine Pitrou in bpo-16500.)

13 Platform Support Removals

FreeBSD 9 and older are no longer officially supported.

14 API and Feature Removals

The following features and APIs have been removed from Python 3.7:

- The `os.stat_float_times()` function has been removed. It was introduced in Python 2.3 for backward compatibility with Python 2.2, and was deprecated since Python 3.1.
- Unknown escapes consisting of `'\'` and an ASCII letter in replacement templates for `re.sub()` were deprecated in Python 3.5, and will now cause an error.
- Removed support of the *exclude* argument in `tarfile.TarFile.add()`. It was deprecated in Python 2.7 and 3.2. Use the *filter* argument instead.
- The `splitunc()` function in the `ntpath` module was deprecated in Python 3.1, and has now been removed. Use the `splitdrive()` function instead.
- `collections.namedtuple()` no longer supports the *verbose* parameter or `_source` attribute which showed the generated source code for the named tuple class. This was part of an optimization designed to speed-up class creation. (Contributed by Jelle Zijlstra with further improvements by INADA Naoki, Serhiy Storchaka, and Raymond Hettinger in bpo-28638.)
- Functions `bool()`, `float()`, `list()` and `tuple()` no longer take keyword arguments. The first argument of `int()` can now be passed only as positional argument.
- Removed previously deprecated in Python 2.4 classes `Plist`, `Dict` and `_InternalDict` in the `plistlib` module. Dict values in the result of functions `readPlist()` and `readPlistFromBytes()` are now normal dicts. You no longer can use attribute access to access items of these dictionaries.
- The `asyncio.windows_utils.socketpair()` function has been removed. Use the `socket.socketpair()` function instead, it is available on all platforms since Python 3.5. `asyncio.windows_utils.socketpair` was just an alias to `socket.socketpair` on Python 3.5 and newer.
- `asyncio` no longer exports the `selectors` and `_overlapped` modules as `asyncio.selectors` and `asyncio._overlapped`. Replace `from asyncio import selectors` with `import selectors`.
- Direct instantiation of `ssl.SSLSocket` and `ssl.SSLObject` objects is now prohibited. The constructors were never documented, tested, or designed as public constructors. Users were supposed to use `ssl.wrap_socket()` or `ssl.SSLContext`. (Contributed by Christian Heimes in bpo-32951.)
- The unused `distutils install_misc` command has been removed. (Contributed by Eric N. Vander Weele in bpo-29218.)

15 Module Removals

The `fpectl` module has been removed. It was never enabled by default, never worked correctly on x86-64, and it changed the Python ABI in ways that caused unexpected breakage of C extensions. (Contributed by Nathaniel J. Smith in bpo-29137.)

16 Windows-only Changes

The python launcher, (py.exe), can accept 32 & 64 bit specifiers **without** having to specify a minor version as well. So `py -3-32` and `py -3-64` become valid as well as `py -3.7-32`, also the *-m*-64 and *-m.n*-64 forms are now accepted to force 64 bit python even if 32 bit would have otherwise been used. If the specified version is not available py.exe will error exit. (Contributed by Steve Barnes in bpo-30291.)

The launcher can be run as `py -0` to produce a list of the installed pythons, *with default marked with an asterisk*. Running `py -0p` will include the paths. If py is run with a version specifier that cannot be matched it will also print the *short form* list of available specifiers. (Contributed by Steve Barnes in bpo-30362.)

17 Porting to Python 3.7

This section lists previously described changes and other bugfixes that may require changes to your code.

17.1 Changes in Python Behavior

- `async` and `await` names are now reserved keywords. Code using these names as identifiers will now raise a `SyntaxError`. (Contributed by Jelle Zijlstra in bpo-30406.)
- **PEP 479** is enabled for all code in Python 3.7, meaning that `StopIteration` exceptions raised directly or indirectly in coroutines and generators are transformed into `RuntimeError` exceptions. (Contributed by Yury Selivanov in bpo-32670.)
- `object.__aiter__()` methods can no longer be declared as asynchronous. (Contributed by Yury Selivanov in bpo-31709.)
- Due to an oversight, earlier Python versions erroneously accepted the following syntax:

```
f(1 for x in [1],)

class C(1 for x in [1]):
    pass
```

  Python 3.7 now correctly raises a `SyntaxError`, as a generator expression always needs to be directly inside a set of parentheses and cannot have a comma on either side, and the duplication of the parentheses can be omitted only on calls. (Contributed by Serhiy Storchaka in bpo-32012 and bpo-32023.)
- When using the `-m` switch, the initial working directory is now added to `sys.path`, rather than an empty string (which dynamically denoted the current working directory at the time of each import). Any programs that are checking for the empty string, or otherwise relying on the previous behaviour, will need to be updated accordingly (e.g. by also checking for `os.getcwd()` or `os.path.dirname(__main__.__file__)`, depending on why the code was checking for the empty string in the first place).

17.2 Changes in the Python API

- `socketserver.ThreadingMixIn.server_close()` now waits until all non-daemon threads complete. Set the new `socketserver.ThreadingMixIn.block_on_close` class attribute to `False` to get the pre-3.7 behaviour. (Contributed by Victor Stinner in bpo-31233 and bpo-33540.)
- `socketserver.ForkingMixIn.server_close()` now waits until all child processes complete. Set the new `socketserver.ForkingMixIn.block_on_close` class attribute to `False` to get the pre-3.7 behaviour. (Contributed by Victor Stinner in bpo-31151 and bpo-33540.)
- The `locale.localeconv()` function now temporarily sets the `LC_CTYPE` locale to the value of `LC_NUMERIC` in some cases. (Contributed by Victor Stinner in bpo-31900.)
- `pkgutil.walk_packages()` now raises a `ValueError` if *path* is a string. Previously an empty list was returned. (Contributed by Sanyam Khurana in bpo-24744.)
- A format string argument for `string.Formatter.format()` is now positional-only. Passing it as a keyword argument was deprecated in Python 3.5. (Contributed by Serhiy Storchaka in bpo-29193.)

- Attributes `key`, `value` and `coded_value` of class `http.cookies.Morsel` are now read-only. Assigning to them was deprecated in Python 3.5. Use the `set()` method for setting them. (Contributed by Serhiy Storchaka in bpo-29192.)
- The *mode* argument of `os.makedirs()` no longer affects the file permission bits of newly-created intermediate-level directories. To set their file permission bits you can set the umask before invoking `makedirs()`. (Contributed by Serhiy Storchaka in bpo-19930.)
- The `struct.Struct.format` type is now `str` instead of `bytes`. (Contributed by Victor Stinner in bpo-21071.)
- `parse_multipart()` now accepts the *encoding* and *errors* arguments and returns the same results as `FieldStorage`: for non-file fields, the value associated to a key is a list of strings, not bytes. (Contributed by Pierre Quentel in bpo-29979.)
- Due to internal changes in `socket`, calling `socket.fromshare()` on a socket created by `socket.share` in older Python versions is not supported.
- `repr` for `BaseException` has changed to not include the trailing comma. Most exceptions are affected by this change. (Contributed by Serhiy Storchaka in bpo-30399.)
- `repr` for `datetime.timedelta` has changed to include the keyword arguments in the output. (Contributed by Utkarsh Upadhyay in bpo-30302.)
- Because `shutil.rmtree()` is now implemented using the `os.scandir()` function, the user specified handler *onerror* is now called with the first argument `os.scandir` instead of `os.listdir` when listing the directory is failed.
- Support for nested sets and set operations in regular expressions as in Unicode Technical Standard #18 might be added in the future. This would change the syntax. To facilitate this future change a `FutureWarning` will be raised in ambiguous cases for the time being. That include sets starting with a literal `'['` or containing literal character sequences `'--'`, `'&&'`, `'~~'`, and `'||'`. To avoid a warning, escape them with a backslash. (Contributed by Serhiy Storchaka in bpo-30349.)
- The result of splitting a string on a `regular expression` that could match an empty string has been changed. For example splitting on `r'\s*'` will now split not only on whitespaces as it did previously, but also on empty strings before all non-whitespace characters and just before the end of the string. The previous behavior can be restored by changing the pattern to `r'\s+'`. A `FutureWarning` was emitted for such patterns since Python 3.5.

  For patterns that match both empty and non-empty strings, the result of searching for all matches may also be changed in other cases. For example in the string `'a\n\n'`, the pattern `r'(?m)^\s*?$'` will not only match empty strings at positions 2 and 3, but also the string `'\n'` at positions 2–3. To match only blank lines, the pattern should be rewritten as `r'(?m)^[^\S\n]*$'`.

  `re.sub()` now replaces empty matches adjacent to a previous non-empty match. For example `re.sub('x*', '-', 'abxd')` returns now `'-a-b--d-'` instead of `'-a-b-d-'` (the first minus between 'b' and 'd' replaces 'x', and the second minus replaces an empty string between 'x' and 'd').

  (Contributed by Serhiy Storchaka in bpo-25054 and bpo-32308.)
- Change `re.escape()` to only escape regex special characters instead of escaping all characters other than ASCII letters, numbers, and `'_'`. (Contributed by Serhiy Storchaka in bpo-29995.)
- `tracemalloc.Traceback` frames are now sorted from oldest to most recent to be more consistent with `traceback`. (Contributed by Jesse Bakker in bpo-32121.)
- On OSes that support `socket.SOCK_NONBLOCK` or `socket.SOCK_CLOEXEC` bit flags, the `socket.type` no longer has them applied. Therefore, checks like `if sock.type == socket.SOCK_STREAM` work as expected on all platforms. (Contributed by Yury Selivanov in bpo-32331.)
- On Windows the default for the *close_fds* argument of `subprocess.Popen` was changed from `False` to `True` when redirecting the standard handles. If you previously depended on handles being inherited

when using `subprocess.Popen` with standard io redirection, you will have to pass `close_fds=False` to preserve the previous behaviour, or use `STARTUPINFO.lpAttributeList`.

- `importlib.machinery.PathFinder.invalidate_caches()` – which implicitly affects `importlib.invalidate_caches()` – now deletes entries in `sys.path_importer_cache` which are set to `None`. (Contributed by Brett Cannon in bpo-33169.)
- In `asyncio`, `loop.sock_recv()`, `loop.sock_sendall()`, `loop.sock_accept()`, `loop.getaddrinfo()`, `loop.getnameinfo()` have been changed to be proper coroutine methods to match their documentation. Previously, these methods returned `asyncio.Future` instances. (Contributed by Yury Selivanov in bpo-32327.)
- `asyncio.Server.sockets` now returns a copy of the internal list of server sockets, instead of returning it directly. (Contributed by Yury Selivanov in bpo-32662.)
- `Struct.format` is now a `str` instance instead of a `bytes` instance. (Contributed by Victor Stinner in bpo-21071.)
- `ast.literal_eval()` is now stricter. Addition and subtraction of arbitrary numbers are no longer allowed. (Contributed by Serhiy Storchaka in bpo-31778.)
- `Calendar.itermonthdates` will now consistently raise an exception when a date falls outside of the `0001-01-01` through `9999-12-31` range. To support applications that cannot tolerate such exceptions, the new `Calendar.itermonthdays3` and `Calendar.itermonthdays4` can be used. The new methods return tuples and are not restricted by the range supported by `datetime.date`. (Contributed by Alexander Belopolsky in bpo-28292.)
- `collections.ChainMap` now preserves the order of the underlying mappings. (Contributed by Raymond Hettinger in bpo-32792.)
- The `submit()` method of `concurrent.futures.ThreadPoolExecutor` and `concurrent.futures.ProcessPoolExecutor` now raises a `RuntimeError` if called during interpreter shutdown. (Contributed by Mark Nemec in bpo-33097.)
- The `configparser.ConfigParser` constructor now uses `read_dict()` to process the default values, making its behavior consistent with the rest of the parser. Non-string keys and values in the defaults dictionary are now being implicitly converted to strings. (Contributed by James Tocknell in bpo-23835.)

17.3 Changes in the C API

The function `PySlice_GetIndicesEx()` is considered unsafe for resizable sequences. If the slice indices are not instances of `int`, but objects that implement the `__index__()` method, the sequence can be resized after passing its length to `PySlice_GetIndicesEx()`. This can lead to returning indices out of the length of the sequence. For avoiding possible problems use new functions `PySlice_Unpack()` and `PySlice_AdjustIndices()`. (Contributed by Serhiy Storchaka in bpo-27867.)

17.4 CPython bytecode changes

There are two new opcodes: `LOAD_METHOD` and `CALL_METHOD`. (Contributed by Yury Selivanov and INADA Naoki in bpo-26110.)

The `STORE_ANNOTATION` opcode has been removed. (Contributed by Mark Shannon in bpo-32550.)

17.5 Windows-only Changes

The file used to override `sys.path` is now called `<python-executable>._pth` instead of `'sys.path'`. See finding_modules for more information. (Contributed by Steve Dower in bpo-28137.)

17.6 Other CPython implementation changes

In preparation for potential future changes to the public CPython runtime initialization API (see **PEP 432** for an initial, but somewhat outdated, draft), CPython's internal startup and configuration management logic has been significantly refactored. While these updates are intended to be entirely transparent to both embedding applications and users of the regular CPython CLI, they're being mentioned here as the refactoring changes the internal order of various operations during interpreter startup, and hence may uncover previously latent defects, either in embedding applications, or in CPython itself. (Initially contributed by Nick Coghlan and Eric Snow as part of bpo-22257, and further updated by Nick, Eric, and Victor Stinner in a number of other issues). Some known details affected:

- `PySys_AddWarnOptionUnicode()` is not currently usable by embedding applications due to the requirement to create a Unicode object prior to calling *Py_Initialize*. Use `PySys_AddWarnOption()` instead.
- warnings filters added by an embedding application with `PySys_AddWarnOption()` should now more consistently take precedence over the default filters set by the interpreter

Due to changes in the way the default warnings filters are configured, setting `Py_BytesWarningFlag` to a value greater than one is no longer sufficient to both emit `BytesWarning` messages and have them converted to exceptions. Instead, the flag must be set (to cause the warnings to be emitted in the first place), and an explicit `error::BytesWarning` warnings filter added to convert them to exceptions.

Due to a change in the way docstrings are handled by the compiler, the implicit `return None` in a function body consisting solely of a docstring is now marked as occurring on the same line as the docstring, not on the function's header line.

The current exception state has been moved from the frame object to the co-routine. This simplified the interpreter and fixed a couple of obscure bugs caused by having swap exception state when entering or exiting a generator. (Contributed by Mark Shannon in bpo-25612.)

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Python Setup and Usage

Release 3.7.0

Guido van Rossum
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Python Software Foundation
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This part of the documentation is devoted to general information on the setup of the Python environment on different platforms, the invocation of the interpreter and things that make working with Python easier.

CHAPTER

ONE

COMMAND LINE AND ENVIRONMENT

The CPython interpreter scans the command line and the environment for various settings.

CPython implementation detail: Other implementations' command line schemes may differ. See implementations for further resources.

1.1 Command line

When invoking Python, you may specify any of these options:

```
python [-bBdEhiIOqsSuvVWx?] [-c command | -m module-name | script | - ] [args]
```

The most common use case is, of course, a simple invocation of a script:

```
python myscript.py
```

1.1.1 Interface options

The interpreter interface resembles that of the UNIX shell, but provides some additional methods of invocation:

- When called with standard input connected to a tty device, it prompts for commands and executes them until an EOF (an end-of-file character, you can produce that with `Ctrl-D` on UNIX or `Ctrl-Z, Enter` on Windows) is read.
- When called with a file name argument or with a file as standard input, it reads and executes a script from that file.
- When called with a directory name argument, it reads and executes an appropriately named script from that directory.
- When called with `-c command`, it executes the Python statement(s) given as *command*. Here *command* may contain multiple statements separated by newlines. Leading whitespace is significant in Python statements!
- When called with `-m module-name`, the given module is located on the Python module path and executed as a script.

In non-interactive mode, the entire input is parsed before it is executed.

An interface option terminates the list of options consumed by the interpreter, all consecutive arguments will end up in `sys.argv` – note that the first element, subscript zero (`sys.argv[0]`), is a string reflecting the program's source.

`-c <command>`
: Execute the Python code in *command*. *command* can be one or more statements separated by newlines, with significant leading whitespace as in normal module code.

  If this option is given, the first element of `sys.argv` will be `"-c"` and the current directory will be added to the start of `sys.path` (allowing modules in that directory to be imported as top level modules).

`-m <module-name>`
: Search `sys.path` for the named module and execute its contents as the `__main__` module.

  Since the argument is a *module* name, you must not give a file extension (`.py`). The module name should be a valid absolute Python module name, but the implementation may not always enforce this (e.g. it may allow you to use a name that includes a hyphen).

  Package names (including namespace packages) are also permitted. When a package name is supplied instead of a normal module, the interpreter will execute `<pkg>.__main__` as the main module. This behaviour is deliberately similar to the handling of directories and zipfiles that are passed to the interpreter as the script argument.

  Note: This option cannot be used with built-in modules and extension modules written in C, since they do not have Python module files. However, it can still be used for precompiled modules, even if the original source file is not available.

  If this option is given, the first element of `sys.argv` will be the full path to the module file (while the module file is being located, the first element will be set to `"-m"`). As with the `-c` option, the current directory will be added to the start of `sys.path`.

  Many standard library modules contain code that is invoked on their execution as a script. An example is the `timeit` module:

  ```
  python -mtimeit -s 'setup here' 'benchmarked code here'
  python -mtimeit -h # for details
  ```

  See also:

  `runpy.run_module()` Equivalent functionality directly available to Python code

  PEP 338 – Executing modules as scripts

  Changed in version 3.1: Supply the package name to run a `__main__` submodule.

  Changed in version 3.4: namespace packages are also supported

`-`
: Read commands from standard input (`sys.stdin`). If standard input is a terminal, `-i` is implied.

  If this option is given, the first element of `sys.argv` will be `"-"` and the current directory will be added to the start of `sys.path`.

`<script>`
: Execute the Python code contained in *script*, which must be a filesystem path (absolute or relative) referring to either a Python file, a directory containing a `__main__.py` file, or a zipfile containing a `__main__.py` file.

  If this option is given, the first element of `sys.argv` will be the script name as given on the command line.

  If the script name refers directly to a Python file, the directory containing that file is added to the start of `sys.path`, and the file is executed as the `__main__` module.

If the script name refers to a directory or zipfile, the script name is added to the start of `sys.path` and the `__main__.py` file in that location is executed as the `__main__` module.

See also:

`runpy.run_path()` Equivalent functionality directly available to Python code

If no interface option is given, *-i* is implied, `sys.argv[0]` is an empty string (`""`) and the current directory will be added to the start of `sys.path`. Also, tab-completion and history editing is automatically enabled, if available on your platform (see rlcompleter-config).

See also:

tut-invoking

Changed in version 3.4: Automatic enabling of tab-completion and history editing.

1.1.2 Generic options

-?
-h
--help
Print a short description of all command line options.

-V
--version
Print the Python version number and exit. Example output could be:

```
Python 3.6.0b2+
```

When given twice, print more information about the build, like:

```
Python 3.6.0b2+ (3.6:84a3c5003510+, Oct 26 2016, 02:33:55)
[GCC 6.2.0 20161005]
```

New in version 3.6: The `-VV` option.

1.1.3 Miscellaneous options

-b
Issue a warning when comparing `bytes` or `bytearray` with `str` or `bytes` with `int`. Issue an error when the option is given twice (`-bb`).

Changed in version 3.5: Affects comparisons of `bytes` with `int`.

-B
If given, Python won't try to write `.pyc` files on the import of source modules. See also *PYTHONDONTWRITEBYTECODE*.

--check-hash-based-pycs default|always|never
Control the validation behavior of hash-based `.pyc` files. See pyc-invalidation. When set to `default`, checked and unchecked hash-based bytecode cache files are validated according to their default semantics. When set to `always`, all hash-based `.pyc` files, whether checked or unchecked, are validated against their corresponding source file. When set to `never`, hash-based `.pyc` files are not validated against their corresponding source files.

The semantics of timestamp-based `.pyc` files are unaffected by this option.

`-d`

Turn on parser debugging output (for expert only, depending on compilation options). See also *PYTHONDEBUG*.

`-E`

Ignore all `PYTHON*` environment variables, e.g. *PYTHONPATH* and *PYTHONHOME*, that might be set.

`-i`

When a script is passed as first argument or the `-c` option is used, enter interactive mode after executing the script or the command, even when `sys.stdin` does not appear to be a terminal. The *PYTHONSTARTUP* file is not read.

This can be useful to inspect global variables or a stack trace when a script raises an exception. See also *PYTHONINSPECT*.

`-I`

Run Python in isolated mode. This also implies -E and -s. In isolated mode `sys.path` contains neither the script's directory nor the user's site-packages directory. All `PYTHON*` environment variables are ignored, too. Further restrictions may be imposed to prevent the user from injecting malicious code.

New in version 3.4.

`-O`

Remove assert statements and any code conditional on the value of `__debug__`. Augment the filename for compiled (*bytecode*) files by adding `.opt-1` before the `.pyc` extension (see **PEP 488**). See also *PYTHONOPTIMIZE*.

Changed in version 3.5: Modify `.pyc` filenames according to **PEP 488**.

`-OO`

Do *-O* and also discard docstrings. Augment the filename for compiled (*bytecode*) files by adding `.opt-2` before the `.pyc` extension (see **PEP 488**).

Changed in version 3.5: Modify `.pyc` filenames according to **PEP 488**.

`-q`

Don't display the copyright and version messages even in interactive mode.

New in version 3.2.

`-R`

Turn on hash randomization. This option only has an effect if the *PYTHONHASHSEED* environment variable is set to `0`, since hash randomization is enabled by default.

On previous versions of Python, this option turns on hash randomization, so that the `__hash__()` values of str, bytes and datetime are "salted" with an unpredictable random value. Although they remain constant within an individual Python process, they are not predictable between repeated invocations of Python.

Hash randomization is intended to provide protection against a denial-of-service caused by carefully-chosen inputs that exploit the worst case performance of a dict construction, O(n^2) complexity. See http://www.ocert.org/advisories/ocert-2011-003.html for details.

PYTHONHASHSEED allows you to set a fixed value for the hash seed secret.

Changed in version 3.7: The option is no longer ignored.

New in version 3.2.3.

`-s`

Don't add the `user site-packages directory` to `sys.path`.

See also:

PEP 370 – Per user site-packages directory

-S

Disable the import of the module `site` and the site-dependent manipulations of `sys.path` that it entails. Also disable these manipulations if `site` is explicitly imported later (call `site.main()` if you want them to be triggered).

-u

Force the stdout and stderr streams to be unbuffered. This option has no effect on the stdin stream.

See also *PYTHONUNBUFFERED*.

Changed in version 3.7: The text layer of the stdout and stderr streams now is unbuffered.

-v

Print a message each time a module is initialized, showing the place (filename or built-in module) from which it is loaded. When given twice (`-vv`), print a message for each file that is checked for when searching for a module. Also provides information on module cleanup at exit. See also *PYTHONVERBOSE*.

-W arg

Warning control. Python's warning machinery by default prints warning messages to `sys.stderr`. A typical warning message has the following form:

```
file:line: category: message
```

By default, each warning is printed once for each source line where it occurs. This option controls how often warnings are printed.

Multiple *-W* options may be given; when a warning matches more than one option, the action for the last matching option is performed. Invalid *-W* options are ignored (though, a warning message is printed about invalid options when the first warning is issued).

Warnings can also be controlled using the *PYTHONWARNINGS* environment variable and from within a Python program using the `warnings` module.

The simplest settings apply a particular action unconditionally to all warnings emitted by a process (even those that are otherwise ignored by default):

```
-Wdefault  # Warn once per call location
-Werror    # Convert to exceptions
-Walways   # Warn every time
-Wmodule   # Warn once per calling module
-Wonce     # Warn once per Python process
-Wignore   # Never warn
```

The action names can be abbreviated as desired (e.g. `-Wi`, `-Wd`, `-Wa`, `-We`) and the interpreter will resolve them to the appropriate action name.

See warning-filter and describing-warning-filters for more details.

-x

Skip the first line of the source, allowing use of non-Unix forms of `#!cmd`. This is intended for a DOS specific hack only.

-X

Reserved for various implementation-specific options. CPython currently defines the following possible values:

- `-X faulthandler` to enable `faulthandler`;
- `-X showrefcount` to output the total reference count and number of used memory blocks when the program finishes or after each statement in the interactive interpreter. This only works on debug builds.

- `-X tracemalloc` to start tracing Python memory allocations using the `tracemalloc` module. By default, only the most recent frame is stored in a traceback of a trace. Use `-X tracemalloc=NFRAME` to start tracing with a traceback limit of *NFRAME* frames. See the `tracemalloc.start()` for more information.
- `-X showalloccount` to output the total count of allocated objects for each type when the program finishes. This only works when Python was built with `COUNT_ALLOCS` defined.
- `-X importtime` to show how long each import takes. It shows module name, cumulative time (including nested imports) and self time (excluding nested imports). Note that its output may be broken in multi-threaded application. Typical usage is `python3 -X importtime -c 'import asyncio'`. See also *PYTHONPROFILEIMPORTTIME*.
- `-X dev`: enable CPython's "development mode", introducing additional runtime checks which are too expensive to be enabled by default. It should not be more verbose than the default if the code is correct: new warnings are only emitted when an issue is detected. Effect of the developer mode:
  - Add `default` warning filter, as *-W* `default`.
  - Install debug hooks on memory allocators: see the `PyMem_SetupDebugHooks()` C function.
  - Enable the `faulthandler` module to dump the Python traceback on a crash.
  - Enable asyncio debug mode.
  - Set the `dev_mode` attribute of `sys.flags` to `True`
- `-X utf8` enables UTF-8 mode for operating system interfaces, overriding the default locale-aware mode. `-X utf8=0` explicitly disables UTF-8 mode (even when it would otherwise activate automatically). See *PYTHONUTF8* for more details.

It also allows passing arbitrary values and retrieving them through the `sys._xoptions` dictionary.

Changed in version 3.2: The *-X* option was added.

New in version 3.3: The `-X faulthandler` option.

New in version 3.4: The `-X showrefcount` and `-X tracemalloc` options.

New in version 3.6: The `-X showalloccount` option.

New in version 3.7: The `-X importtime`, `-X dev` and `-X utf8` options.

1.1.4 Options you shouldn't use

`-J`
: Reserved for use by Jython.

1.2 Environment variables

These environment variables influence Python's behavior, they are processed before the command-line switches other than -E or -I. It is customary that command-line switches override environmental variables where there is a conflict.

`PYTHONHOME`
: Change the location of the standard Python libraries. By default, the libraries are searched in *prefix*`/lib/python`*version* and *exec_prefix*`/lib/python`*version*, where *prefix* and *exec_prefix* are installation-dependent directories, both defaulting to `/usr/local`.

  When *PYTHONHOME* is set to a single directory, its value replaces both *prefix* and *exec_prefix*. To specify different values for these, set *PYTHONHOME* to *prefix*`:`*exec_prefix*.

PYTHONPATH
: Augment the default search path for module files. The format is the same as the shell's PATH: one or more directory pathnames separated by os.pathsep (e.g. colons on Unix or semicolons on Windows). Non-existent directories are silently ignored.

  In addition to normal directories, individual *PYTHONPATH* entries may refer to zipfiles containing pure Python modules (in either source or compiled form). Extension modules cannot be imported from zipfiles.

  The default search path is installation dependent, but generally begins with *prefix*/lib/pythonversion (see *PYTHONHOME* above). It is *always* appended to *PYTHONPATH*.

  An additional directory will be inserted in the search path in front of *PYTHONPATH* as described above under *Interface options*. The search path can be manipulated from within a Python program as the variable sys.path.

PYTHONSTARTUP
: If this is the name of a readable file, the Python commands in that file are executed before the first prompt is displayed in interactive mode. The file is executed in the same namespace where interactive commands are executed so that objects defined or imported in it can be used without qualification in the interactive session. You can also change the prompts sys.ps1 and sys.ps2 and the hook sys.__interactivehook__ in this file.

PYTHONOPTIMIZE
: If this is set to a non-empty string it is equivalent to specifying the *-O* option. If set to an integer, it is equivalent to specifying *-O* multiple times.

PYTHONBREAKPOINT
: If this is set, it names a callable using dotted-path notation. The module containing the callable will be imported and then the callable will be run by the default implementation of sys.breakpointhook() which itself is called by built-in breakpoint(). If not set, or set to the empty string, it is equivalent to the value "pdb.set_trace". Setting this to the string "0" causes the default implementation of sys.breakpointhook() to do nothing but return immediately.

  New in version 3.7.

PYTHONDEBUG
: If this is set to a non-empty string it is equivalent to specifying the *-d* option. If set to an integer, it is equivalent to specifying *-d* multiple times.

PYTHONINSPECT
: If this is set to a non-empty string it is equivalent to specifying the *-i* option.

  This variable can also be modified by Python code using os.environ to force inspect mode on program termination.

PYTHONUNBUFFERED
: If this is set to a non-empty string it is equivalent to specifying the *-u* option.

PYTHONVERBOSE
: If this is set to a non-empty string it is equivalent to specifying the *-v* option. If set to an integer, it is equivalent to specifying *-v* multiple times.

PYTHONCASEOK
: If this is set, Python ignores case in import statements. This only works on Windows and OS X.

PYTHONDONTWRITEBYTECODE
: If this is set to a non-empty string, Python won't try to write .pyc files on the import of source modules. This is equivalent to specifying the *-B* option.

PYTHONHASHSEED
: If this variable is not set or set to random, a random value is used to seed the hashes of str, bytes and datetime objects.

If *PYTHONHASHSEED* is set to an integer value, it is used as a fixed seed for generating the hash() of the types covered by the hash randomization.

Its purpose is to allow repeatable hashing, such as for selftests for the interpreter itself, or to allow a cluster of python processes to share hash values.

The integer must be a decimal number in the range [0,4294967295]. Specifying the value 0 will disable hash randomization.

New in version 3.2.3.

`PYTHONIOENCODING`
: If this is set before running the interpreter, it overrides the encoding used for stdin/stdout/stderr, in the syntax `encodingname:errorhandler`. Both the `encodingname` and the `:errorhandler` parts are optional and have the same meaning as in `str.encode()`.

  For stderr, the `:errorhandler` part is ignored; the handler will always be `'backslashreplace'`.

  Changed in version 3.4: The `encodingname` part is now optional.

  Changed in version 3.6: On Windows, the encoding specified by this variable is ignored for interactive console buffers unless *PYTHONLEGACYWINDOWSSTDIO* is also specified. Files and pipes redirected through the standard streams are not affected.

`PYTHONNOUSERSITE`
: If this is set, Python won't add the `user site-packages directory` to `sys.path`.

  See also:

  PEP 370 – Per user site-packages directory

`PYTHONUSERBASE`
: Defines the `user base directory`, which is used to compute the path of the `user site-packages directory` and Distutils installation paths for `python setup.py install --user`.

  See also:

  PEP 370 – Per user site-packages directory

`PYTHONEXECUTABLE`
: If this environment variable is set, `sys.argv[0]` will be set to its value instead of the value got through the C runtime. Only works on Mac OS X.

`PYTHONWARNINGS`
: This is equivalent to the *-W* option. If set to a comma separated string, it is equivalent to specifying *-W* multiple times, with filters later in the list taking precedence over those earlier in the list.

  The simplest settings apply a particular action unconditionally to all warnings emitted by a process (even those that are otherwise ignored by default):

```
PYTHONWARNINGS=default  # Warn once per call location
PYTHONWARNINGS=error    # Convert to exceptions
PYTHONWARNINGS=always   # Warn every time
PYTHONWARNINGS=module   # Warn once per calling module
PYTHONWARNINGS=once     # Warn once per Python process
PYTHONWARNINGS=ignore   # Never warn
```

  See warning-filter and describing-warning-filters for more details.

`PYTHONFAULTHANDLER`
: If this environment variable is set to a non-empty string, `faulthandler.enable()` is called at startup: install a handler for `SIGSEGV`, `SIGFPE`, `SIGABRT`, `SIGBUS` and `SIGILL` signals to dump the Python traceback. This is equivalent to *-X* `faulthandler` option.

  New in version 3.3.

PYTHONTRACEMALLOC
: If this environment variable is set to a non-empty string, start tracing Python memory allocations using the `tracemalloc` module. The value of the variable is the maximum number of frames stored in a traceback of a trace. For example, `PYTHONTRACEMALLOC=1` stores only the most recent frame. See the `tracemalloc.start()` for more information.

  New in version 3.4.

PYTHONPROFILEIMPORTTIME
: If this environment variable is set to a non-empty string, Python will show how long each import takes. This is exactly equivalent to setting `-X importtime` on the command line.

  New in version 3.7.

PYTHONASYNCIODEBUG
: If this environment variable is set to a non-empty string, enable the debug mode of the `asyncio` module.

  New in version 3.4.

PYTHONMALLOC
: Set the Python memory allocators and/or install debug hooks.

  Set the family of memory allocators used by Python:

  - `default`: use the default memory allocators.
  - `malloc`: use the `malloc()` function of the C library for all domains (`PYMEM_DOMAIN_RAW`, `PYMEM_DOMAIN_MEM`, `PYMEM_DOMAIN_OBJ`).
  - `pymalloc`: use the pymalloc allocator for `PYMEM_DOMAIN_MEM` and `PYMEM_DOMAIN_OBJ` domains and use the `malloc()` function for the `PYMEM_DOMAIN_RAW` domain.

  Install debug hooks:

  - `debug`: install debug hooks on top of the default memory allocators.
  - `malloc_debug`: same as `malloc` but also install debug hooks
  - `pymalloc_debug`: same as `pymalloc` but also install debug hooks

  See the default memory allocators and the `PyMem_SetupDebugHooks()` function (install debug hooks on Python memory allocators).

  Changed in version 3.7: Added the `"default"` allocator.

  New in version 3.6.

PYTHONMALLOCSTATS
: If set to a non-empty string, Python will print statistics of the pymalloc memory allocator every time a new pymalloc object arena is created, and on shutdown.

  This variable is ignored if the *PYTHONMALLOC* environment variable is used to force the `malloc()` allocator of the C library, or if Python is configured without `pymalloc` support.

  Changed in version 3.6: This variable can now also be used on Python compiled in release mode. It now has no effect if set to an empty string.

PYTHONLEGACYWINDOWSFSENCODING
: If set to a non-empty string, the default filesystem encoding and errors mode will revert to their pre-3.6 values of 'mbcs' and 'replace', respectively. Otherwise, the new defaults 'utf-8' and 'surrogatepass' are used.

  This may also be enabled at runtime with `sys._enablelegacywindowsfsencoding()`.

  Availability: Windows

  New in version 3.6: See **PEP 529** for more details.

PYTHONLEGACYWINDOWSSTDIO
: If set to a non-empty string, does not use the new console reader and writer. This means that Unicode characters will be encoded according to the active console code page, rather than using utf-8.

  This variable is ignored if the standard streams are redirected (to files or pipes) rather than referring to console buffers.

  Availability: Windows

  New in version 3.6.

PYTHONCOERCECLOCALE
: If set to the value `0`, causes the main Python command line application to skip coercing the legacy ASCII-based C and POSIX locales to a more capable UTF-8 based alternative.

  If this variable is *not* set (or is set to a value other than `0`), the `LC_ALL` locale override environment variable is also not set, and the current locale reported for the `LC_CTYPE` category is either the default `C` locale, or else the explicitly ASCII-based `POSIX` locale, then the Python CLI will attempt to configure the following locales for the `LC_CTYPE` category in the order listed before loading the interpreter runtime:

  - `C.UTF-8`
  - `C.utf8`
  - `UTF-8`

  If setting one of these locale categories succeeds, then the `LC_CTYPE` environment variable will also be set accordingly in the current process environment before the Python runtime is initialized. This ensures that in addition to being seen by both the interpreter itself and other locale-aware components running in the same process (such as the GNU `readline` library), the updated setting is also seen in subprocesses (regardless of whether or not those processes are running a Python interpreter), as well as in operations that query the environment rather than the current C locale (such as Python's own `locale.getdefaultlocale()`).

  Configuring one of these locales (either explicitly or via the above implicit locale coercion) automatically enables the `surrogateescape` error handler for `sys.stdin` and `sys.stdout` (`sys.stderr` continues to use `backslashreplace` as it does in any other locale). This stream handling behavior can be overridden using *PYTHONIOENCODING* as usual.

  For debugging purposes, setting `PYTHONCOERCECLOCALE=warn` will cause Python to emit warning messages on `stderr` if either the locale coercion activates, or else if a locale that *would* have triggered coercion is still active when the Python runtime is initialized.

  Also note that even when locale coercion is disabled, or when it fails to find a suitable target locale, *PYTHONUTF8* will still activate by default in legacy ASCII-based locales. Both features must be disabled in order to force the interpreter to use `ASCII` instead of `UTF-8` for system interfaces.

  Availability: *nix

  New in version 3.7: See **PEP 538** for more details.

PYTHONDEVMODE
: If this environment variable is set to a non-empty string, enable the CPython "development mode". See the *-X* `dev` option.

  New in version 3.7.

PYTHONUTF8
: If set to `1`, enables the interpreter's UTF-8 mode, where `UTF-8` is used as the text encoding for system interfaces, regardless of the current locale setting.

  This means that:

  - `sys.getfilesystemencoding()` returns `'UTF-8'` (the locale encoding is ignored).

- `locale.getpreferredencoding()` returns `'UTF-8'` (the locale encoding is ignored, and the function's `do_setlocale` parameter has no effect).
- `sys.stdin`, `sys.stdout`, and `sys.stderr` all use UTF-8 as their text encoding, with the `surrogateescape` error handler being enabled for `sys.stdin` and `sys.stdout` (`sys.stderr` continues to use `backslashreplace` as it does in the default locale-aware mode)

As a consequence of the changes in those lower level APIs, other higher level APIs also exhibit different default behaviours:

- Command line arguments, environment variables and filenames are decoded to text using the UTF-8 encoding.
- `os.fsdecode()` and `os.fsencode()` use the UTF-8 encoding.
- `open()`, `io.open()`, and `codecs.open()` use the UTF-8 encoding by default. However, they still use the strict error handler by default so that attempting to open a binary file in text mode is likely to raise an exception rather than producing nonsense data.

Note that the standard stream settings in UTF-8 mode can be overridden by *PYTHONIOENCODING* (just as they can be in the default locale-aware mode).

If set to `0`, the interpreter runs in its default locale-aware mode.

Setting any other non-empty string causes an error during interpreter initialisation.

If this environment variable is not set at all, then the interpreter defaults to using the current locale settings, *unless* the current locale is identified as a legacy ASCII-based locale (as described for *PYTHONCOERCECLOCALE*), and locale coercion is either disabled or fails. In such legacy locales, the interpreter will default to enabling UTF-8 mode unless explicitly instructed not to do so.

Also available as the *-X* `utf8` option.

Availability: *nix

New in version 3.7: See **PEP 540** for more details.

1.2.1 Debug-mode variables

Setting these variables only has an effect in a debug build of Python, that is, if Python was configured with the `--with-pydebug` build option.

`PYTHONTHREADDEBUG`
If set, Python will print threading debug info.

`PYTHONDUMPREFS`
If set, Python will dump objects and reference counts still alive after shutting down the interpreter.

CHAPTER

TWO

USING PYTHON ON UNIX PLATFORMS

2.1 Getting and installing the latest version of Python

2.1.1 On Linux

Python comes preinstalled on most Linux distributions, and is available as a package on all others. However there are certain features you might want to use that are not available on your distro's package. You can easily compile the latest version of Python from source.

In the event that Python doesn't come preinstalled and isn't in the repositories as well, you can easily make packages for your own distro. Have a look at the following links:

See also:

https://www.debian.org/doc/manuals/maint-guide/first.en.html for Debian users

https://en.opensuse.org/Portal:Packaging for OpenSuse users

https://docs-old.fedoraproject.org/en-US/Fedora_Draft_Documentation/0.1/html/RPM_Guide/ch-creati for Fedora users

http://www.slackbook.org/html/package-management-making-packages.html for Slackware users

2.1.2 On FreeBSD and OpenBSD

- FreeBSD users, to add the package use:

```
pkg install python3
```

- OpenBSD users, to add the package use:

```
pkg_add -r python

pkg_add ftp://ftp.openbsd.org/pub/OpenBSD/4.2/packages/<insert your architecture here>/python-
↪<version>.tgz
```

For example i386 users get the 2.5.1 version of Python using:

```
pkg_add ftp://ftp.openbsd.org/pub/OpenBSD/4.2/packages/i386/python-2.5.1p2.tgz
```

2.1.3 On OpenSolaris

You can get Python from OpenCSW. Various versions of Python are available and can be installed with e.g. `pkgutil -i python27`.

2.2 Building Python

If you want to compile CPython yourself, first thing you should do is get the source. You can download either the latest release's source or just grab a fresh clone. (If you want to contribute patches, you will need a clone.)

The build process consists in the usual

```
./configure
make
make install
```

invocations. Configuration options and caveats for specific Unix platforms are extensively documented in the README.rst file in the root of the Python source tree.

> **Warning:** `make install` can overwrite or masquerade the `python3` binary. `make altinstall` is therefore recommended instead of `make install` since it only installs *exec_prefix*`/bin/python`*version*.

2.3 Python-related paths and files

These are subject to difference depending on local installation conventions; `prefix` (`${prefix}`) and `exec_prefix` (`${exec_prefix}`) are installation-dependent and should be interpreted as for GNU software; they may be the same.

For example, on most Linux systems, the default for both is `/usr`.

File/directory	Meaning
exec_prefix`/bin/python3`	Recommended location of the interpreter.
prefix`/lib/python`*version*, *exec_prefix*`/lib/python`*version*	Recommended locations of the directories containing the standard modules.
prefix`/include/python`*version*, *exec_prefix*`/include/python`*version*	Recommended locations of the directories containing the include files needed for developing Python extensions and embedding the interpreter.

2.4 Miscellaneous

To easily use Python scripts on Unix, you need to make them executable, e.g. with

```
$ chmod +x script
```

and put an appropriate Shebang line at the top of the script. A good choice is usually

```
#!/usr/bin/env python3
```

which searches for the Python interpreter in the whole `PATH`. However, some Unices may not have the `env` command, so you may need to hardcode `/usr/bin/python3` as the interpreter path.

To use shell commands in your Python scripts, look at the `subprocess` module.

2.5 Editors and IDEs

There are a number of IDEs that support Python programming language. Many editors and IDEs provide syntax highlighting, debugging tools, and PEP-8 checks.

Please go to Python Editors and Integrated Development Environments for a comprehensive list.

CHAPTER

THREE

USING PYTHON ON WINDOWS

This document aims to give an overview of Windows-specific behaviour you should know about when using Python on Microsoft Windows.

3.1 Installing Python

Unlike most Unix systems and services, Windows does not include a system supported installation of Python. To make Python available, the CPython team has compiled Windows installers (MSI packages) with every release for many years. These installers are primarily intended to add a per-user installation of Python, with the core interpreter and library being used by a single user. The installer is also able to install for all users of a single machine, and a separate ZIP file is available for application-local distributions.

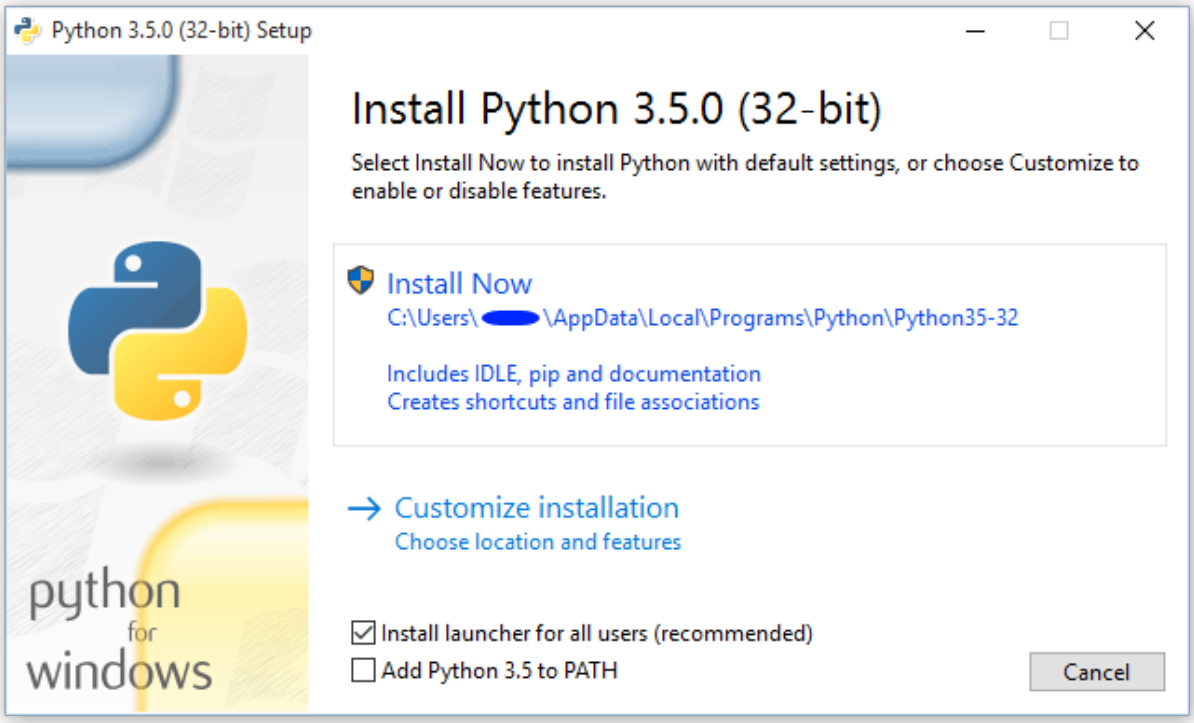
3.1.1 Supported Versions

As specified in **PEP 11**, a Python release only supports a Windows platform while Microsoft considers the platform under extended support. This means that Python 3.7 supports Windows Vista and newer. If you require Windows XP support then please install Python 3.4.

3.1.2 Installation Steps

Four Python 3.7 installers are available for download - two each for the 32-bit and 64-bit versions of the interpreter. The *web installer* is a small initial download, and it will automatically download the required components as necessary. The *offline installer* includes the components necessary for a default installation and only requires an internet connection for optional features. See *Installing Without Downloading* for other ways to avoid downloading during installation.

After starting the installer, one of two options may be selected:



If you select "Install Now":

- You will *not* need to be an administrator (unless a system update for the C Runtime Library is required or you install the *Python Launcher for Windows* for all users)
- Python will be installed into your user directory
- The *Python Launcher for Windows* will be installed according to the option at the bottom of the first page
- The standard library, test suite, launcher and pip will be installed
- If selected, the install directory will be added to your `PATH`
- Shortcuts will only be visible for the current user

Selecting "Customize installation" will allow you to select the features to install, the installation location and other options or post-install actions. To install debugging symbols or binaries, you will need to use this option.

To perform an all-users installation, you should select "Customize installation". In this case:

- You may be required to provide administrative credentials or approval
- Python will be installed into the Program Files directory
- The *Python Launcher for Windows* will be installed into the Windows directory
- Optional features may be selected during installation
- The standard library can be pre-compiled to bytecode
- If selected, the install directory will be added to the system `PATH`
- Shortcuts are available for all users

3.1.3 Removing the MAX_PATH Limitation

Windows historically has limited path lengths to 260 characters. This meant that paths longer than this would not resolve and errors would result.

In the latest versions of Windows, this limitation can be expanded to approximately 32,000 characters. Your administrator will need to activate the "Enable Win32 long paths" group policy, or set the registry value `HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Control\FileSystem@LongPathsEnabled` to `1`.

This allows the `open()` function, the `os` module and most other path functionality to accept and return paths longer than 260 characters when using strings. (Use of bytes as paths is deprecated on Windows, and this feature is not available when using bytes.)

After changing the above option, no further configuration is required.

Changed in version 3.6: Support for long paths was enabled in Python.

3.1.4 Installing Without UI

All of the options available in the installer UI can also be specified from the command line, allowing scripted installers to replicate an installation on many machines without user interaction. These options may also be set without suppressing the UI in order to change some of the defaults.

To completely hide the installer UI and install Python silently, pass the `/quiet` option. To skip past the user interaction but still display progress and errors, pass the `/passive` option. The `/uninstall` option may be passed to immediately begin removing Python - no prompt will be displayed.

All other options are passed as `name=value`, where the value is usually `0` to disable a feature, `1` to enable a feature, or a path. The full list of available options is shown below.

Name	Description	Default
InstallAllUsers	Perform a system-wide installation.	0
TargetDir	The installation directory	Selected based on InstallAllUsers
DefaultAllUsersTargetDir	The default installation directory for all-user installs	`%ProgramFiles%\Python X.Y` or `%ProgramFiles(x86)%\Python X.Y`
DefaultJustForMeTargetDir	The default install directory for just-for-me installs	`%LocalAppData%\Programs\PythonXY` or `%LocalAppData%\Programs\PythonXY-32`
DefaultCustomTargetDir	The default custom install directory displayed in the UI	(empty)
AssociateFiles	Create file associations if the launcher is also installed.	1
CompileAll	Compile all `.py` files to `.pyc`.	0
PrependPath	Add install and Scripts directories tho `PATH` and `.PY` to `PATHEXT`	0
Shortcuts	Create shortcuts for the interpreter, documentation and IDLE if installed.	1
Include_doc	Install Python manual	1
Include_debug	Install debug binaries	0
Include_dev	Install developer headers and libraries	1
Include_exe	Install `python.exe` and related files	1
Include_launcher	Install *Python Launcher for Windows*.	1
InstallLauncherAllUsers	Installs *Python Launcher for Windows* for all users.	1
Include_lib	Install standard library and extension modules	1
Include_pip	Install bundled pip and setuptools	1
Include_symbols	Install debugging symbols (*.pdb)	0
Include_tcltk	Install Tcl/Tk support and IDLE	1
Include_test	Install standard library test suite	1
Include_tools	Install utility scripts	1
LauncherOnly	Only installs the launcher. This will override most other options.	0
SimpleInstall	Disable most install UI	0
SimpleInstallDescription	A custom message to display when the simplified install UI is used.	(empty)

For example, to silently install a default, system-wide Python installation, you could use the following command (from an elevated command prompt):

```
python-3.6.0.exe /quiet InstallAllUsers=1 PrependPath=1 Include_test=0
```

To allow users to easily install a personal copy of Python without the test suite, you could provide a shortcut with the following command. This will display a simplified initial page and disallow customization:

```
python-3.6.0.exe InstallAllUsers=0 Include_launcher=0 Include_test=0
    SimpleInstall=1 SimpleInstallDescription="Just for me, no test suite."
```

(Note that omitting the launcher also omits file associations, and is only recommended for per-user installs when there is also a system-wide installation that included the launcher.)

The options listed above can also be provided in a file named `unattend.xml` alongside the executable. This file specifies a list of options and values. When a value is provided as an attribute, it will be converted to a number if possible. Values provided as element text are always left as strings. This example file sets the same options and the previous example:

```
<Options>
    <Option Name="InstallAllUsers" Value="no" />
    <Option Name="Include_launcher" Value="0" />
    <Option Name="Include_test" Value="no" />
    <Option Name="SimpleInstall" Value="yes" />
    <Option Name="SimpleInstallDescription">Just for me, no test suite</Option>
</Options>
```

3.1.5 Installing Without Downloading

As some features of Python are not included in the initial installer download, selecting those features may require an internet connection. To avoid this need, all possible components may be downloaded on-demand to create a complete *layout* that will no longer require an internet connection regardless of the selected features. Note that this download may be bigger than required, but where a large number of installations are going to be performed it is very useful to have a locally cached copy.

Execute the following command from Command Prompt to download all possible required files. Remember to substitute `python-3.6.0.exe` for the actual name of your installer, and to create layouts in their own directories to avoid collisions between files with the same name.

```
python-3.6.0.exe /layout [optional target directory]
```

You may also specify the `/quiet` option to hide the progress display.

3.1.6 Modifying an install

Once Python has been installed, you can add or remove features through the Programs and Features tool that is part of Windows. Select the Python entry and choose "Uninstall/Change" to open the installer in maintenance mode.

"Modify" allows you to add or remove features by modifying the checkboxes - unchanged checkboxes will not install or remove anything. Some options cannot be changed in this mode, such as the install directory; to modify these, you will need to remove and then reinstall Python completely.

"Repair" will verify all the files that should be installed using the current settings and replace any that have been removed or modified.

"Uninstall" will remove Python entirely, with the exception of the *Python Launcher for Windows*, which has its own entry in Programs and Features.

3.1.7 Other Platforms

With ongoing development of Python, some platforms that used to be supported earlier are no longer supported (due to the lack of users or developers). Check **PEP 11** for details on all unsupported platforms.

- Windows CE is still supported.
- The Cygwin installer offers to install the Python interpreter as well (cf. Cygwin package source, Maintainer releases)

See Python for Windows for detailed information about platforms with pre-compiled installers.

See also:

Python on XP "7 Minutes to "Hello World!"" by Richard Dooling, 2006

Installing on Windows in "Dive into Python: Python from novice to pro" by Mark Pilgrim, 2004, ISBN 1-59059-356-1

For Windows users in "Installing Python" in "A Byte of Python" by Swaroop C H, 2003

3.2 Alternative bundles

Besides the standard CPython distribution, there are modified packages including additional functionality. The following is a list of popular versions and their key features:

ActivePython Installer with multi-platform compatibility, documentation, PyWin32

Anaconda Popular scientific modules (such as numpy, scipy and pandas) and the `conda` package manager.

Canopy A "comprehensive Python analysis environment" with editors and other development tools.

WinPython Windows-specific distribution with prebuilt scientific packages and tools for building packages.

Note that these packages may not include the latest versions of Python or other libraries, and are not maintained or supported by the core Python team.

3.3 Configuring Python

To run Python conveniently from a command prompt, you might consider changing some default environment variables in Windows. While the installer provides an option to configure the PATH and PATHEXT variables for you, this is only reliable for a single, system-wide installation. If you regularly use multiple versions of Python, consider using the *Python Launcher for Windows*.

3.3.1 Excursus: Setting environment variables

Windows allows environment variables to be configured permanently at both the User level and the System level, or temporarily in a command prompt.

To temporarily set environment variables, open Command Prompt and use the **set** command:

```
C:\>set PATH=C:\Program Files\Python 3.6;%PATH%
C:\>set PYTHONPATH=%PYTHONPATH%;C:\My_python_lib
C:\>python
```

These changes will apply to any further commands executed in that console, and will be inherited by any applications started from the console.

Including the variable name within percent signs will expand to the existing value, allowing you to add your new value at either the start or the end. Modifying `PATH` by adding the directory containing **`python.exe`** to the start is a common way to ensure the correct version of Python is launched.

To permanently modify the default environment variables, click Start and search for 'edit environment variables', or open System properties, *Advanced system settings* and click the *Environment Variables* button. In this dialog, you can add or modify User and System variables. To change System variables, you need non-restricted access to your machine (i.e. Administrator rights).

Note: Windows will concatenate User variables *after* System variables, which may cause unexpected results when modifying `PATH`.

The *PYTHONPATH* variable is used by all versions of Python 2 and Python 3, so you should not permanently configure this variable unless it only includes code that is compatible with all of your installed Python versions.

See also:

https://support.microsoft.com/en-us/help/100843/environment-variables-in-windows-nt Environment variables in Windows NT

https://technet.microsoft.com/en-us/library/cc754250.aspx The SET command, for temporarily modifying environment variables

https://technet.microsoft.com/en-us/library/cc755104.aspx The SETX command, for permanently modifying environment variables

https://support.microsoft.com/en-us/help/310519/how-to-manage-environment-variables-in-windows-xp How To Manage Environment Variables in Windows XP

https://www.chem.gla.ac.uk/~louis/software/faq/q1.html Setting Environment variables, Louis J. Farrugia

3.3.2 Finding the Python executable

Changed in version 3.5.

Besides using the automatically created start menu entry for the Python interpreter, you might want to start Python in the command prompt. The installer has an option to set that up for you.

On the first page of the installer, an option labelled "Add Python to PATH" may be selected to have the installer add the install location into the `PATH`. The location of the `Scripts\` folder is also added. This allows you to type **`python`** to run the interpreter, and **`pip`** for the package installer. Thus, you can also execute your scripts with command line options, see *Command line* documentation.

If you don't enable this option at install time, you can always re-run the installer, select Modify, and enable it. Alternatively, you can manually modify the `PATH` using the directions in *Excursus: Setting environment variables*. You need to set your `PATH` environment variable to include the directory of your Python installation, delimited by a semicolon from other entries. An example variable could look like this (assuming the first two entries already existed):

```
C:\WINDOWS\system32;C:\WINDOWS;C:\Program Files\Python 3.6
```

3.4 Python Launcher for Windows

New in version 3.3.

The Python launcher for Windows is a utility which aids in locating and executing of different Python versions. It allows scripts (or the command-line) to indicate a preference for a specific Python version, and will locate and execute that version.

Unlike the `PATH` variable, the launcher will correctly select the most appropriate version of Python. It will prefer per-user installations over system-wide ones, and orders by language version rather than using the most recently installed version.

3.4.1 Getting started

From the command-line

Changed in version 3.6.

System-wide installations of Python 3.3 and later will put the launcher on your `PATH`. The launcher is compatible with all available versions of Python, so it does not matter which version is installed. To check that the launcher is available, execute the following command in Command Prompt:

```
py
```

You should find that the latest version of Python you have installed is started - it can be exited as normal, and any additional command-line arguments specified will be sent directly to Python.

If you have multiple versions of Python installed (e.g., 2.7 and 3.7) you will have noticed that Python 3.7 was started - to launch Python 2.7, try the command:

```
py -2.7
```

If you want the latest version of Python 2.x you have installed, try the command:

```
py -2
```

You should find the latest version of Python 2.x starts.

If you see the following error, you do not have the launcher installed:

```
'py' is not recognized as an internal or external command,
operable program or batch file.
```

Per-user installations of Python do not add the launcher to `PATH` unless the option was selected on installation.

Virtual environments

New in version 3.5.

If the launcher is run with no explicit Python version specification, and a virtual environment (created with the standard library `venv` module or the external `virtualenv` tool) active, the launcher will run the virtual environment's interpreter rather than the global one. To run the global interpreter, either deactivate the virtual environment, or explicitly specify the global Python version.

From a script

Let's create a test Python script - create a file called `hello.py` with the following contents

```
#! python
import sys
sys.stdout.write("hello from Python %s\n" % (sys.version,))
```

From the directory in which hello.py lives, execute the command:

```
py hello.py
```

You should notice the version number of your latest Python 2.x installation is printed. Now try changing the first line to be:

```
#! python3
```

Re-executing the command should now print the latest Python 3.x information. As with the above command-line examples, you can specify a more explicit version qualifier. Assuming you have Python 2.6 installed, try changing the first line to `#! python2.6` and you should find the 2.6 version information printed.

Note that unlike interactive use, a bare "python" will use the latest version of Python 2.x that you have installed. This is for backward compatibility and for compatibility with Unix, where the command `python` typically refers to Python 2.

From file associations

The launcher should have been associated with Python files (i.e. `.py`, `.pyw`, `.pyc` files) when it was installed. This means that when you double-click on one of these files from Windows explorer the launcher will be used, and therefore you can use the same facilities described above to have the script specify the version which should be used.

The key benefit of this is that a single launcher can support multiple Python versions at the same time depending on the contents of the first line.

3.4.2 Shebang Lines

If the first line of a script file starts with `#!`, it is known as a "shebang" line. Linux and other Unix like operating systems have native support for such lines and they are commonly used on such systems to indicate how a script should be executed. This launcher allows the same facilities to be used with Python scripts on Windows and the examples above demonstrate their use.

To allow shebang lines in Python scripts to be portable between Unix and Windows, this launcher supports a number of 'virtual' commands to specify which interpreter to use. The supported virtual commands are:

- `/usr/bin/env python`
- `/usr/bin/python`
- `/usr/local/bin/python`
- `python`

For example, if the first line of your script starts with

```
#! /usr/bin/python
```

The default Python will be located and used. As many Python scripts written to work on Unix will already have this line, you should find these scripts can be used by the launcher without modification. If you are writing a new script on Windows which you hope will be useful on Unix, you should use one of the shebang lines starting with `/usr`.

Any of the above virtual commands can be suffixed with an explicit version (either just the major version, or the major and minor version) - for example `/usr/bin/python2.7` - which will cause that specific version to be located and used.

The `/usr/bin/env` form of shebang line has one further special property. Before looking for installed Python interpreters, this form will search the executable `PATH` for a Python executable. This corresponds to the behaviour of the Unix `env` program, which performs a `PATH` search.

3.4.3 Arguments in shebang lines

The shebang lines can also specify additional options to be passed to the Python interpreter. For example, if you have a shebang line:

```
#! /usr/bin/python -v
```

Then Python will be started with the `-v` option

3.4.4 Customization

Customization via INI files

Two .ini files will be searched by the launcher - `py.ini` in the current user's "application data" directory (i.e. the directory returned by calling the Windows function SHGetFolderPath with CSIDL_LOCAL_APPDATA) and `py.ini` in the same directory as the launcher. The same .ini files are used for both the 'console' version of the launcher (i.e. py.exe) and for the 'windows' version (i.e. pyw.exe)

Customization specified in the "application directory" will have precedence over the one next to the executable, so a user, who may not have write access to the .ini file next to the launcher, can override commands in that global .ini file)

Customizing default Python versions

In some cases, a version qualifier can be included in a command to dictate which version of Python will be used by the command. A version qualifier starts with a major version number and can optionally be followed by a period ('.') and a minor version specifier. If the minor qualifier is specified, it may optionally be followed by "-32" to indicate the 32-bit implementation of that version be used.

For example, a shebang line of `#!python` has no version qualifier, while `#!python3` has a version qualifier which specifies only a major version.

If no version qualifiers are found in a command, the environment variable `PY_PYTHON` can be set to specify the default version qualifier - the default value is "2". Note this value could specify just a major version (e.g. "2") or a major.minor qualifier (e.g. "2.6"), or even major.minor-32.

If no minor version qualifiers are found, the environment variable `PY_PYTHON{major}` (where `{major}` is the current major version qualifier as determined above) can be set to specify the full version. If no such option is found, the launcher will enumerate the installed Python versions and use the latest minor release found for the major version, which is likely, although not guaranteed, to be the most recently installed version in that family.

On 64-bit Windows with both 32-bit and 64-bit implementations of the same (major.minor) Python version installed, the 64-bit version will always be preferred. This will be true for both 32-bit and 64-bit implementations of the launcher - a 32-bit launcher will prefer to execute a 64-bit Python installation of the specified version if available. This is so the behavior of the launcher can be predicted knowing only what versions are installed on the PC and without regard to the order in which they were installed (i.e., without knowing whether a 32 or 64-bit version of Python and corresponding launcher was installed last). As noted above, an optional "-32" suffix can be used on a version specifier to change this behaviour.

Examples:

- If no relevant options are set, the commands `python` and `python2` will use the latest Python 2.x version installed and the command `python3` will use the latest Python 3.x installed.
- The commands `python3.1` and `python2.7` will not consult any options at all as the versions are fully specified.

- If `PY_PYTHON=3`, the commands `python` and `python3` will both use the latest installed Python 3 version.
- If `PY_PYTHON=3.1-32`, the command `python` will use the 32-bit implementation of 3.1 whereas the command `python3` will use the latest installed Python (PY_PYTHON was not considered at all as a major version was specified.)
- If `PY_PYTHON=3` and `PY_PYTHON3=3.1`, the commands `python` and `python3` will both use specifically 3.1

In addition to environment variables, the same settings can be configured in the .INI file used by the launcher. The section in the INI file is called `[defaults]` and the key name will be the same as the environment variables without the leading `PY_` prefix (and note that the key names in the INI file are case insensitive.) The contents of an environment variable will override things specified in the INI file.

For example:

- Setting `PY_PYTHON=3.1` is equivalent to the INI file containing:

```
[defaults]
python=3.1
```

- Setting `PY_PYTHON=3` and `PY_PYTHON3=3.1` is equivalent to the INI file containing:

```
[defaults]
python=3
python3=3.1
```

3.4.5 Diagnostics

If an environment variable `PYLAUNCH_DEBUG` is set (to any value), the launcher will print diagnostic information to stderr (i.e. to the console). While this information manages to be simultaneously verbose *and* terse, it should allow you to see what versions of Python were located, why a particular version was chosen and the exact command-line used to execute the target Python.

3.5 Finding modules

Python usually stores its library (and thereby your site-packages folder) in the installation directory. So, if you had installed Python to `C:\Python\`, the default library would reside in `C:\Python\Lib\` and third-party modules should be stored in `C:\Python\Lib\site-packages\`.

To completely override `sys.path`, create a `._pth` file with the same name as the DLL (`python37._pth`) or the executable (`python._pth`) and specify one line for each path to add to `sys.path`. The file based on the DLL name overrides the one based on the executable, which allows paths to be restricted for any program loading the runtime if desired.

When the file exists, all registry and environment variables are ignored, isolated mode is enabled, and `site` is not imported unless one line in the file specifies `import site`. Blank paths and lines starting with `#` are ignored. Each path may be absolute or relative to the location of the file. Import statements other than to `site` are not permitted, and arbitrary code cannot be specified.

Note that `.pth` files (without leading underscore) will be processed normally by the `site` module when `import site` has been specified.

When no `._pth` file is found, this is how `sys.path` is populated on Windows:

- An empty entry is added at the start, which corresponds to the current directory.

- If the environment variable *PYTHONPATH* exists, as described in *Environment variables*, its entries are added next. Note that on Windows, paths in this variable must be separated by semicolons, to distinguish them from the colon used in drive identifiers (`C:\` etc.).
- Additional "application paths" can be added in the registry as subkeys of `\SOFTWARE\Python\PythonCore\`*version*`\PythonPath` under both the `HKEY_CURRENT_USER` and `HKEY_LOCAL_MACHINE` hives. Subkeys which have semicolon-delimited path strings as their default value will cause each path to be added to `sys.path`. (Note that all known installers only use HKLM, so HKCU is typically empty.)
- If the environment variable *PYTHONHOME* is set, it is assumed as "Python Home". Otherwise, the path of the main Python executable is used to locate a "landmark file" (either `Lib\os.py` or `pythonXY.zip`) to deduce the "Python Home". If a Python home is found, the relevant sub-directories added to `sys.path` (`Lib`, `plat-win`, etc) are based on that folder. Otherwise, the core Python path is constructed from the PythonPath stored in the registry.
- If the Python Home cannot be located, no *PYTHONPATH* is specified in the environment, and no registry entries can be found, a default path with relative entries is used (e.g. `.\Lib;.\plat-win`, etc).

If a `pyvenv.cfg` file is found alongside the main executable or in the directory one level above the executable, the following variations apply:

- If `home` is an absolute path and *PYTHONHOME* is not set, this path is used instead of the path to the main executable when deducing the home location.

The end result of all this is:

- When running `python.exe`, or any other .exe in the main Python directory (either an installed version, or directly from the PCbuild directory), the core path is deduced, and the core paths in the registry are ignored. Other "application paths" in the registry are always read.
- When Python is hosted in another .exe (different directory, embedded via COM, etc), the "Python Home" will not be deduced, so the core path from the registry is used. Other "application paths" in the registry are always read.
- If Python can't find its home and there are no registry value (frozen .exe, some very strange installation setup) you get a path with some default, but relative, paths.

For those who want to bundle Python into their application or distribution, the following advice will prevent conflicts with other installations:

- Include a `._pth` file alongside your executable containing the directories to include. This will ignore paths listed in the registry and environment variables, and also ignore `site` unless `import site` is listed.
- If you are loading `python3.dll` or `python37.dll` in your own executable, explicitly call `Py_SetPath()` or (at least) `Py_SetProgramName()` before `Py_Initialize()`.
- Clear and/or overwrite *PYTHONPATH* and set *PYTHONHOME* before launching `python.exe` from your application.
- If you cannot use the previous suggestions (for example, you are a distribution that allows people to run `python.exe` directly), ensure that the landmark file (`Lib\os.py`) exists in your install directory. (Note that it will not be detected inside a ZIP file, but a correctly named ZIP file will be detected instead.)

These will ensure that the files in a system-wide installation will not take precedence over the copy of the standard library bundled with your application. Otherwise, your users may experience problems using your application. Note that the first suggestion is the best, as the other may still be susceptible to non-standard paths in the registry and user site-packages.

Changed in version 3.6:

- Adds `._pth` file support and removes `applocal` option from `pyvenv.cfg`.

- Adds `pythonXX.zip` as a potential landmark when directly adjacent to the executable.

Deprecated since version 3.6: Modules specified in the registry under `Modules` (not `PythonPath`) may be imported by `importlib.machinery.WindowsRegistryFinder`. This finder is enabled on Windows in 3.6.0 and earlier, but may need to be explicitly added to `sys.meta_path` in the future.

3.6 Additional modules

Even though Python aims to be portable among all platforms, there are features that are unique to Windows. A couple of modules, both in the standard library and external, and snippets exist to use these features.

The Windows-specific standard modules are documented in mswin-specific-services.

3.6.1 PyWin32

The PyWin32 module by Mark Hammond is a collection of modules for advanced Windows-specific support. This includes utilities for:

- Component Object Model (COM)
- Win32 API calls
- Registry
- Event log
- Microsoft Foundation Classes (MFC) user interfaces

PythonWin is a sample MFC application shipped with PyWin32. It is an embeddable IDE with a built-in debugger.

See also:

Win32 How Do I...? by Tim Golden

Python and COM by David and Paul Boddie

3.6.2 cx_Freeze

cx_Freeze is a `distutils` extension (see extending-distutils) which wraps Python scripts into executable Windows programs (`*.exe` files). When you have done this, you can distribute your application without requiring your users to install Python.

3.6.3 WConio

Since Python's advanced terminal handling layer, `curses`, is restricted to Unix-like systems, there is a library exclusive to Windows as well: Windows Console I/O for Python.

WConio is a wrapper for Turbo-C's `CONIO.H`, used to create text user interfaces.

3.7 Compiling Python on Windows

If you want to compile CPython yourself, first thing you should do is get the source. You can download either the latest release's source or just grab a fresh checkout.

The source tree contains a build solution and project files for Microsoft Visual Studio 2015, which is the compiler used to build the official Python releases. These files are in the `PCbuild` directory.

Check `PCbuild/readme.txt` for general information on the build process.

For extension modules, consult building-on-windows.

See also:

Python + Windows + distutils + SWIG + gcc MinGW or "Creating Python extensions in C/C++ with SWIG and compiling them with MinGW gcc under Windows" or "Installing Python extension with distutils and without Microsoft Visual C++" by Sébastien Sauvage, 2003

MingW – Python extensions by Trent Apted et al, 2007

3.8 Embedded Distribution

New in version 3.5.

The embedded distribution is a ZIP file containing a minimal Python environment. It is intended for acting as part of another application, rather than being directly accessed by end-users.

When extracted, the embedded distribution is (almost) fully isolated from the user's system, including environment variables, system registry settings, and installed packages. The standard library is included as pre-compiled and optimized `.pyc` files in a ZIP, and `python3.dll`, `python37.dll`, `python.exe` and `pythonw.exe` are all provided. Tcl/tk (including all dependants, such as Idle), pip and the Python documentation are not included.

Note: The embedded distribution does not include the Microsoft C Runtime and it is the responsibility of the application installer to provide this. The runtime may have already been installed on a user's system previously or automatically via Windows Update, and can be detected by finding `ucrtbase.dll` in the system directory.

Third-party packages should be installed by the application installer alongside the embedded distribution. Using pip to manage dependencies as for a regular Python installation is not supported with this distribution, though with some care it may be possible to include and use pip for automatic updates. In general, third-party packages should be treated as part of the application ("vendoring") so that the developer can ensure compatibility with newer versions before providing updates to users.

The two recommended use cases for this distribution are described below.

3.8.1 Python Application

An application written in Python does not necessarily require users to be aware of that fact. The embedded distribution may be used in this case to include a private version of Python in an install package. Depending on how transparent it should be (or conversely, how professional it should appear), there are two options.

Using a specialized executable as a launcher requires some coding, but provides the most transparent experience for users. With a customized launcher, there are no obvious indications that the program is running on Python: icons can be customized, company and version information can be specified, and file associations behave properly. In most cases, a custom launcher should simply be able to call `Py_Main` with a hard-coded command line.

The simpler approach is to provide a batch file or generated shortcut that directly calls the `python.exe` or `pythonw.exe` with the required command-line arguments. In this case, the application will appear to be Python and not its actual name, and users may have trouble distinguishing it from other running Python processes or file associations.

With the latter approach, packages should be installed as directories alongside the Python executable to ensure they are available on the path. With the specialized launcher, packages can be located in other locations as there is an opportunity to specify the search path before launching the application.

3.8.2 Embedding Python

Applications written in native code often require some form of scripting language, and the embedded Python distribution can be used for this purpose. In general, the majority of the application is in native code, and some part will either invoke `python.exe` or directly use `python3.dll`. For either case, extracting the embedded distribution to a subdirectory of the application installation is sufficient to provide a loadable Python interpreter.

As with the application use, packages can be installed to any location as there is an opportunity to specify search paths before initializing the interpreter. Otherwise, there is no fundamental differences between using the embedded distribution and a regular installation.

3.9 Other resources

See also:

Python Programming On Win32 "Help for Windows Programmers" by Mark Hammond and Andy Robinson, O'Reilly Media, 2000, ISBN 1-56592-621-8

A Python for Windows Tutorial by Amanda Birmingham, 2004

PEP 397 - Python launcher for Windows The proposal for the launcher to be included in the Python distribution.

CHAPTER

FOUR

USING PYTHON ON A MACINTOSH

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Python on a Macintosh running Mac OS X is in principle very similar to Python on any other Unix platform, but there are a number of additional features such as the IDE and the Package Manager that are worth pointing out.

4.1 Getting and Installing MacPython

Mac OS X 10.8 comes with Python 2.7 pre-installed by Apple. If you wish, you are invited to install the most recent version of Python 3 from the Python website (https://www.python.org). A current "universal binary" build of Python, which runs natively on the Mac's new Intel and legacy PPC CPU's, is available there.

What you get after installing is a number of things:

- A `MacPython 3.6` folder in your `Applications` folder. In here you find IDLE, the development environment that is a standard part of official Python distributions; PythonLauncher, which handles double-clicking Python scripts from the Finder; and the "Build Applet" tool, which allows you to package Python scripts as standalone applications on your system.
- A framework `/Library/Frameworks/Python.framework`, which includes the Python executable and libraries. The installer adds this location to your shell path. To uninstall MacPython, you can simply remove these three things. A symlink to the Python executable is placed in /usr/local/bin/.

The Apple-provided build of Python is installed in `/System/Library/Frameworks/Python.framework` and `/usr/bin/python`, respectively. You should never modify or delete these, as they are Apple-controlled and are used by Apple- or third-party software. Remember that if you choose to install a newer Python version from python.org, you will have two different but functional Python installations on your computer, so it will be important that your paths and usages are consistent with what you want to do.

IDLE includes a help menu that allows you to access Python documentation. If you are completely new to Python you should start reading the tutorial introduction in that document.

If you are familiar with Python on other Unix platforms you should read the section on running Python scripts from the Unix shell.

4.1.1 How to run a Python script

Your best way to get started with Python on Mac OS X is through the IDLE integrated development environment, see section *The IDE* and use the Help menu when the IDE is running.

If you want to run Python scripts from the Terminal window command line or from the Finder you first need an editor to create your script. Mac OS X comes with a number of standard Unix command line editors, **`vim`** and **`emacs`** among them. If you want a more Mac-like editor, **`BBEdit`** or **`TextWrangler`** from Bare Bones

Software (see http://www.barebones.com/products/bbedit/index.html) are good choices, as is **TextMate** (see https://macromates.com/). Other editors include **Gvim** (http://macvim-dev.github.io/macvim/) and **Aquamacs** (http://aquamacs.org/).

To run your script from the Terminal window you must make sure that `/usr/local/bin` is in your shell search path.

To run your script from the Finder you have two options:

- Drag it to **PythonLauncher**
- Select **PythonLauncher** as the default application to open your script (or any .py script) through the finder Info window and double-click it. **PythonLauncher** has various preferences to control how your script is launched. Option-dragging allows you to change these for one invocation, or use its Preferences menu to change things globally.

4.1.2 Running scripts with a GUI

With older versions of Python, there is one Mac OS X quirk that you need to be aware of: programs that talk to the Aqua window manager (in other words, anything that has a GUI) need to be run in a special way. Use **pythonw** instead of **python** to start such scripts.

With Python 3.6, you can use either **python** or **pythonw**.

4.1.3 Configuration

Python on OS X honors all standard Unix environment variables such as *PYTHONPATH*, but setting these variables for programs started from the Finder is non-standard as the Finder does not read your `.profile` or `.cshrc` at startup. You need to create a file `~/.MacOSX/environment.plist`. See Apple's Technical Document QA1067 for details.

For more information on installation Python packages in MacPython, see section *Installing Additional Python Packages*.

4.2 The IDE

MacPython ships with the standard IDLE development environment. A good introduction to using IDLE can be found at http://www.hashcollision.org/hkn/python/idle_intro/index.html.

4.3 Installing Additional Python Packages

There are several methods to install additional Python packages:

- Packages can be installed via the standard Python distutils mode (`python setup.py install`).
- Many packages can also be installed via the **setuptools** extension or **pip** wrapper, see https://pip.pypa.io/.

4.4 GUI Programming on the Mac

There are several options for building GUI applications on the Mac with Python.

PyObjC is a Python binding to Apple's Objective-C/Cocoa framework, which is the foundation of most modern Mac development. Information on PyObjC is available from https://pythonhosted.org/pyobjc/.

The standard Python GUI toolkit is `tkinter`, based on the cross-platform Tk toolkit (https://www.tcl.tk). An Aqua-native version of Tk is bundled with OS X by Apple, and the latest version can be downloaded and installed from https://www.activestate.com; it can also be built from source.

wxPython is another popular cross-platform GUI toolkit that runs natively on Mac OS X. Packages and documentation are available from https://www.wxpython.org.

PyQt is another popular cross-platform GUI toolkit that runs natively on Mac OS X. More information can be found at https://riverbankcomputing.com/software/pyqt/intro.

4.5 Distributing Python Applications on the Mac

The "Build Applet" tool that is placed in the MacPython 3.6 folder is fine for packaging small Python scripts on your own machine to run as a standard Mac application. This tool, however, is not robust enough to distribute Python applications to other users.

The standard tool for deploying standalone Python applications on the Mac is `py2app`. More information on installing and using py2app can be found at http://undefined.org/python/#py2app.

4.6 Other Resources

The MacPython mailing list is an excellent support resource for Python users and developers on the Mac:

https://www.python.org/community/sigs/current/pythonmac-sig/

Another useful resource is the MacPython wiki:

https://wiki.python.org/moin/MacPython

APPENDIX

A

GLOSSARY

>>> The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

... The default Python prompt of the interactive shell when entering code for an indented code block, when within a pair of matching left and right delimiters (parentheses, square brackets, curly braces or triple quotes), or after specifying a decorator.

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See 2to3-reference.

abstract base class Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with magic methods). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections.abc` module), numbers (in the `numbers` module), streams (in the `io` module), import finders and loaders (in the `importlib.abc` module). You can create your own ABCs with the `abc` module.

annotation A label associated with a variable, a class attribute or a function parameter or return value, used by convention as a *type hint*.

Annotations of local variables cannot be accessed at runtime, but annotations of global variables, class attributes, and functions are stored in the `__annotations__` special attribute of modules, classes, and functions, respectively.

See *variable annotation*, *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

argument A value passed to a *function* (or *method*) when calling the function. There are two kinds of argument:

- *keyword argument*: an argument preceded by an identifier (e.g. `name=`) in a function call or passed as a value in a dictionary preceded by `**`. For example, `3` and `5` are both keyword arguments in the following calls to `complex()`:

```
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- *positional argument*: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an *iterable* preceded by `*`. For example, `3` and `5` are both positional arguments in the following calls:

```
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the calls section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the *parameter* glossary entry, the FAQ question on the difference between arguments and parameters, and **PEP 362**.

asynchronous context manager An object which controls the environment seen in an `async with` statement by defining `__aenter__()` and `__aexit__()` methods. Introduced by **PEP 492**.

asynchronous generator A function which returns an *asynchronous generator iterator*. It looks like a coroutine function defined with `async def` except that it contains `yield` expressions for producing a series of values usable in an `async for` loop.

Usually refers to a asynchronous generator function, but may refer to an *asynchronous generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

An asynchronous generator function may contain `await` expressions as well as `async for`, and `async with` statements.

asynchronous generator iterator An object created by a *asynchronous generator* function.

This is an *asynchronous iterator* which when called using the `__anext__()` method returns an awaitable object which will execute that the body of the asynchronous generator function until the next `yield` expression.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *asynchronous generator iterator* effectively resumes with another awaitable returned by `__anext__()`, it picks up where it left off. See **PEP 492** and **PEP 525**.

asynchronous iterable An object, that can be used in an `async for` statement. Must return an *asynchronous iterator* from its `__aiter__()` method. Introduced by **PEP 492**.

asynchronous iterator An object that implements `__aiter__()` and `__anext__()` methods. `__anext__` must return an *awaitable* object. `async for` resolves awaitable returned from asynchronous iterator's `__anext__()` method until it raises `StopAsyncIteration` exception. Introduced by **PEP 492**.

attribute A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

awaitable An object that can be used in an `await` expression. Can be a *coroutine* or an object with an `__await__()` method. See also **PEP 492**.

BDFL Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

binary file A *file object* able to read and write *bytes-like objects*. Examples of binary files are files opened in binary mode (`'rb'`, `'wb'` or `'rb+'`), `sys.stdin.buffer`, `sys.stdout.buffer`, and instances of `io.BytesIO` and `gzip.GzipFile`.

See also *text file* for a file object able to read and write `str` objects.

bytes-like object An object that supports the bufferobjects and can export a C-*contiguous* buffer. This includes all `bytes`, `bytearray`, and `array.array` objects, as well as many common `memoryview` objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as "read-write bytes-like objects". Example mutable buffer objects include `bytearray` and a `memoryview` of a `bytearray`. Other operations require the binary data to be stored in immutable objects ("read-only bytes-like objects"); examples of these include `bytes` and a `memoryview` of a `bytes` object.

bytecode Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for the dis module.

class A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

class variable A variable defined in a class and intended to be modified only at class level (i.e., not in an instance of the class).

coercion The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer `3`, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

complex number An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of `-1`), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

context manager An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See **PEP 343**.

contiguous A buffer is considered contiguous exactly if it is either *C-contiguous* or *Fortran contiguous*. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be laid out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

coroutine Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the `async def` statement. See also **PEP 492**.

coroutine function A function which returns a *coroutine* object. A coroutine function may be defined with the `async def` statement, and may contain `await`, `async for`, and `async with` keywords. These were introduced by **PEP 492**.

CPython The canonical implementation of the Python programming language, as distributed on python.org. The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

decorator A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)
```

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```
@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for function definitions and class definitions for more about decorators.

descriptor Any object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using *a.b* to get, set or delete an attribute looks up the object named *b* in the class dictionary for *a*, but if *b* is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see descriptors.

dictionary An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

dictionary view The objects returned from `dict.keys()`, `dict.values()`, and `dict.items()` are called dictionary views. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use `list(dictview)`. See dict-views.

docstring A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

duck-typing A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note, however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

EAFP Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

expression A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statement*s which cannot be used as expressions, such as `if`. Assignments are also statements, not expressions.

extension module A module written in C or C++, using Python's C API to interact with the core and with user code.

f-string String literals prefixed with `'f'` or `'F'` are commonly called "f-strings" which is short for formatted string literals. See also **PEP 498**.

file object An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw *binary files*, buffered *binary files* and *text files*. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the

`open()` function.

file-like object A synonym for *file object*.

finder An object that tries to find the *loader* for a module that is being imported.

Since Python 3.3, there are two types of finder: *meta path finders* for use with `sys.meta_path`, and *path entry finders* for use with `sys.path_hooks`.

See **PEP 302**, **PEP 420** and **PEP 451** for much more detail.

floor division Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See **PEP 238**.

function A series of statements which returns some value to a caller. It can also be passed zero or more *arguments* which may be used in the execution of the body. See also *parameter*, *method*, and the function section.

function annotation An *annotation* of a function parameter or return value.

Function annotations are usually used for *type hints*: for example this function is expected to take two `int` arguments and is also expected to have an `int` return value:

```
def sum_two_numbers(a: int, b: int) -> int:
   return a + b
```

Function annotation syntax is explained in section function.

See *variable annotation* and **PEP 484**, which describe this functionality.

___future___ A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

garbage collection The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles. The garbage collector can be controlled using the `gc` module.

generator A function which returns a *generator iterator*. It looks like a normal function except that it contains `yield` expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the `next()` function.

Usually refers to a generator function, but may refer to a *generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

generator iterator An object created by a *generator* function.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *generator iterator* resumes, it picks up where it left off (in contrast to functions which start fresh on every invocation).

generator expression An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))         # sum of squares 0, 1, 4, ... 81
285
```

generic function A function composed of multiple functions implementing the same operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the *single dispatch* glossary entry, the `functools.singledispatch()` decorator, and **PEP 443**.

GIL See *global interpreter lock*.

global interpreter lock The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a "free-threaded" interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

hash-based pyc A bytecode cache file that uses the hash rather than the last-modified time of the corresponding source file to determine its validity. See pyc-invalidation.

hashable An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python's immutable built-in objects are hashable; mutable containers (such as lists or dictionaries) are not. Objects which are instances of user-defined classes are hashable by default. They all compare unequal (except with themselves), and their hash value is derived from their `id()`.

IDLE An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

immutable An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

import path A list of locations (or *path entries*) that are searched by the *path based finder* for modules to import. During import, this list of locations usually comes from `sys.path`, but for subpackages it may also come from the parent package's `__path__` attribute.

importing The process by which Python code in one module is made available to Python code in another module.

importer An object that both finds and loads a module; both a *finder* and *loader* object.

interactive Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer's main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

interpreted Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically

have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the *garbage collector*. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the `__main__` module or the script being run has finished executing.

iterable An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict`, *file objects*, and objects of any classes you define with an `__iter__()` method or with a `__getitem__()` method that implements *Sequence* semantics.

Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

iterator An object representing a stream of data. Repeated calls to the iterator's `__next__()` method (or passing it to the built-in function `next()`) return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `__next__()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in typeiter.

key function A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.merge()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example. the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the Sorting HOW TO for examples of how to create and use key functions.

keyword argument See *argument*.

lambda An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [parameters]: expression`

LBYL Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between "the looking" and "the leaping". For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

list A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements is O(1).

list comprehension A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ['{:#04x}'.format(x) for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

loader An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details and `importlib.abc.Loader` for an *abstract base class*.

mapping A container object that supports arbitrary key lookups and implements the methods specified in the `Mapping` or `MutableMapping` abstract base classes. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

meta path finder A *finder* returned by a search of `sys.meta_path`. Meta path finders are related to, but different from *path entry finders*.

See `importlib.abc.MetaPathFinder` for the methods that meta path finders implement.

metaclass The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in metaclasses.

method A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

method resolution order Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order for details of the algorithm used by the Python interpreter since the 2.3 release.

module An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects. Modules are loaded into Python by the process of *importing*.

See also *package*.

module spec A namespace containing the import-related information used to load a module. An instance of `importlib.machinery.ModuleSpec`.

MRO See *method resolution order*.

mutable Mutable objects can change their value but keep their `id()`. See also *immutable*.

named tuple Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

namespace The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `builtins.open` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.islice()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

namespace package A **PEP 420** *package* which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a *regular package* because they have no `__init__.py` file.

See also *module*.

nested scope The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The `nonlocal` allows writing to outer scopes.

new-style class Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python's newer, versatile features like `__slots__`, descriptors, properties, `__getattribute__()`, class methods, and static methods.

object Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

package A Python *module* which can contain submodules or recursively, subpackages. Technically, a package is a Python module with an `__path__` attribute.

See also *regular package* and *namespace package*.

parameter A named entity in a *function* (or method) definition that specifies an *argument* (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- *positional-or-keyword*: specifies an argument that can be passed either *positionally* or as a *keyword argument*. This is the default kind of parameter, for example *foo* and *bar* in the following:

```
def func(foo, bar=None): ...
```

- *positional-only*: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. `abs()`).
- *keyword-only*: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare `*` in the parameter list of the function definition before them, for example *kw_only1* and *kw_only2* in the following:

```
def func(arg, *, kw_only1, kw_only2): ...
```

- *var-positional*: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `*`, for example *args* in the following:

```
def func(*args, **kwargs): ...
```

- *var-keyword*: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `**`, for example *kwargs* in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the *argument* glossary entry, the FAQ question on the difference between arguments and parameters, the `inspect.Parameter` class, the function section, and **PEP 362**.

path entry A single location on the *import path* which the *path based finder* consults to find modules for importing.

path entry finder A *finder* returned by a callable on `sys.path_hooks` (i.e. a *path entry hook*) which knows how to locate modules given a *path entry*.

See `importlib.abc.PathEntryFinder` for the methods that path entry finders implement.

path entry hook A callable on the `sys.path_hook` list which returns a *path entry finder* if it knows how to find modules on a specific *path entry*.

path based finder One of the default *meta path finders* which searches an *import path* for modules.

path-like object An object representing a file system path. A path-like object is either a `str` or `bytes` object representing a path, or an object implementing the `os.PathLike` protocol. An object that supports the `os.PathLike` protocol can be converted to a `str` or `bytes` file system path by calling the `os.fspath()` function; `os.fsdecode()` and `os.fsencode()` can be used to guarantee a `str` or `bytes` result instead, respectively. Introduced by **PEP 519**.

PEP Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python or its processes or environment. PEPs should provide a concise technical specification and a rationale for proposed features.

PEPs are intended to be the primary mechanisms for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible for building consensus within the community and documenting dissenting opinions.

See **PEP 1**.

portion A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in **PEP 420**.

positional argument See *argument*.

provisional API A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a "solution of last resort" - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See **PEP 411** for more details.

provisional package See *provisional API*.

Python 3000 Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

Pythonic An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print(piece)
```

qualified name A dotted name showing the "path" from a module's global scope to a class, function or method defined in that module, as defined in **PEP 3155**. For top-level functions and classes, the qualified name is the same as the object's name:

```
>>> class C:
...     class D:
...         def meth(self):
...             pass
...
>>> C.__qualname__
'C'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```

When used to refer to modules, the *fully qualified name* means the entire dotted path to the module, including any parent packages, e.g. `email.mime.text`:

```
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

reference count The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

regular package A traditional *package*, such as a directory containing an `__init__.py` file.

See also *namespace package*.

___slots___ A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

sequence An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `__len__()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `bytes`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

The `collections.abc.Sequence` abstract base class defines a much richer interface that goes beyond just `__getitem__()` and `__len__()`, adding `count()`, `index()`, `__contains__()`, and `__reversed__()`. Types that implement this expanded interface can be registered explicitly using `register()`.

single dispatch A form of *generic function* dispatch where the implementation is chosen based on the type of a single argument.

slice An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally.

special method A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in specialnames.

statement A statement is part of a suite (a "block" of code). A statement is either an *expression* or one of several constructs with a keyword, such as `if`, `while` or `for`.

struct sequence A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

text encoding A codec which encodes Unicode strings to bytes.

text file A *file object* able to read and write `str` objects. Often, a text file actually accesses a byte-oriented datastream and handles the *text encoding* automatically. Examples of text files are files opened in text mode (`'r'` or `'w'`), `sys.stdin`, `sys.stdout`, and instances of `io.StringIO`.

See also *binary file* for a file object able to read and write *bytes-like objects*.

triple-quoted string A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

type The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

type alias A synonym for a type, created by assigning the type to an identifier.

Type aliases are useful for simplifying *type hints*. For example:

```
from typing import List, Tuple

def remove_gray_shades(
        colors: List[Tuple[int, int, int]]) -> List[Tuple[int, int, int]]:
    pass
```

could be made more readable like this:

```
from typing import List, Tuple

Color = Tuple[int, int, int]

def remove_gray_shades(colors: List[Color]) -> List[Color]:
    pass
```

See `typing` and **PEP 484**, which describe this functionality.

type hint An *annotation* that specifies the expected type for a variable, a class attribute, or a function parameter or return value.

Type hints are optional and are not enforced by Python but they are useful to static type analysis tools, and aid IDEs with code completion and refactoring.

Type hints of global variables, class attributes, and functions, but not local variables, can be accessed using `typing.get_type_hints()`.

See `typing` and **PEP 484**, which describe this functionality.

universal newlines A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old

Macintosh convention `'\r'`. See **PEP 278** and **PEP 3116**, as well as `bytes.splitlines()` for an additional use.

variable annotation An *annotation* of a variable or a class attribute.

When annotating a variable or a class attribute, assignment is optional:

```
class C:
    field: 'annotation'
```

Variable annotations are usually used for *type hints*: for example this variable is expected to take `int` values:

```
count: int = 0
```

Variable annotation syntax is explained in section annassign.

See *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

virtual environment A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also `venv`.

virtual machine A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

Zen of Python Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing "`import this`" at the interactive prompt.

APPENDIX

B

ABOUT THESE DOCUMENTS

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the reporting-bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the Docutils project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.

B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See Misc/ACKS in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!

APPENDIX

C

HISTORY AND LICENSE

C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see https://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see https://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see https://opensource.org/ for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2 and above	2.1.1	2001-now	PSF	yes

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Thanks to the many outside volunteers who have worked under Guido's direction to make these releases possible.

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```
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Coded by Takuji Nishimura and Makoto Matsumoto.

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http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html
email: m-mat @ math.sci.hiroshima-u.ac.jp (remove space)
```

C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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```

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Original location:
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   djb (supercop/crypto_auth/siphash24/little2)
   Jean-Philippe Aumasson (https://131002.net/siphash/siphash24.c)
```

C.3.11 strtod and dtoa

The file `Python/dtoa.c`, which supplies C functions dtoa and strtod for conversion of C doubles to and from strings, is derived from the file of the same name by David M. Gay, currently available from http://www.netlib.org/fp/. The original file, as retrieved on March 16, 2009, contains the following copyright and licensing notice:

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C.3.16 cfuhash

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C.3.17 libmpdec

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APPENDIX

D

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Index **147**

Python is an easy to learn, powerful programming language. It has efficient high-level data structures and a simple but effective approach to object-oriented programming. Python's elegant syntax and dynamic typing, together with its interpreted nature, make it an ideal language for scripting and rapid application development in many areas on most platforms.

The Python interpreter and the extensive standard library are freely available in source or binary form for all major platforms from the Python Web site, https://www.python.org/, and may be freely distributed. The same site also contains distributions of and pointers to many free third party Python modules, programs and tools, and additional documentation.

The Python interpreter is easily extended with new functions and data types implemented in C or C++ (or other languages callable from C). Python is also suitable as an extension language for customizable applications.

This tutorial introduces the reader informally to the basic concepts and features of the Python language and system. It helps to have a Python interpreter handy for hands-on experience, but all examples are self-contained, so the tutorial can be read off-line as well.

For a description of standard objects and modules, see library-index. reference-index gives a more formal definition of the language. To write extensions in C or C++, read extending-index and c-api-index. There are also several books covering Python in depth.

This tutorial does not attempt to be comprehensive and cover every single feature, or even every commonly used feature. Instead, it introduces many of Python's most noteworthy features, and will give you a good idea of the language's flavor and style. After reading it, you will be able to read and write Python modules and programs, and you will be ready to learn more about the various Python library modules described in library-index.

The *Glossary* is also worth going through.

CHAPTER

ONE

WHETTING YOUR APPETITE

If you do much work on computers, eventually you find that there's some task you'd like to automate. For example, you may wish to perform a search-and-replace over a large number of text files, or rename and rearrange a bunch of photo files in a complicated way. Perhaps you'd like to write a small custom database, or a specialized GUI application, or a simple game.

If you're a professional software developer, you may have to work with several C/C++/Java libraries but find the usual write/compile/test/re-compile cycle is too slow. Perhaps you're writing a test suite for such a library and find writing the testing code a tedious task. Or maybe you've written a program that could use an extension language, and you don't want to design and implement a whole new language for your application.

Python is just the language for you.

You could write a Unix shell script or Windows batch files for some of these tasks, but shell scripts are best at moving around files and changing text data, not well-suited for GUI applications or games. You could write a C/C++/Java program, but it can take a lot of development time to get even a first-draft program. Python is simpler to use, available on Windows, Mac OS X, and Unix operating systems, and will help you get the job done more quickly.

Python is simple to use, but it is a real programming language, offering much more structure and support for large programs than shell scripts or batch files can offer. On the other hand, Python also offers much more error checking than C, and, being a *very-high-level language*, it has high-level data types built in, such as flexible arrays and dictionaries. Because of its more general data types Python is applicable to a much larger problem domain than Awk or even Perl, yet many things are at least as easy in Python as in those languages.

Python allows you to split your program into modules that can be reused in other Python programs. It comes with a large collection of standard modules that you can use as the basis of your programs — or as examples to start learning to program in Python. Some of these modules provide things like file I/O, system calls, sockets, and even interfaces to graphical user interface toolkits like Tk.

Python is an interpreted language, which can save you considerable time during program development because no compilation and linking is necessary. The interpreter can be used interactively, which makes it easy to experiment with features of the language, to write throw-away programs, or to test functions during bottom-up program development. It is also a handy desk calculator.

Python enables programs to be written compactly and readably. Programs written in Python are typically much shorter than equivalent C, C++, or Java programs, for several reasons:

- the high-level data types allow you to express complex operations in a single statement;
- statement grouping is done by indentation instead of beginning and ending brackets;
- no variable or argument declarations are necessary.

Python is *extensible*: if you know how to program in C it is easy to add a new built-in function or module to the interpreter, either to perform critical operations at maximum speed, or to link Python programs to libraries that may only be available in binary form (such as a vendor-specific graphics library). Once you

are really hooked, you can link the Python interpreter into an application written in C and use it as an extension or command language for that application.

By the way, the language is named after the BBC show "Monty Python's Flying Circus" and has nothing to do with reptiles. Making references to Monty Python skits in documentation is not only allowed, it is encouraged!

Now that you are all excited about Python, you'll want to examine it in some more detail. Since the best way to learn a language is to use it, the tutorial invites you to play with the Python interpreter as you read.

In the next chapter, the mechanics of using the interpreter are explained. This is rather mundane information, but essential for trying out the examples shown later.

The rest of the tutorial introduces various features of the Python language and system through examples, beginning with simple expressions, statements and data types, through functions and modules, and finally touching upon advanced concepts like exceptions and user-defined classes.

CHAPTER

TWO

USING THE PYTHON INTERPRETER

2.1 Invoking the Interpreter

The Python interpreter is usually installed as `/usr/local/bin/python3.7` on those machines where it is available; putting `/usr/local/bin` in your Unix shell's search path makes it possible to start it by typing the command:

```
python3.7
```

to the shell.[1] Since the choice of the directory where the interpreter lives is an installation option, other places are possible; check with your local Python guru or system administrator. (E.g., `/usr/local/python` is a popular alternative location.)

On Windows machines, the Python installation is usually placed in `C:\Python36`, though you can change this when you're running the installer. To add this directory to your path, you can type the following command into the command prompt in a DOS box:

```
set path=%path%;C:\python36
```

Typing an end-of-file character (`Control-D` on Unix, `Control-Z` on Windows) at the primary prompt causes the interpreter to exit with a zero exit status. If that doesn't work, you can exit the interpreter by typing the following command: `quit()`.

The interpreter's line-editing features include interactive editing, history substitution and code completion on systems that support readline. Perhaps the quickest check to see whether command line editing is supported is typing `Control-P` to the first Python prompt you get. If it beeps, you have command line editing; see Appendix *Interactive Input Editing and History Substitution* for an introduction to the keys. If nothing appears to happen, or if `^P` is echoed, command line editing isn't available; you'll only be able to use backspace to remove characters from the current line.

The interpreter operates somewhat like the Unix shell: when called with standard input connected to a tty device, it reads and executes commands interactively; when called with a file name argument or with a file as standard input, it reads and executes a *script* from that file.

A second way of starting the interpreter is `python -c command [arg] ...`, which executes the statement(s) in *command*, analogous to the shell's `-c` option. Since Python statements often contain spaces or other characters that are special to the shell, it is usually advised to quote *command* in its entirety with single quotes.

Some Python modules are also useful as scripts. These can be invoked using `python -m module [arg] ...`, which executes the source file for *module* as if you had spelled out its full name on the command line.

When a script file is used, it is sometimes useful to be able to run the script and enter interactive mode afterwards. This can be done by passing `-i` before the script.

[1] On Unix, the Python 3.x interpreter is by default not installed with the executable named `python`, so that it does not conflict with a simultaneously installed Python 2.x executable.

All command line options are described in using-on-general.

2.1.1 Argument Passing

When known to the interpreter, the script name and additional arguments thereafter are turned into a list of strings and assigned to the `argv` variable in the `sys` module. You can access this list by executing `import sys`. The length of the list is at least one; when no script and no arguments are given, `sys.argv[0]` is an empty string. When the script name is given as `'-'` (meaning standard input), `sys.argv[0]` is set to `'-'`. When `-c` *command* is used, `sys.argv[0]` is set to `'-c'`. When `-m` *module* is used, `sys.argv[0]` is set to the full name of the located module. Options found after `-c` *command* or `-m` *module* are not consumed by the Python interpreter's option processing but left in `sys.argv` for the command or module to handle.

2.1.2 Interactive Mode

When commands are read from a tty, the interpreter is said to be in *interactive mode*. In this mode it prompts for the next command with the *primary prompt*, usually three greater-than signs (`>>>`); for continuation lines it prompts with the *secondary prompt*, by default three dots (`...`). The interpreter prints a welcome message stating its version number and a copyright notice before printing the first prompt:

```
$ python3.7
Python 3.7 (default, Sep 16 2015, 09:25:04)
[GCC 4.8.2] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

Continuation lines are needed when entering a multi-line construct. As an example, take a look at this `if` statement:

```
>>> the_world_is_flat = True
>>> if the_world_is_flat:
...     print("Be careful not to fall off!")
...
Be careful not to fall off!
```

For more on interactive mode, see *Interactive Mode*.

2.2 The Interpreter and Its Environment

2.2.1 Source Code Encoding

By default, Python source files are treated as encoded in UTF-8. In that encoding, characters of most languages in the world can be used simultaneously in string literals, identifiers and comments — although the standard library only uses ASCII characters for identifiers, a convention that any portable code should follow. To display all these characters properly, your editor must recognize that the file is UTF-8, and it must use a font that supports all the characters in the file.

To declare an encoding other than the default one, a special comment line should be added as the *first* line of the file. The syntax is as follows:

```
# -*- coding: encoding -*-
```

where *encoding* is one of the valid `codecs` supported by Python.

For example, to declare that Windows-1252 encoding is to be used, the first line of your source code file should be:

```
# -*- coding: cp1252 -*-
```

One exception to the *first line* rule is when the source code starts with a *UNIX "shebang" line*. In this case, the encoding declaration should be added as the second line of the file. For example:

```
#!/usr/bin/env python3
# -*- coding: cp1252 -*-
```

CHAPTER

THREE

AN INFORMAL INTRODUCTION TO PYTHON

In the following examples, input and output are distinguished by the presence or absence of prompts (>>> and ...): to repeat the example, you must type everything after the prompt, when the prompt appears; lines that do not begin with a prompt are output from the interpreter. Note that a secondary prompt on a line by itself in an example means you must type a blank line; this is used to end a multi-line command.

Many of the examples in this manual, even those entered at the interactive prompt, include comments. Comments in Python start with the hash character, #, and extend to the end of the physical line. A comment may appear at the start of a line or following whitespace or code, but not within a string literal. A hash character within a string literal is just a hash character. Since comments are to clarify code and are not interpreted by Python, they may be omitted when typing in examples.

Some examples:

```
# this is the first comment
spam = 1  # and this is the second comment
          # ... and now a third!
text = "# This is not a comment because it's inside quotes."
```

3.1 Using Python as a Calculator

Let's try some simple Python commands. Start the interpreter and wait for the primary prompt, >>>. (It shouldn't take long.)

3.1.1 Numbers

The interpreter acts as a simple calculator: you can type an expression at it and it will write the value. Expression syntax is straightforward: the operators +, -, * and / work just like in most other languages (for example, Pascal or C); parentheses (()) can be used for grouping. For example:

```
>>> 2 + 2
4
>>> 50 - 5*6
20
>>> (50 - 5*6) / 4
5.0
>>> 8 / 5  # division always returns a floating point number
1.6
```

The integer numbers (e.g. 2, 4, 20) have type int, the ones with a fractional part (e.g. 5.0, 1.6) have type float. We will see more about numeric types later in the tutorial.

Division (/) always returns a float. To do *floor division* and get an integer result (discarding any fractional result) you can use the // operator; to calculate the remainder you can use %:

```
>>> 17 / 3  # classic division returns a float
5.666666666666667
>>>
>>> 17 // 3  # floor division discards the fractional part
5
>>> 17 % 3  # the % operator returns the remainder of the division
2
>>> 5 * 3 + 2  # result * divisor + remainder
17
```

With Python, it is possible to use the ** operator to calculate powers[1]:

```
>>> 5 ** 2  # 5 squared
25
>>> 2 ** 7  # 2 to the power of 7
128
```

The equal sign (=) is used to assign a value to a variable. Afterwards, no result is displayed before the next interactive prompt:

```
>>> width = 20
>>> height = 5 * 9
>>> width * height
900
```

If a variable is not "defined" (assigned a value), trying to use it will give you an error:

```
>>> n  # try to access an undefined variable
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'n' is not defined
```

There is full support for floating point; operators with mixed type operands convert the integer operand to floating point:

```
>>> 4 * 3.75 - 1
14.0
```

In interactive mode, the last printed expression is assigned to the variable _. This means that when you are using Python as a desk calculator, it is somewhat easier to continue calculations, for example:

```
>>> tax = 12.5 / 100
>>> price = 100.50
>>> price * tax
12.5625
>>> price + _
113.0625
>>> round(_, 2)
113.06
```

This variable should be treated as read-only by the user. Don't explicitly assign a value to it — you would create an independent local variable with the same name masking the built-in variable with its magic behavior.

[1] Since ** has higher precedence than -, -3**2 will be interpreted as -(3**2) and thus result in -9. To avoid this and get 9, you can use (-3)**2.

In addition to `int` and `float`, Python supports other types of numbers, such as `Decimal` and `Fraction`. Python also has built-in support for complex numbers, and uses the `j` or `J` suffix to indicate the imaginary part (e.g. `3+5j`).

3.1.2 Strings

Besides numbers, Python can also manipulate strings, which can be expressed in several ways. They can be enclosed in single quotes (`'...'`) or double quotes (`"..."`) with the same result[2]. `\` can be used to escape quotes:

```
>>> 'spam eggs'  # single quotes
'spam eggs'
>>> 'doesn\'t'  # use \' to escape the single quote...
"doesn't"
>>> "doesn't"  # ...or use double quotes instead
"doesn't"
>>> '"Yes," they said.'
'"Yes," they said.'
>>> "\"Yes,\" they said."
'"Yes," they said.'
>>> '"Isn\'t," they said.'
'"Isn\'t," they said.'
```

In the interactive interpreter, the output string is enclosed in quotes and special characters are escaped with backslashes. While this might sometimes look different from the input (the enclosing quotes could change), the two strings are equivalent. The string is enclosed in double quotes if the string contains a single quote and no double quotes, otherwise it is enclosed in single quotes. The `print()` function produces a more readable output, by omitting the enclosing quotes and by printing escaped and special characters:

```
>>> '"Isn\'t," they said.'
'"Isn\'t," they said.'
>>> print('"Isn\'t," they said.')
"Isn't," they said.
>>> s = 'First line.\nSecond line.'  # \n means newline
>>> s  # without print(), \n is included in the output
'First line.\nSecond line.'
>>> print(s)  # with print(), \n produces a new line
First line.
Second line.
```

If you don't want characters prefaced by `\` to be interpreted as special characters, you can use *raw strings* by adding an `r` before the first quote:

```
>>> print('C:\some\name')  # here \n means newline!
C:\some
ame
>>> print(r'C:\some\name')  # note the r before the quote
C:\some\name
```

String literals can span multiple lines. One way is using triple-quotes: `"""..."""` or `'''...'''`. End of lines are automatically included in the string, but it's possible to prevent this by adding a `\` at the end of the line. The following example:

[2] Unlike other languages, special characters such as `\n` have the same meaning with both single (`'...'`) and double (`"..."`) quotes. The only difference between the two is that within single quotes you don't need to escape `"` (but you have to escape `\'`) and vice versa.

```
print("""\
Usage: thingy [OPTIONS]
     -h                        Display this usage message
     -H hostname               Hostname to connect to
""")
```

produces the following output (note that the initial newline is not included):

```
Usage: thingy [OPTIONS]
     -h                        Display this usage message
     -H hostname               Hostname to connect to
```

Strings can be concatenated (glued together) with the + operator, and repeated with *:

```
>>> # 3 times 'un', followed by 'ium'
>>> 3 * 'un' + 'ium'
'ununununium'
```

Two or more *string literals* (i.e. the ones enclosed between quotes) next to each other are automatically concatenated.

```
>>> 'Py' 'thon'
'Python'
```

This feature is particularly useful when you want to break long strings:

```
>>> text = ('Put several strings within parentheses '
...         'to have them joined together.')
>>> text
'Put several strings within parentheses to have them joined together.'
```

This only works with two literals though, not with variables or expressions:

```
>>> prefix = 'Py'
>>> prefix 'thon'  # can't concatenate a variable and a string literal
  ...
SyntaxError: invalid syntax
>>> ('un' * 3) 'ium'
  ...
SyntaxError: invalid syntax
```

If you want to concatenate variables or a variable and a literal, use +:

```
>>> prefix + 'thon'
'Python'
```

Strings can be *indexed* (subscripted), with the first character having index 0. There is no separate character type; a character is simply a string of size one:

```
>>> word = 'Python'
>>> word[0]  # character in position 0
'P'
>>> word[5]  # character in position 5
'n'
```

Indices may also be negative numbers, to start counting from the right:

```
>>> word[-1]  # last character
'n'
>>> word[-2]  # second-last character
'o'
>>> word[-6]
'P'
```

Note that since -0 is the same as 0, negative indices start from -1.

In addition to indexing, *slicing* is also supported. While indexing is used to obtain individual characters, *slicing* allows you to obtain substring:

```
>>> word[0:2]  # characters from position 0 (included) to 2 (excluded)
'Py'
>>> word[2:5]  # characters from position 2 (included) to 5 (excluded)
'tho'
```

Note how the start is always included, and the end always excluded. This makes sure that `s[:i] + s[i:]` is always equal to `s`:

```
>>> word[:2] + word[2:]
'Python'
>>> word[:4] + word[4:]
'Python'
```

Slice indices have useful defaults; an omitted first index defaults to zero, an omitted second index defaults to the size of the string being sliced.

```
>>> word[:2]   # character from the beginning to position 2 (excluded)
'Py'
>>> word[4:]   # characters from position 4 (included) to the end
'on'
>>> word[-2:]  # characters from the second-last (included) to the end
'on'
```

One way to remember how slices work is to think of the indices as pointing *between* characters, with the left edge of the first character numbered 0. Then the right edge of the last character of a string of n characters has index n, for example:

```
 +---+---+---+---+---+---+
 | P | y | t | h | o | n |
 +---+---+---+---+---+---+
 0   1   2   3   4   5   6
-6  -5  -4  -3  -2  -1
```

The first row of numbers gives the position of the indices 0…6 in the string; the second row gives the corresponding negative indices. The slice from i to j consists of all characters between the edges labeled i and j, respectively.

For non-negative indices, the length of a slice is the difference of the indices, if both are within bounds. For example, the length of `word[1:3]` is 2.

Attempting to use an index that is too large will result in an error:

```
>>> word[42]  # the word only has 6 characters
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: string index out of range
```

However, out of range slice indexes are handled gracefully when used for slicing:

```
>>> word[4:42]
'on'
>>> word[42:]
''
```

Python strings cannot be changed — they are *immutable*. Therefore, assigning to an indexed position in the string results in an error:

```
>>> word[0] = 'J'
  ...
TypeError: 'str' object does not support item assignment
>>> word[2:] = 'py'
  ...
TypeError: 'str' object does not support item assignment
```

If you need a different string, you should create a new one:

```
>>> 'J' + word[1:]
'Jython'
>>> word[:2] + 'py'
'Pypy'
```

The built-in function `len()` returns the length of a string:

```
>>> s = 'supercalifragilisticexpialidocious'
>>> len(s)
34
```

See also:

textseq Strings are examples of *sequence types*, and support the common operations supported by such types.

string-methods Strings support a large number of methods for basic transformations and searching.

f-strings String literals that have embedded expressions.

formatstrings Information about string formatting with `str.format()`.

old-string-formatting The old formatting operations invoked when strings are the left operand of the `%` operator are described in more detail here.

3.1.3 Lists

Python knows a number of *compound* data types, used to group together other values. The most versatile is the *list*, which can be written as a list of comma-separated values (items) between square brackets. Lists might contain items of different types, but usually the items all have the same type.

```
>>> squares = [1, 4, 9, 16, 25]
>>> squares
[1, 4, 9, 16, 25]
```

Like strings (and all other built-in *sequence* type), lists can be indexed and sliced:

```
>>> squares[0]  # indexing returns the item
1
>>> squares[-1]
```

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```
25
>>> squares[-3:]  # slicing returns a new list
[9, 16, 25]
```

All slice operations return a new list containing the requested elements. This means that the following slice returns a new (shallow) copy of the list:

```
>>> squares[:]
[1, 4, 9, 16, 25]
```

Lists also support operations like concatenation:

```
>>> squares + [36, 49, 64, 81, 100]
[1, 4, 9, 16, 25, 36, 49, 64, 81, 100]
```

Unlike strings, which are *immutable*, lists are a *mutable* type, i.e. it is possible to change their content:

```
>>> cubes = [1, 8, 27, 65, 125]  # something's wrong here
>>> 4 ** 3  # the cube of 4 is 64, not 65!
64
>>> cubes[3] = 64  # replace the wrong value
>>> cubes
[1, 8, 27, 64, 125]
```

You can also add new items at the end of the list, by using the `append()` *method* (we will see more about methods later):

```
>>> cubes.append(216)  # add the cube of 6
>>> cubes.append(7 ** 3)  # and the cube of 7
>>> cubes
[1, 8, 27, 64, 125, 216, 343]
```

Assignment to slices is also possible, and this can even change the size of the list or clear it entirely:

```
>>> letters = ['a', 'b', 'c', 'd', 'e', 'f', 'g']
>>> letters
['a', 'b', 'c', 'd', 'e', 'f', 'g']
>>> # replace some values
>>> letters[2:5] = ['C', 'D', 'E']
>>> letters
['a', 'b', 'C', 'D', 'E', 'f', 'g']
>>> # now remove them
>>> letters[2:5] = []
>>> letters
['a', 'b', 'f', 'g']
>>> # clear the list by replacing all the elements with an empty list
>>> letters[:] = []
>>> letters
[]
```

The built-in function `len()` also applies to lists:

```
>>> letters = ['a', 'b', 'c', 'd']
>>> len(letters)
4
```

It is possible to nest lists (create lists containing other lists), for example:

```
>>> a = ['a', 'b', 'c']
>>> n = [1, 2, 3]
>>> x = [a, n]
>>> x
[['a', 'b', 'c'], [1, 2, 3]]
>>> x[0]
['a', 'b', 'c']
>>> x[0][1]
'b'
```

3.2 First Steps Towards Programming

Of course, we can use Python for more complicated tasks than adding two and two together. For instance, we can write an initial sub-sequence of the Fibonacci series as follows:

```
>>> # Fibonacci series:
... # the sum of two elements defines the next
... a, b = 0, 1
>>> while a < 10:
...     print(a)
...     a, b = b, a+b
...
0
1
1
2
3
5
8
```

This example introduces several new features.

- The first line contains a *multiple assignment*: the variables `a` and `b` simultaneously get the new values 0 and 1. On the last line this is used again, demonstrating that the expressions on the right-hand side are all evaluated first before any of the assignments take place. The right-hand side expressions are evaluated from the left to the right.
- The `while` loop executes as long as the condition (here: `a < 10`) remains true. In Python, like in C, any non-zero integer value is true; zero is false. The condition may also be a string or list value, in fact any sequence; anything with a non-zero length is true, empty sequences are false. The test used in the example is a simple comparison. The standard comparison operators are written the same as in C: `<` (less than), `>` (greater than), `==` (equal to), `<=` (less than or equal to), `>=` (greater than or equal to) and `!=` (not equal to).
- The *body* of the loop is *indented*: indentation is Python's way of grouping statements. At the interactive prompt, you have to type a tab or space(s) for each indented line. In practice you will prepare more complicated input for Python with a text editor; all decent text editors have an auto-indent facility. When a compound statement is entered interactively, it must be followed by a blank line to indicate completion (since the parser cannot guess when you have typed the last line). Note that each line within a basic block must be indented by the same amount.
- The `print()` function writes the value of the argument(s) it is given. It differs from just writing the expression you want to write (as we did earlier in the calculator examples) in the way it handles multiple arguments, floating point quantities, and strings. Strings are printed without quotes, and a space is inserted between items, so you can format things nicely, like this:

```
>>> i = 256*256
>>> print('The value of i is', i)
The value of i is 65536
```

The keyword argument *end* can be used to avoid the newline after the output, or end the output with a different string:

```
>>> a, b = 0, 1
>>> while a < 1000:
...     print(a, end=',')
...     a, b = b, a+b
...
0,1,1,2,3,5,8,13,21,34,55,89,144,233,377,610,987,
```

CHAPTER

FOUR

MORE CONTROL FLOW TOOLS

Besides the `while` statement just introduced, Python knows the usual control flow statements known from other languages, with some twists.

4.1 `if` Statements

Perhaps the most well-known statement type is the `if` statement. For example:

```
>>> x = int(input("Please enter an integer: "))
Please enter an integer: 42
>>> if x < 0:
...     x = 0
...     print('Negative changed to zero')
... elif x == 0:
...     print('Zero')
... elif x == 1:
...     print('Single')
... else:
...     print('More')
...
More
```

There can be zero or more `elif` parts, and the `else` part is optional. The keyword '`elif`' is short for 'else if', and is useful to avoid excessive indentation. An `if` … `elif` … `elif` … sequence is a substitute for the `switch` or `case` statements found in other languages.

4.2 `for` Statements

The `for` statement in Python differs a bit from what you may be used to in C or Pascal. Rather than always iterating over an arithmetic progression of numbers (like in Pascal), or giving the user the ability to define both the iteration step and halting condition (as C), Python's `for` statement iterates over the items of any sequence (a list or a string), in the order that they appear in the sequence. For example (no pun intended):

```
>>> # Measure some strings:
... words = ['cat', 'window', 'defenestrate']
>>> for w in words:
...     print(w, len(w))
...
cat 3
window 6
defenestrate 12
```

If you need to modify the sequence you are iterating over while inside the loop (for example to duplicate selected items), it is recommended that you first make a copy. Iterating over a sequence does not implicitly make a copy. The slice notation makes this especially convenient:

```
>>> for w in words[:]:  # Loop over a slice copy of the entire list.
...     if len(w) > 6:
...         words.insert(0, w)
...
>>> words
['defenestrate', 'cat', 'window', 'defenestrate']
```

With `for w in words:`, the example would attempt to create an infinite list, inserting `defenestrate` over and over again.

4.3 The `range()` Function

If you do need to iterate over a sequence of numbers, the built-in function `range()` comes in handy. It generates arithmetic progressions:

```
>>> for i in range(5):
...     print(i)
...
0
1
2
3
4
```

The given end point is never part of the generated sequence; `range(10)` generates 10 values, the legal indices for items of a sequence of length 10. It is possible to let the range start at another number, or to specify a different increment (even negative; sometimes this is called the 'step'):

```
range(5, 10)
   5, 6, 7, 8, 9

range(0, 10, 3)
   0, 3, 6, 9

range(-10, -100, -30)
  -10, -40, -70
```

To iterate over the indices of a sequence, you can combine `range()` and `len()` as follows:

```
>>> a = ['Mary', 'had', 'a', 'little', 'lamb']
>>> for i in range(len(a)):
...     print(i, a[i])
...
0 Mary
1 had
2 a
3 little
4 lamb
```

In most such cases, however, it is convenient to use the `enumerate()` function, see *Looping Techniques*.

A strange thing happens if you just print a range:

```
>>> print(range(10))
range(0, 10)
```

In many ways the object returned by `range()` behaves as if it is a list, but in fact it isn't. It is an object which returns the successive items of the desired sequence when you iterate over it, but it doesn't really make the list, thus saving space.

We say such an object is *iterable*, that is, suitable as a target for functions and constructs that expect something from which they can obtain successive items until the supply is exhausted. We have seen that the `for` statement is such an *iterator*. The function `list()` is another; it creates lists from iterables:

```
>>> list(range(5))
[0, 1, 2, 3, 4]
```

Later we will see more functions that return iterables and take iterables as argument.

4.4 `break` and `continue` Statements, and `else` Clauses on Loops

The `break` statement, like in C, breaks out of the innermost enclosing `for` or `while` loop.

Loop statements may have an `else` clause; it is executed when the loop terminates through exhaustion of the list (with `for`) or when the condition becomes false (with `while`), but not when the loop is terminated by a `break` statement. This is exemplified by the following loop, which searches for prime numbers:

```
>>> for n in range(2, 10):
...     for x in range(2, n):
...         if n % x == 0:
...             print(n, 'equals', x, '*', n//x)
...             break
...     else:
...         # loop fell through without finding a factor
...         print(n, 'is a prime number')
...
2 is a prime number
3 is a prime number
4 equals 2 * 2
5 is a prime number
6 equals 2 * 3
7 is a prime number
8 equals 2 * 4
9 equals 3 * 3
```

(Yes, this is the correct code. Look closely: the `else` clause belongs to the `for` loop, **not** the `if` statement.)

When used with a loop, the `else` clause has more in common with the `else` clause of a `try` statement than it does that of `if` statements: a `try` statement's `else` clause runs when no exception occurs, and a loop's `else` clause runs when no `break` occurs. For more on the `try` statement and exceptions, see *Handling Exceptions*.

The `continue` statement, also borrowed from C, continues with the next iteration of the loop:

```
>>> for num in range(2, 10):
...     if num % 2 == 0:
...         print("Found an even number", num)
...         continue
...     print("Found a number", num)
Found an even number 2
```

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```
Found a number 3
Found an even number 4
Found a number 5
Found an even number 6
Found a number 7
Found an even number 8
Found a number 9
```

4.5 pass Statements

The pass statement does nothing. It can be used when a statement is required syntactically but the program requires no action. For example:

```
>>> while True:
...     pass  # Busy-wait for keyboard interrupt (Ctrl+C)
...
```

This is commonly used for creating minimal classes:

```
>>> class MyEmptyClass:
...     pass
...
```

Another place pass can be used is as a place-holder for a function or conditional body when you are working on new code, allowing you to keep thinking at a more abstract level. The pass is silently ignored:

```
>>> def initlog(*args):
...     pass   # Remember to implement this!
...
```

4.6 Defining Functions

We can create a function that writes the Fibonacci series to an arbitrary boundary:

```
>>> def fib(n):    # write Fibonacci series up to n
...     """Print a Fibonacci series up to n."""
...     a, b = 0, 1
...     while a < n:
...         print(a, end=' ')
...         a, b = b, a+b
...     print()
...
>>> # Now call the function we just defined:
... fib(2000)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597
```

The keyword def introduces a function *definition*. It must be followed by the function name and the parenthesized list of formal parameters. The statements that form the body of the function start at the next line, and must be indented.

The first statement of the function body can optionally be a string literal; this string literal is the function's documentation string, or *docstring*. (More about docstrings can be found in the section *Documentation*

Strings.) There are tools which use docstrings to automatically produce online or printed documentation, or to let the user interactively browse through code; it's good practice to include docstrings in code that you write, so make a habit of it.

The *execution* of a function introduces a new symbol table used for the local variables of the function. More precisely, all variable assignments in a function store the value in the local symbol table; whereas variable references first look in the local symbol table, then in the local symbol tables of enclosing functions, then in the global symbol table, and finally in the table of built-in names. Thus, global variables cannot be directly assigned a value within a function (unless named in a `global` statement), although they may be referenced.

The actual parameters (arguments) to a function call are introduced in the local symbol table of the called function when it is called; thus, arguments are passed using *call by value* (where the *value* is always an object *reference*, not the value of the object).[1] When a function calls another function, a new local symbol table is created for that call.

A function definition introduces the function name in the current symbol table. The value of the function name has a type that is recognized by the interpreter as a user-defined function. This value can be assigned to another name which can then also be used as a function. This serves as a general renaming mechanism:

```
>>> fib
<function fib at 10042ed0>
>>> f = fib
>>> f(100)
0 1 1 2 3 5 8 13 21 34 55 89
```

Coming from other languages, you might object that `fib` is not a function but a procedure since it doesn't return a value. In fact, even functions without a `return` statement do return a value, albeit a rather boring one. This value is called `None` (it's a built-in name). Writing the value `None` is normally suppressed by the interpreter if it would be the only value written. You can see it if you really want to using `print()`:

```
>>> fib(0)
>>> print(fib(0))
None
```

It is simple to write a function that returns a list of the numbers of the Fibonacci series, instead of printing it:

```
>>> def fib2(n):  # return Fibonacci series up to n
...     """Return a list containing the Fibonacci series up to n."""
...     result = []
...     a, b = 0, 1
...     while a < n:
...         result.append(a)    # see below
...         a, b = b, a+b
...     return result
...
>>> f100 = fib2(100)    # call it
>>> f100                # write the result
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
```

This example, as usual, demonstrates some new Python features:

- The `return` statement returns with a value from a function. `return` without an expression argument returns `None`. Falling off the end of a function also returns `None`.
- The statement `result.append(a)` calls a *method* of the list object `result`. A method is a function that 'belongs' to an object and is named `obj.methodname`, where `obj` is some object (this may be an

[1] Actually, *call by object reference* would be a better description, since if a mutable object is passed, the caller will see any changes the callee makes to it (items inserted into a list).

expression), and `methodname` is the name of a method that is defined by the object's type. Different types define different methods. Methods of different types may have the same name without causing ambiguity. (It is possible to define your own object types and methods, using *classes*, see *Classes*) The method `append()` shown in the example is defined for list objects; it adds a new element at the end of the list. In this example it is equivalent to `result = result + [a]`, but more efficient.

4.7 More on Defining Functions

It is also possible to define functions with a variable number of arguments. There are three forms, which can be combined.

4.7.1 Default Argument Values

The most useful form is to specify a default value for one or more arguments. This creates a function that can be called with fewer arguments than it is defined to allow. For example:

```
def ask_ok(prompt, retries=4, reminder='Please try again!'):
    while True:
        ok = input(prompt)
        if ok in ('y', 'ye', 'yes'):
            return True
        if ok in ('n', 'no', 'nop', 'nope'):
            return False
        retries = retries - 1
        if retries < 0:
            raise ValueError('invalid user response')
        print(reminder)
```

This function can be called in several ways:

- giving only the mandatory argument: `ask_ok('Do you really want to quit?')`
- giving one of the optional arguments: `ask_ok('OK to overwrite the file?', 2)`
- or even giving all arguments: `ask_ok('OK to overwrite the file?', 2, 'Come on, only yes or no!')`

This example also introduces the `in` keyword. This tests whether or not a sequence contains a certain value.

The default values are evaluated at the point of function definition in the *defining* scope, so that

```
i = 5

def f(arg=i):
    print(arg)

i = 6
f()
```

will print 5.

Important warning: The default value is evaluated only once. This makes a difference when the default is a mutable object such as a list, dictionary, or instances of most classes. For example, the following function accumulates the arguments passed to it on subsequent calls:

```
def f(a, L=[]):
    L.append(a)
    return L

print(f(1))
print(f(2))
print(f(3))
```

This will print

```
[1]
[1, 2]
[1, 2, 3]
```

If you don't want the default to be shared between subsequent calls, you can write the function like this instead:

```
def f(a, L=None):
    if L is None:
        L = []
    L.append(a)
    return L
```

4.7.2 Keyword Arguments

Functions can also be called using *keyword arguments* of the form `kwarg=value`. For instance, the following function:

```
def parrot(voltage, state='a stiff', action='voom', type='Norwegian Blue'):
    print("-- This parrot wouldn't", action, end=' ')
    print("if you put", voltage, "volts through it.")
    print("-- Lovely plumage, the", type)
    print("-- It's", state, "!")
```

accepts one required argument (`voltage`) and three optional arguments (`state`, `action`, and `type`). This function can be called in any of the following ways:

```
parrot(1000)                                          # 1 positional argument
parrot(voltage=1000)                                  # 1 keyword argument
parrot(voltage=1000000, action='VOOOOOM')             # 2 keyword arguments
parrot(action='VOOOOOM', voltage=1000000)             # 2 keyword arguments
parrot('a million', 'bereft of life', 'jump')         # 3 positional arguments
parrot('a thousand', state='pushing up the daisies')  # 1 positional, 1 keyword
```

but all the following calls would be invalid:

```
parrot()                     # required argument missing
parrot(voltage=5.0, 'dead')  # non-keyword argument after a keyword argument
parrot(110, voltage=220)     # duplicate value for the same argument
parrot(actor='John Cleese')  # unknown keyword argument
```

In a function call, keyword arguments must follow positional arguments. All the keyword arguments passed must match one of the arguments accepted by the function (e.g. `actor` is not a valid argument for the `parrot` function), and their order is not important. This also includes non-optional arguments (e.g. `parrot(voltage=1000)` is valid too). No argument may receive a value more than once. Here's an example that fails due to this restriction:

```
>>> def function(a):
...     pass
...
>>> function(0, a=0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: function() got multiple values for keyword argument 'a'
```

When a final formal parameter of the form **name is present, it receives a dictionary (see typesmapping) containing all keyword arguments except for those corresponding to a formal parameter. This may be combined with a formal parameter of the form *name (described in the next subsection) which receives a tuple containing the positional arguments beyond the formal parameter list. (*name must occur before **name.) For example, if we define a function like this:

```
def cheeseshop(kind, *arguments, **keywords):
    print("-- Do you have any", kind, "?")
    print("-- I'm sorry, we're all out of", kind)
    for arg in arguments:
        print(arg)
    print("-" * 40)
    for kw in keywords:
        print(kw, ":", keywords[kw])
```

It could be called like this:

```
cheeseshop("Limburger", "It's very runny, sir.",
           "It's really very, VERY runny, sir.",
           shopkeeper="Michael Palin",
           client="John Cleese",
           sketch="Cheese Shop Sketch")
```

and of course it would print:

```
-- Do you have any Limburger ?
-- I'm sorry, we're all out of Limburger
It's very runny, sir.
It's really very, VERY runny, sir.
----------------------------------------
shopkeeper : Michael Palin
client : John Cleese
sketch : Cheese Shop Sketch
```

Note that the order in which the keyword arguments are printed is guaranteed to match the order in which they were provided in the function call.

4.7.3 Arbitrary Argument Lists

Finally, the least frequently used option is to specify that a function can be called with an arbitrary number of arguments. These arguments will be wrapped up in a tuple (see *Tuples and Sequences*). Before the variable number of arguments, zero or more normal arguments may occur.

```
def write_multiple_items(file, separator, *args):
    file.write(separator.join(args))
```

Normally, these variadic arguments will be last in the list of formal parameters, because they scoop up all remaining input arguments that are passed to the function. Any formal parameters which occur after

the *args parameter are 'keyword-only' arguments, meaning that they can only be used as keywords rather than positional arguments.

```
>>> def concat(*args, sep="/"):
...     return sep.join(args)
...
>>> concat("earth", "mars", "venus")
'earth/mars/venus'
>>> concat("earth", "mars", "venus", sep=".")
'earth.mars.venus'
```

4.7.4 Unpacking Argument Lists

The reverse situation occurs when the arguments are already in a list or tuple but need to be unpacked for a function call requiring separate positional arguments. For instance, the built-in `range()` function expects separate *start* and *stop* arguments. If they are not available separately, write the function call with the *-operator to unpack the arguments out of a list or tuple:

```
>>> list(range(3, 6))            # normal call with separate arguments
[3, 4, 5]
>>> args = [3, 6]
>>> list(range(*args))            # call with arguments unpacked from a list
[3, 4, 5]
```

In the same fashion, dictionaries can deliver keyword arguments with the **-operator:

```
>>> def parrot(voltage, state='a stiff', action='voom'):
...     print("-- This parrot wouldn't", action, end=' ')
...     print("if you put", voltage, "volts through it.", end=' ')
...     print("E's", state, "!")
...
>>> d = {"voltage": "four million", "state": "bleedin' demised", "action": "VOOM"}
>>> parrot(**d)
-- This parrot wouldn't VOOM if you put four million volts through it. E's bleedin' demised !
```

4.7.5 Lambda Expressions

Small anonymous functions can be created with the `lambda` keyword. This function returns the sum of its two arguments: `lambda a, b: a+b`. Lambda functions can be used wherever function objects are required. They are syntactically restricted to a single expression. Semantically, they are just syntactic sugar for a normal function definition. Like nested function definitions, lambda functions can reference variables from the containing scope:

```
>>> def make_incrementor(n):
...     return lambda x: x + n
...
>>> f = make_incrementor(42)
>>> f(0)
42
>>> f(1)
43
```

The above example uses a lambda expression to return a function. Another use is to pass a small function as an argument:

```
>>> pairs = [(1, 'one'), (2, 'two'), (3, 'three'), (4, 'four')]
>>> pairs.sort(key=lambda pair: pair[1])
>>> pairs
[(4, 'four'), (1, 'one'), (3, 'three'), (2, 'two')]
```

4.7.6 Documentation Strings

Here are some conventions about the content and formatting of documentation strings.

The first line should always be a short, concise summary of the object's purpose. For brevity, it should not explicitly state the object's name or type, since these are available by other means (except if the name happens to be a verb describing a function's operation). This line should begin with a capital letter and end with a period.

If there are more lines in the documentation string, the second line should be blank, visually separating the summary from the rest of the description. The following lines should be one or more paragraphs describing the object's calling conventions, its side effects, etc.

The Python parser does not strip indentation from multi-line string literals in Python, so tools that process documentation have to strip indentation if desired. This is done using the following convention. The first non-blank line *after* the first line of the string determines the amount of indentation for the entire documentation string. (We can't use the first line since it is generally adjacent to the string's opening quotes so its indentation is not apparent in the string literal.) Whitespace "equivalent" to this indentation is then stripped from the start of all lines of the string. Lines that are indented less should not occur, but if they occur all their leading whitespace should be stripped. Equivalence of whitespace should be tested after expansion of tabs (to 8 spaces, normally).

Here is an example of a multi-line docstring:

```
>>> def my_function():
...     """Do nothing, but document it.
...
...     No, really, it doesn't do anything.
...     """
...     pass
...
>>> print(my_function.__doc__)
Do nothing, but document it.

    No, really, it doesn't do anything.
```

4.7.7 Function Annotations

Function annotations are completely optional metadata information about the types used by user-defined functions (see **PEP 3107** and **PEP 484** for more information).

Annotations are stored in the `__annotations__` attribute of the function as a dictionary and have no effect on any other part of the function. Parameter annotations are defined by a colon after the parameter name, followed by an expression evaluating to the value of the annotation. Return annotations are defined by a literal `->`, followed by an expression, between the parameter list and the colon denoting the end of the `def` statement. The following example has a positional argument, a keyword argument, and the return value annotated:

```
>>> def f(ham: str, eggs: str = 'eggs') -> str:
...     print("Annotations:", f.__annotations__)
```

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```
...     print("Arguments:", ham, eggs)
...     return ham + ' and ' + eggs
...
>>> f('spam')
Annotations: {'ham': <class 'str'>, 'return': <class 'str'>, 'eggs': <class 'str'>}
Arguments: spam eggs
'spam and eggs'
```

4.8 Intermezzo: Coding Style

Now that you are about to write longer, more complex pieces of Python, it is a good time to talk about *coding style*. Most languages can be written (or more concise, *formatted*) in different styles; some are more readable than others. Making it easy for others to read your code is always a good idea, and adopting a nice coding style helps tremendously for that.

For Python, **PEP 8** has emerged as the style guide that most projects adhere to; it promotes a very readable and eye-pleasing coding style. Every Python developer should read it at some point; here are the most important points extracted for you:

- Use 4-space indentation, and no tabs.

  4 spaces are a good compromise between small indentation (allows greater nesting depth) and large indentation (easier to read). Tabs introduce confusion, and are best left out.

- Wrap lines so that they don't exceed 79 characters.

  This helps users with small displays and makes it possible to have several code files side-by-side on larger displays.

- Use blank lines to separate functions and classes, and larger blocks of code inside functions.

- When possible, put comments on a line of their own.

- Use docstrings.

- Use spaces around operators and after commas, but not directly inside bracketing constructs: `a = f(1, 2) + g(3, 4)`.

- Name your classes and functions consistently; the convention is to use `CamelCase` for classes and `lower_case_with_underscores` for functions and methods. Always use `self` as the name for the first method argument (see *A First Look at Classes* for more on classes and methods).

- Don't use fancy encodings if your code is meant to be used in international environments. Python's default, UTF-8, or even plain ASCII work best in any case.

- Likewise, don't use non-ASCII characters in identifiers if there is only the slightest chance people speaking a different language will read or maintain the code.

CHAPTER

FIVE

DATA STRUCTURES

This chapter describes some things you've learned about already in more detail, and adds some new things as well.

5.1 More on Lists

The list data type has some more methods. Here are all of the methods of list objects:

`list.append(`*x*`)`
Add an item to the end of the list. Equivalent to `a[len(a):] = [x]`.

`list.extend(`*iterable*`)`
Extend the list by appending all the items from the iterable. Equivalent to `a[len(a):] = iterable`.

`list.insert(`*i*, *x*`)`
Insert an item at a given position. The first argument is the index of the element before which to insert, so `a.insert(0, x)` inserts at the front of the list, and `a.insert(len(a), x)` is equivalent to `a.append(x)`.

`list.remove(`*x*`)`
Remove the first item from the list whose value is equal to *x*. It is an error if there is no such item.

`list.pop(`$\left[i\right]$`)`
Remove the item at the given position in the list, and return it. If no index is specified, `a.pop()` removes and returns the last item in the list. (The square brackets around the *i* in the method signature denote that the parameter is optional, not that you should type square brackets at that position. You will see this notation frequently in the Python Library Reference.)

`list.clear()`
Remove all items from the list. Equivalent to `del a[:]`.

`list.index(`*x*$\left[$, *start*$\left[$, *end*$\right]\right]$`)`
Return zero-based index in the list of the first item whose value is equal to *x*. Raises a `ValueError` if there is no such item.

The optional arguments *start* and *end* are interpreted as in the slice notation and are used to limit the search to a particular subsequence of the list. The returned index is computed relative to the beginning of the full sequence rather than the *start* argument.

`list.count(`*x*`)`
Return the number of times *x* appears in the list.

`list.sort(`*key=None*, *reverse=False*`)`
Sort the items of the list in place (the arguments can be used for sort customization, see `sorted()` for their explanation).

`list.reverse()`
Reverse the elements of the list in place.

`list.copy()`
Return a shallow copy of the list. Equivalent to `a[:]`.

An example that uses most of the list methods:

```
>>> fruits = ['orange', 'apple', 'pear', 'banana', 'kiwi', 'apple', 'banana']
>>> fruits.count('apple')
2
>>> fruits.count('tangerine')
0
>>> fruits.index('banana')
3
>>> fruits.index('banana', 4)  # Find next banana starting a position 4
6
>>> fruits.reverse()
>>> fruits
['banana', 'apple', 'kiwi', 'banana', 'pear', 'apple', 'orange']
>>> fruits.append('grape')
>>> fruits
['banana', 'apple', 'kiwi', 'banana', 'pear', 'apple', 'orange', 'grape']
>>> fruits.sort()
>>> fruits
['apple', 'apple', 'banana', 'banana', 'grape', 'kiwi', 'orange', 'pear']
>>> fruits.pop()
'pear'
```

You might have noticed that methods like `insert`, `remove` or `sort` that only modify the list have no return value printed – they return the default `None`.[1] This is a design principle for all mutable data structures in Python.

5.1.1 Using Lists as Stacks

The list methods make it very easy to use a list as a stack, where the last element added is the first element retrieved ("last-in, first-out"). To add an item to the top of the stack, use `append()`. To retrieve an item from the top of the stack, use `pop()` without an explicit index. For example:

```
>>> stack = [3, 4, 5]
>>> stack.append(6)
>>> stack.append(7)
>>> stack
[3, 4, 5, 6, 7]
>>> stack.pop()
7
>>> stack
[3, 4, 5, 6]
>>> stack.pop()
6
>>> stack.pop()
5
>>> stack
[3, 4]
```

[1] Other languages may return the mutated object, which allows method chaining, such as `d->insert("a")->remove("b")->sort();`.

5.1.2 Using Lists as Queues

It is also possible to use a list as a queue, where the first element added is the first element retrieved ("first-in, first-out"); however, lists are not efficient for this purpose. While appends and pops from the end of list are fast, doing inserts or pops from the beginning of a list is slow (because all of the other elements have to be shifted by one).

To implement a queue, use `collections.deque` which was designed to have fast appends and pops from both ends. For example:

```
>>> from collections import deque
>>> queue = deque(["Eric", "John", "Michael"])
>>> queue.append("Terry")           # Terry arrives
>>> queue.append("Graham")          # Graham arrives
>>> queue.popleft()                 # The first to arrive now leaves
'Eric'
>>> queue.popleft()                 # The second to arrive now leaves
'John'
>>> queue                           # Remaining queue in order of arrival
deque(['Michael', 'Terry', 'Graham'])
```

5.1.3 List Comprehensions

List comprehensions provide a concise way to create lists. Common applications are to make new lists where each element is the result of some operations applied to each member of another sequence or iterable, or to create a subsequence of those elements that satisfy a certain condition.

For example, assume we want to create a list of squares, like:

```
>>> squares = []
>>> for x in range(10):
...     squares.append(x**2)
...
>>> squares
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

Note that this creates (or overwrites) a variable named `x` that still exists after the loop completes. We can calculate the list of squares without any side effects using:

```
squares = list(map(lambda x: x**2, range(10)))
```

or, equivalently:

```
squares = [x**2 for x in range(10)]
```

which is more concise and readable.

A list comprehension consists of brackets containing an expression followed by a `for` clause, then zero or more `for` or `if` clauses. The result will be a new list resulting from evaluating the expression in the context of the `for` and `if` clauses which follow it. For example, this listcomp combines the elements of two lists if they are not equal:

```
>>> [(x, y) for x in [1,2,3] for y in [3,1,4] if x != y]
[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]
```

and it's equivalent to:

```
>>> combs = []
>>> for x in [1,2,3]:
...     for y in [3,1,4]:
...         if x != y:
...             combs.append((x, y))
...
>>> combs
[(1, 3), (1, 4), (2, 3), (2, 1), (2, 4), (3, 1), (3, 4)]
```

Note how the order of the `for` and `if` statements is the same in both these snippets.

If the expression is a tuple (e.g. the `(x, y)` in the previous example), it must be parenthesized.

```
>>> vec = [-4, -2, 0, 2, 4]
>>> # create a new list with the values doubled
>>> [x*2 for x in vec]
[-8, -4, 0, 4, 8]
>>> # filter the list to exclude negative numbers
>>> [x for x in vec if x >= 0]
[0, 2, 4]
>>> # apply a function to all the elements
>>> [abs(x) for x in vec]
[4, 2, 0, 2, 4]
>>> # call a method on each element
>>> freshfruit = ['  banana', '  loganberry ', 'passion fruit  ']
>>> [weapon.strip() for weapon in freshfruit]
['banana', 'loganberry', 'passion fruit']
>>> # create a list of 2-tuples like (number, square)
>>> [(x, x**2) for x in range(6)]
[(0, 0), (1, 1), (2, 4), (3, 9), (4, 16), (5, 25)]
>>> # the tuple must be parenthesized, otherwise an error is raised
>>> [x, x**2 for x in range(6)]
  File "<stdin>", line 1, in <module>
    [x, x**2 for x in range(6)]
               ^
SyntaxError: invalid syntax
>>> # flatten a list using a listcomp with two 'for'
>>> vec = [[1,2,3], [4,5,6], [7,8,9]]
>>> [num for elem in vec for num in elem]
[1, 2, 3, 4, 5, 6, 7, 8, 9]
```

List comprehensions can contain complex expressions and nested functions:

```
>>> from math import pi
>>> [str(round(pi, i)) for i in range(1, 6)]
['3.1', '3.14', '3.142', '3.1416', '3.14159']
```

5.1.4 Nested List Comprehensions

The initial expression in a list comprehension can be any arbitrary expression, including another list comprehension.

Consider the following example of a 3x4 matrix implemented as a list of 3 lists of length 4:

```
>>> matrix = [
...     [1, 2, 3, 4],
...     [5, 6, 7, 8],
```

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```
...     [9, 10, 11, 12],
... ]
```

The following list comprehension will transpose rows and columns:

```
>>> [[row[i] for row in matrix] for i in range(4)]
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```

As we saw in the previous section, the nested listcomp is evaluated in the context of the `for` that follows it, so this example is equivalent to:

```
>>> transposed = []
>>> for i in range(4):
...     transposed.append([row[i] for row in matrix])
...
>>> transposed
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```

which, in turn, is the same as:

```
>>> transposed = []
>>> for i in range(4):
...     # the following 3 lines implement the nested listcomp
...     transposed_row = []
...     for row in matrix:
...         transposed_row.append(row[i])
...     transposed.append(transposed_row)
...
>>> transposed
[[1, 5, 9], [2, 6, 10], [3, 7, 11], [4, 8, 12]]
```

In the real world, you should prefer built-in functions to complex flow statements. The `zip()` function would do a great job for this use case:

```
>>> list(zip(*matrix))
[(1, 5, 9), (2, 6, 10), (3, 7, 11), (4, 8, 12)]
```

See *Unpacking Argument Lists* for details on the asterisk in this line.

5.2 The `del` statement

There is a way to remove an item from a list given its index instead of its value: the `del` statement. This differs from the `pop()` method which returns a value. The `del` statement can also be used to remove slices from a list or clear the entire list (which we did earlier by assignment of an empty list to the slice). For example:

```
>>> a = [-1, 1, 66.25, 333, 333, 1234.5]
>>> del a[0]
>>> a
[1, 66.25, 333, 333, 1234.5]
>>> del a[2:4]
>>> a
[1, 66.25, 1234.5]
>>> del a[:]
```

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```
>>> a
[]
```

`del` can also be used to delete entire variables:

```
>>> del a
```

Referencing the name `a` hereafter is an error (at least until another value is assigned to it). We'll find other uses for `del` later.

5.3 Tuples and Sequences

We saw that lists and strings have many common properties, such as indexing and slicing operations. They are two examples of *sequence* data types (see typesseq). Since Python is an evolving language, other sequence data types may be added. There is also another standard sequence data type: the *tuple*.

A tuple consists of a number of values separated by commas, for instance:

```
>>> t = 12345, 54321, 'hello!'
>>> t[0]
12345
>>> t
(12345, 54321, 'hello!')
>>> # Tuples may be nested:
... u = t, (1, 2, 3, 4, 5)
>>> u
((12345, 54321, 'hello!'), (1, 2, 3, 4, 5))
>>> # Tuples are immutable:
... t[0] = 88888
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> # but they can contain mutable objects:
... v = ([1, 2, 3], [3, 2, 1])
>>> v
([1, 2, 3], [3, 2, 1])
```

As you see, on output tuples are always enclosed in parentheses, so that nested tuples are interpreted correctly; they may be input with or without surrounding parentheses, although often parentheses are necessary anyway (if the tuple is part of a larger expression). It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.

Though tuples may seem similar to lists, they are often used in different situations and for different purposes. Tuples are *immutable*, and usually contain a heterogeneous sequence of elements that are accessed via unpacking (see later in this section) or indexing (or even by attribute in the case of `namedtuples`). Lists are *mutable*, and their elements are usually homogeneous and are accessed by iterating over the list.

A special problem is the construction of tuples containing 0 or 1 items: the syntax has some extra quirks to accommodate these. Empty tuples are constructed by an empty pair of parentheses; a tuple with one item is constructed by following a value with a comma (it is not sufficient to enclose a single value in parentheses). Ugly, but effective. For example:

```
>>> empty = ()
>>> singleton = 'hello',    # <-- note trailing comma
>>> len(empty)
```

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```
0
>>> len(singleton)
1
>>> singleton
('hello',)
```

The statement `t = 12345, 54321, 'hello!'` is an example of *tuple packing*: the values `12345`, `54321` and `'hello!'` are packed together in a tuple. The reverse operation is also possible:

```
>>> x, y, z = t
```

This is called, appropriately enough, *sequence unpacking* and works for any sequence on the right-hand side. Sequence unpacking requires that there are as many variables on the left side of the equals sign as there are elements in the sequence. Note that multiple assignment is really just a combination of tuple packing and sequence unpacking.

5.4 Sets

Python also includes a data type for *sets*. A set is an unordered collection with no duplicate elements. Basic uses include membership testing and eliminating duplicate entries. Set objects also support mathematical operations like union, intersection, difference, and symmetric difference.

Curly braces or the `set()` function can be used to create sets. Note: to create an empty set you have to use `set()`, not `{}`; the latter creates an empty dictionary, a data structure that we discuss in the next section.

Here is a brief demonstration:

```
>>> basket = {'apple', 'orange', 'apple', 'pear', 'orange', 'banana'}
>>> print(basket)                      # show that duplicates have been removed
{'orange', 'banana', 'pear', 'apple'}
>>> 'orange' in basket                 # fast membership testing
True
>>> 'crabgrass' in basket
False

>>> # Demonstrate set operations on unique letters from two words
...
>>> a = set('abracadabra')
>>> b = set('alacazam')
>>> a                                  # unique letters in a
{'a', 'r', 'b', 'c', 'd'}
>>> a - b                              # letters in a but not in b
{'r', 'd', 'b'}
>>> a | b                              # letters in a or b or both
{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}
>>> a & b                              # letters in both a and b
{'a', 'c'}
>>> a ^ b                              # letters in a or b but not both
{'r', 'd', 'b', 'm', 'z', 'l'}
```

Similarly to *list comprehensions*, set comprehensions are also supported:

```
>>> a = {x for x in 'abracadabra' if x not in 'abc'}
>>> a
{'r', 'd'}
```

5.5 Dictionaries

Another useful data type built into Python is the *dictionary* (see typesmapping). Dictionaries are sometimes found in other languages as "associative memories" or "associative arrays". Unlike sequences, which are indexed by a range of numbers, dictionaries are indexed by *keys*, which can be any immutable type; strings and numbers can always be keys. Tuples can be used as keys if they contain only strings, numbers, or tuples; if a tuple contains any mutable object either directly or indirectly, it cannot be used as a key. You can't use lists as keys, since lists can be modified in place using index assignments, slice assignments, or methods like `append()` and `extend()`.

It is best to think of a dictionary as a set of *key: value* pairs, with the requirement that the keys are unique (within one dictionary). A pair of braces creates an empty dictionary: `{}`. Placing a comma-separated list of key:value pairs within the braces adds initial key:value pairs to the dictionary; this is also the way dictionaries are written on output.

The main operations on a dictionary are storing a value with some key and extracting the value given the key. It is also possible to delete a key:value pair with `del`. If you store using a key that is already in use, the old value associated with that key is forgotten. It is an error to extract a value using a non-existent key.

Performing `list(d)` on a dictionary returns a list of all the keys used in the dictionary, in insertion order (if you want it sorted, just use `sorted(d)` instead). To check whether a single key is in the dictionary, use the `in` keyword.

Here is a small example using a dictionary:

```
>>> tel = {'jack': 4098, 'sape': 4139}
>>> tel['guido'] = 4127
>>> tel
{'jack': 4098, 'sape': 4139, 'guido': 4127}
>>> tel['jack']
4098
>>> del tel['sape']
>>> tel['irv'] = 4127
>>> tel
{'jack': 4098, 'guido': 4127, 'irv': 4127}
>>> list(tel)
['jack', 'guido', 'irv']
>>> sorted(tel)
['guido', 'irv', 'jack']
>>> 'guido' in tel
True
>>> 'jack' not in tel
False
```

The `dict()` constructor builds dictionaries directly from sequences of key-value pairs:

```
>>> dict([('sape', 4139), ('guido', 4127), ('jack', 4098)])
{'sape': 4139, 'guido': 4127, 'jack': 4098}
```

In addition, dict comprehensions can be used to create dictionaries from arbitrary key and value expressions:

```
>>> {x: x**2 for x in (2, 4, 6)}
{2: 4, 4: 16, 6: 36}
```

When the keys are simple strings, it is sometimes easier to specify pairs using keyword arguments:

```
>>> dict(sape=4139, guido=4127, jack=4098)
{'sape': 4139, 'guido': 4127, 'jack': 4098}
```

5.6 Looping Techniques

When looping through dictionaries, the key and corresponding value can be retrieved at the same time using the `items()` method.

```
>>> knights = {'gallahad': 'the pure', 'robin': 'the brave'}
>>> for k, v in knights.items():
...     print(k, v)
...
gallahad the pure
robin the brave
```

When looping through a sequence, the position index and corresponding value can be retrieved at the same time using the `enumerate()` function.

```
>>> for i, v in enumerate(['tic', 'tac', 'toe']):
...     print(i, v)
...
0 tic
1 tac
2 toe
```

To loop over two or more sequences at the same time, the entries can be paired with the `zip()` function.

```
>>> questions = ['name', 'quest', 'favorite color']
>>> answers = ['lancelot', 'the holy grail', 'blue']
>>> for q, a in zip(questions, answers):
...     print('What is your {0}?  It is {1}.'.format(q, a))
...
What is your name?  It is lancelot.
What is your quest?  It is the holy grail.
What is your favorite color?  It is blue.
```

To loop over a sequence in reverse, first specify the sequence in a forward direction and then call the `reversed()` function.

```
>>> for i in reversed(range(1, 10, 2)):
...     print(i)
...
9
7
5
3
1
```

To loop over a sequence in sorted order, use the `sorted()` function which returns a new sorted list while leaving the source unaltered.

```
>>> basket = ['apple', 'orange', 'apple', 'pear', 'orange', 'banana']
>>> for f in sorted(set(basket)):
...     print(f)
...
apple
banana
orange
pear
```

It is sometimes tempting to change a list while you are looping over it; however, it is often simpler and safer to create a new list instead.

```
>>> import math
>>> raw_data = [56.2, float('NaN'), 51.7, 55.3, 52.5, float('NaN'), 47.8]
>>> filtered_data = []
>>> for value in raw_data:
...     if not math.isnan(value):
...         filtered_data.append(value)
...
>>> filtered_data
[56.2, 51.7, 55.3, 52.5, 47.8]
```

5.7 More on Conditions

The conditions used in `while` and `if` statements can contain any operators, not just comparisons.

The comparison operators `in` and `not in` check whether a value occurs (does not occur) in a sequence. The operators `is` and `is not` compare whether two objects are really the same object; this only matters for mutable objects like lists. All comparison operators have the same priority, which is lower than that of all numerical operators.

Comparisons can be chained. For example, `a < b == c` tests whether `a` is less than `b` and moreover `b` equals `c`.

Comparisons may be combined using the Boolean operators `and` and `or`, and the outcome of a comparison (or of any other Boolean expression) may be negated with `not`. These have lower priorities than comparison operators; between them, `not` has the highest priority and `or` the lowest, so that `A and not B or C` is equivalent to `(A and (not B)) or C`. As always, parentheses can be used to express the desired composition.

The Boolean operators `and` and `or` are so-called *short-circuit* operators: their arguments are evaluated from left to right, and evaluation stops as soon as the outcome is determined. For example, if `A` and `C` are true but `B` is false, `A and B and C` does not evaluate the expression `C`. When used as a general value and not as a Boolean, the return value of a short-circuit operator is the last evaluated argument.

It is possible to assign the result of a comparison or other Boolean expression to a variable. For example,

```
>>> string1, string2, string3 = '', 'Trondheim', 'Hammer Dance'
>>> non_null = string1 or string2 or string3
>>> non_null
'Trondheim'
```

Note that in Python, unlike C, assignment cannot occur inside expressions. C programmers may grumble about this, but it avoids a common class of problems encountered in C programs: typing `=` in an expression when `==` was intended.

5.8 Comparing Sequences and Other Types

Sequence objects may be compared to other objects with the same sequence type. The comparison uses *lexicographical* ordering: first the first two items are compared, and if they differ this determines the outcome of the comparison; if they are equal, the next two items are compared, and so on, until either sequence is exhausted. If two items to be compared are themselves sequences of the same type, the lexicographical comparison is carried out recursively. If all items of two sequences compare equal, the sequences are considered equal. If one sequence is an initial sub-sequence of the other, the shorter sequence is the smaller (lesser)

one. Lexicographical ordering for strings uses the Unicode code point number to order individual characters. Some examples of comparisons between sequences of the same type:

```
(1, 2, 3)              < (1, 2, 4)
[1, 2, 3]              < [1, 2, 4]
'ABC' < 'C' < 'Pascal' < 'Python'
(1, 2, 3, 4)           < (1, 2, 4)
(1, 2)                 < (1, 2, -1)
(1, 2, 3)             == (1.0, 2.0, 3.0)
(1, 2, ('aa', 'ab'))   < (1, 2, ('abc', 'a'), 4)
```

Note that comparing objects of different types with < or > is legal provided that the objects have appropriate comparison methods. For example, mixed numeric types are compared according to their numeric value, so 0 equals 0.0, etc. Otherwise, rather than providing an arbitrary ordering, the interpreter will raise a `TypeError` exception.

CHAPTER

SIX

MODULES

If you quit from the Python interpreter and enter it again, the definitions you have made (functions and variables) are lost. Therefore, if you want to write a somewhat longer program, you are better off using a text editor to prepare the input for the interpreter and running it with that file as input instead. This is known as creating a *script*. As your program gets longer, you may want to split it into several files for easier maintenance. You may also want to use a handy function that you've written in several programs without copying its definition into each program.

To support this, Python has a way to put definitions in a file and use them in a script or in an interactive instance of the interpreter. Such a file is called a *module*; definitions from a module can be *imported* into other modules or into the *main* module (the collection of variables that you have access to in a script executed at the top level and in calculator mode).

A module is a file containing Python definitions and statements. The file name is the module name with the suffix `.py` appended. Within a module, the module's name (as a string) is available as the value of the global variable `__name__`. For instance, use your favorite text editor to create a file called `fibo.py` in the current directory with the following contents:

```
# Fibonacci numbers module

def fib(n):    # write Fibonacci series up to n
    a, b = 0, 1
    while a < n:
        print(a, end=' ')
        a, b = b, a+b
    print()

def fib2(n):   # return Fibonacci series up to n
    result = []
    a, b = 0, 1
    while a < n:
        result.append(a)
        a, b = b, a+b
    return result
```

Now enter the Python interpreter and import this module with the following command:

```
>>> import fibo
```

This does not enter the names of the functions defined in `fibo` directly in the current symbol table; it only enters the module name `fibo` there. Using the module name you can access the functions:

```
>>> fibo.fib(1000)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987
>>> fibo.fib2(100)
```

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```
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89]
>>> fibo.__name__
'fibo'
```

If you intend to use a function often you can assign it to a local name:

```
>>> fib = fibo.fib
>>> fib(500)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

6.1 More on Modules

A module can contain executable statements as well as function definitions. These statements are intended to initialize the module. They are executed only the *first* time the module name is encountered in an import statement.[1] (They are also run if the file is executed as a script.)

Each module has its own private symbol table, which is used as the global symbol table by all functions defined in the module. Thus, the author of a module can use global variables in the module without worrying about accidental clashes with a user's global variables. On the other hand, if you know what you are doing you can touch a module's global variables with the same notation used to refer to its functions, `modname.itemname`.

Modules can import other modules. It is customary but not required to place all `import` statements at the beginning of a module (or script, for that matter). The imported module names are placed in the importing module's global symbol table.

There is a variant of the `import` statement that imports names from a module directly into the importing module's symbol table. For example:

```
>>> from fibo import fib, fib2
>>> fib(500)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

This does not introduce the module name from which the imports are taken in the local symbol table (so in the example, `fibo` is not defined).

There is even a variant to import all names that a module defines:

```
>>> from fibo import *
>>> fib(500)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

This imports all names except those beginning with an underscore (_). In most cases Python programmers do not use this facility since it introduces an unknown set of names into the interpreter, possibly hiding some things you have already defined.

Note that in general the practice of importing `*` from a module or package is frowned upon, since it often causes poorly readable code. However, it is okay to use it to save typing in interactive sessions.

If the module name is followed by `as`, then the name following `as` is bound directly to the imported module.

```
>>> import fibo as fib
>>> fib.fib(500)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

[1] In fact function definitions are also 'statements' that are 'executed'; the execution of a module-level function definition enters the function name in the module's global symbol table.

This is effectively importing the module in the same way that `import fibo` will do, with the only difference of it being available as `fib`.

It can also be used when utilising `from` with similar effects:

```
>>> from fibo import fib as fibonacci
>>> fibonacci(500)
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377
```

Note: For efficiency reasons, each module is only imported once per interpreter session. Therefore, if you change your modules, you must restart the interpreter – or, if it's just one module you want to test interactively, use `importlib.reload()`, e.g. `import importlib; importlib.reload(modulename)`.

6.1.1 Executing modules as scripts

When you run a Python module with

```
python fibo.py <arguments>
```

the code in the module will be executed, just as if you imported it, but with the `__name__` set to `"__main__"`. That means that by adding this code at the end of your module:

```
if __name__ == "__main__":
    import sys
    fib(int(sys.argv[1]))
```

you can make the file usable as a script as well as an importable module, because the code that parses the command line only runs if the module is executed as the "main" file:

```
$ python fibo.py 50
0 1 1 2 3 5 8 13 21 34
```

If the module is imported, the code is not run:

```
>>> import fibo
>>>
```

This is often used either to provide a convenient user interface to a module, or for testing purposes (running the module as a script executes a test suite).

6.1.2 The Module Search Path

When a module named `spam` is imported, the interpreter first searches for a built-in module with that name. If not found, it then searches for a file named `spam.py` in a list of directories given by the variable `sys.path`. `sys.path` is initialized from these locations:

- The directory containing the input script (or the current directory when no file is specified).
- `PYTHONPATH` (a list of directory names, with the same syntax as the shell variable `PATH`).
- The installation-dependent default.

Note: On file systems which support symlinks, the directory containing the input script is calculated after the symlink is followed. In other words the directory containing the symlink is **not** added to the module

search path.

After initialization, Python programs can modify `sys.path`. The directory containing the script being run is placed at the beginning of the search path, ahead of the standard library path. This means that scripts in that directory will be loaded instead of modules of the same name in the library directory. This is an error unless the replacement is intended. See section *Standard Modules* for more information.

6.1.3 "Compiled" Python files

To speed up loading modules, Python caches the compiled version of each module in the `__pycache__` directory under the name `module.version.pyc`, where the version encodes the format of the compiled file; it generally contains the Python version number. For example, in CPython release 3.3 the compiled version of spam.py would be cached as `__pycache__/spam.cpython-33.pyc`. This naming convention allows compiled modules from different releases and different versions of Python to coexist.

Python checks the modification date of the source against the compiled version to see if it's out of date and needs to be recompiled. This is a completely automatic process. Also, the compiled modules are platform-independent, so the same library can be shared among systems with different architectures.

Python does not check the cache in two circumstances. First, it always recompiles and does not store the result for the module that's loaded directly from the command line. Second, it does not check the cache if there is no source module. To support a non-source (compiled only) distribution, the compiled module must be in the source directory, and there must not be a source module.

Some tips for experts:

- You can use the `-O` or `-OO` switches on the Python command to reduce the size of a compiled module. The `-O` switch removes assert statements, the `-OO` switch removes both assert statements and ___doc___ strings. Since some programs may rely on having these available, you should only use this option if you know what you're doing. "Optimized" modules have an `opt-` tag and are usually smaller. Future releases may change the effects of optimization.
- A program doesn't run any faster when it is read from a `.pyc` file than when it is read from a `.py` file; the only thing that's faster about `.pyc` files is the speed with which they are loaded.
- The module `compileall` can create .pyc files for all modules in a directory.
- There is more detail on this process, including a flow chart of the decisions, in **PEP 3147**.

6.2 Standard Modules

Python comes with a library of standard modules, described in a separate document, the Python Library Reference ("Library Reference" hereafter). Some modules are built into the interpreter; these provide access to operations that are not part of the core of the language but are nevertheless built in, either for efficiency or to provide access to operating system primitives such as system calls. The set of such modules is a configuration option which also depends on the underlying platform. For example, the `winreg` module is only provided on Windows systems. One particular module deserves some attention: `sys`, which is built into every Python interpreter. The variables `sys.ps1` and `sys.ps2` define the strings used as primary and secondary prompts:

```
>>> import sys
>>> sys.ps1
'>>> '
>>> sys.ps2
'... '
```

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```
>>> sys.ps1 = 'C> '
C> print('Yuck!')
Yuck!
C>
```

These two variables are only defined if the interpreter is in interactive mode.

The variable `sys.path` is a list of strings that determines the interpreter's search path for modules. It is initialized to a default path taken from the environment variable `PYTHONPATH`, or from a built-in default if `PYTHONPATH` is not set. You can modify it using standard list operations:

```
>>> import sys
>>> sys.path.append('/ufs/guido/lib/python')
```

6.3 The `dir()` Function

The built-in function `dir()` is used to find out which names a module defines. It returns a sorted list of strings:

```
>>> import fibo, sys
>>> dir(fibo)
['__name__', 'fib', 'fib2']
>>> dir(sys)
['__displayhook__', '__doc__', '__excepthook__', '__loader__', '__name__',
 '__package__', '__stderr__', '__stdin__', '__stdout__',
 '_clear_type_cache', '_current_frames', '_debugmallocstats', '_getframe',
 '_home', '_mercurial', '_xoptions', 'abiflags', 'api_version', 'argv',
 'base_exec_prefix', 'base_prefix', 'builtin_module_names', 'byteorder',
 'call_tracing', 'callstats', 'copyright', 'displayhook',
 'dont_write_bytecode', 'exc_info', 'excepthook', 'exec_prefix',
 'executable', 'exit', 'flags', 'float_info', 'float_repr_style',
 'getcheckinterval', 'getdefaultencoding', 'getdlopenflags',
 'getfilesystemencoding', 'getobjects', 'getprofile', 'getrecursionlimit',
 'getrefcount', 'getsizeof', 'getswitchinterval', 'gettotalrefcount',
 'gettrace', 'hash_info', 'hexversion', 'implementation', 'int_info',
 'intern', 'maxsize', 'maxunicode', 'meta_path', 'modules', 'path',
 'path_hooks', 'path_importer_cache', 'platform', 'prefix', 'ps1',
 'setcheckinterval', 'setdlopenflags', 'setprofile', 'setrecursionlimit',
 'setswitchinterval', 'settrace', 'stderr', 'stdin', 'stdout',
 'thread_info', 'version', 'version_info', 'warnoptions']
```

Without arguments, `dir()` lists the names you have defined currently:

```
>>> a = [1, 2, 3, 4, 5]
>>> import fibo
>>> fib = fibo.fib
>>> dir()
['__builtins__', '__name__', 'a', 'fib', 'fibo', 'sys']
```

Note that it lists all types of names: variables, modules, functions, etc.

`dir()` does not list the names of built-in functions and variables. If you want a list of those, they are defined in the standard module `builtins`:

```
>>> import builtins
>>> dir(builtins)
['ArithmeticError', 'AssertionError', 'AttributeError', 'BaseException',
 'BlockingIOError', 'BrokenPipeError', 'BufferError', 'BytesWarning',
 'ChildProcessError', 'ConnectionAbortedError', 'ConnectionError',
 'ConnectionRefusedError', 'ConnectionResetError', 'DeprecationWarning',
 'EOFError', 'Ellipsis', 'EnvironmentError', 'Exception', 'False',
 'FileExistsError', 'FileNotFoundError', 'FloatingPointError',
 'FutureWarning', 'GeneratorExit', 'IOError', 'ImportError',
 'ImportWarning', 'IndentationError', 'IndexError', 'InterruptedError',
 'IsADirectoryError', 'KeyError', 'KeyboardInterrupt', 'LookupError',
 'MemoryError', 'NameError', 'None', 'NotADirectoryError', 'NotImplemented',
 'NotImplementedError', 'OSError', 'OverflowError',
 'PendingDeprecationWarning', 'PermissionError', 'ProcessLookupError',
 'ReferenceError', 'ResourceWarning', 'RuntimeError', 'RuntimeWarning',
 'StopIteration', 'SyntaxError', 'SyntaxWarning', 'SystemError',
 'SystemExit', 'TabError', 'TimeoutError', 'True', 'TypeError',
 'UnboundLocalError', 'UnicodeDecodeError', 'UnicodeEncodeError',
 'UnicodeError', 'UnicodeTranslateError', 'UnicodeWarning', 'UserWarning',
 'ValueError', 'Warning', 'ZeroDivisionError', '_', '__build_class__',
 '__debug__', '__doc__', '__import__', '__name__', '__package__', 'abs',
 'all', 'any', 'ascii', 'bin', 'bool', 'bytearray', 'bytes', 'callable',
 'chr', 'classmethod', 'compile', 'complex', 'copyright', 'credits',
 'delattr', 'dict', 'dir', 'divmod', 'enumerate', 'eval', 'exec', 'exit',
 'filter', 'float', 'format', 'frozenset', 'getattr', 'globals', 'hasattr',
 'hash', 'help', 'hex', 'id', 'input', 'int', 'isinstance', 'issubclass',
 'iter', 'len', 'license', 'list', 'locals', 'map', 'max', 'memoryview',
 'min', 'next', 'object', 'oct', 'open', 'ord', 'pow', 'print', 'property',
 'quit', 'range', 'repr', 'reversed', 'round', 'set', 'setattr', 'slice',
 'sorted', 'staticmethod', 'str', 'sum', 'super', 'tuple', 'type', 'vars',
 'zip']
```

6.4 Packages

Packages are a way of structuring Python's module namespace by using "dotted module names". For example, the module name `A.B` designates a submodule named `B` in a package named `A`. Just like the use of modules saves the authors of different modules from having to worry about each other's global variable names, the use of dotted module names saves the authors of multi-module packages like NumPy or Pillow from having to worry about each other's module names.

Suppose you want to design a collection of modules (a "package") for the uniform handling of sound files and sound data. There are many different sound file formats (usually recognized by their extension, for example: `.wav`, `.aiff`, `.au`), so you may need to create and maintain a growing collection of modules for the conversion between the various file formats. There are also many different operations you might want to perform on sound data (such as mixing, adding echo, applying an equalizer function, creating an artificial stereo effect), so in addition you will be writing a never-ending stream of modules to perform these operations. Here's a possible structure for your package (expressed in terms of a hierarchical filesystem):

```
sound/                          Top-level package
      __init__.py               Initialize the sound package
      formats/                  Subpackage for file format conversions
              __init__.py
              wavread.py
              wavwrite.py
```

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```
              aiffread.py
              aiffwrite.py
              auread.py
              auwrite.py
              ...
      effects/                Subpackage for sound effects
              __init__.py
              echo.py
              surround.py
              reverse.py
              ...
      filters/                Subpackage for filters
              __init__.py
              equalizer.py
              vocoder.py
              karaoke.py
              ...
```

When importing the package, Python searches through the directories on `sys.path` looking for the package subdirectory.

The `__init__.py` files are required to make Python treat the directories as containing packages; this is done to prevent directories with a common name, such as `string`, from unintentionally hiding valid modules that occur later on the module search path. In the simplest case, `__init__.py` can just be an empty file, but it can also execute initialization code for the package or set the `__all__` variable, described later.

Users of the package can import individual modules from the package, for example:

```
import sound.effects.echo
```

This loads the submodule `sound.effects.echo`. It must be referenced with its full name.

```
sound.effects.echo.echofilter(input, output, delay=0.7, atten=4)
```

An alternative way of importing the submodule is:

```
from sound.effects import echo
```

This also loads the submodule `echo`, and makes it available without its package prefix, so it can be used as follows:

```
echo.echofilter(input, output, delay=0.7, atten=4)
```

Yet another variation is to import the desired function or variable directly:

```
from sound.effects.echo import echofilter
```

Again, this loads the submodule `echo`, but this makes its function `echofilter()` directly available:

```
echofilter(input, output, delay=0.7, atten=4)
```

Note that when using `from package import item`, the item can be either a submodule (or subpackage) of the package, or some other name defined in the package, like a function, class or variable. The `import` statement first tests whether the item is defined in the package; if not, it assumes it is a module and attempts to load it. If it fails to find it, an `ImportError` exception is raised.

Contrarily, when using syntax like `import item.subitem.subsubitem`, each item except for the last must be a package; the last item can be a module or a package but can't be a class or function or variable defined

in the previous item.

6.4.1 Importing * From a Package

Now what happens when the user writes `from sound.effects import *`? Ideally, one would hope that this somehow goes out to the filesystem, finds which submodules are present in the package, and imports them all. This could take a long time and importing sub-modules might have unwanted side-effects that should only happen when the sub-module is explicitly imported.

The only solution is for the package author to provide an explicit index of the package. The `import` statement uses the following convention: if a package's `__init__.py` code defines a list named `__all__`, it is taken to be the list of module names that should be imported when `from package import *` is encountered. It is up to the package author to keep this list up-to-date when a new version of the package is released. Package authors may also decide not to support it, if they don't see a use for importing * from their package. For example, the file `sound/effects/__init__.py` could contain the following code:

```
__all__ = ["echo", "surround", "reverse"]
```

This would mean that `from sound.effects import *` would import the three named submodules of the `sound` package.

If `__all__` is not defined, the statement `from sound.effects import *` does *not* import all submodules from the package `sound.effects` into the current namespace; it only ensures that the package `sound.effects` has been imported (possibly running any initialization code in `__init__.py`) and then imports whatever names are defined in the package. This includes any names defined (and submodules explicitly loaded) by `__init__.py`. It also includes any submodules of the package that were explicitly loaded by previous `import` statements. Consider this code:

```
import sound.effects.echo
import sound.effects.surround
from sound.effects import *
```

In this example, the `echo` and `surround` modules are imported in the current namespace because they are defined in the `sound.effects` package when the `from...import` statement is executed. (This also works when `__all__` is defined.)

Although certain modules are designed to export only names that follow certain patterns when you use `import *`, it is still considered bad practice in production code.

Remember, there is nothing wrong with using `from Package import specific_submodule`! In fact, this is the recommended notation unless the importing module needs to use submodules with the same name from different packages.

6.4.2 Intra-package References

When packages are structured into subpackages (as with the `sound` package in the example), you can use absolute imports to refer to submodules of siblings packages. For example, if the module `sound.filters.vocoder` needs to use the `echo` module in the `sound.effects` package, it can use `from sound.effects import echo`.

You can also write relative imports, with the `from module import name` form of import statement. These imports use leading dots to indicate the current and parent packages involved in the relative import. From the `surround` module for example, you might use:

```
from . import echo
from .. import formats
from ..filters import equalizer
```

Note that relative imports are based on the name of the current module. Since the name of the main module is always `"__main__"`, modules intended for use as the main module of a Python application must always use absolute imports.

6.4.3 Packages in Multiple Directories

Packages support one more special attribute, `__path__`. This is initialized to be a list containing the name of the directory holding the package's `__init__.py` before the code in that file is executed. This variable can be modified; doing so affects future searches for modules and subpackages contained in the package.

While this feature is not often needed, it can be used to extend the set of modules found in a package.

CHAPTER

SEVEN

INPUT AND OUTPUT

There are several ways to present the output of a program; data can be printed in a human-readable form, or written to a file for future use. This chapter will discuss some of the possibilities.

7.1 Fancier Output Formatting

So far we've encountered two ways of writing values: *expression statements* and the `print()` function. (A third way is using the `write()` method of file objects; the standard output file can be referenced as `sys.stdout`. See the Library Reference for more information on this.)

Often you'll want more control over the formatting of your output than simply printing space-separated values. There are two ways to format your output; the first way is to do all the string handling yourself; using string slicing and concatenation operations you can create any layout you can imagine. The string type has some methods that perform useful operations for padding strings to a given column width; these will be discussed shortly. The second way is to use formatted string literals, or the `str.format()` method.

The `string` module contains a `Template` class which offers yet another way to substitute values into strings.

One question remains, of course: how do you convert values to strings? Luckily, Python has ways to convert any value to a string: pass it to the `repr()` or `str()` functions.

The `str()` function is meant to return representations of values which are fairly human-readable, while `repr()` is meant to generate representations which can be read by the interpreter (or will force a `SyntaxError` if there is no equivalent syntax). For objects which don't have a particular representation for human consumption, `str()` will return the same value as `repr()`. Many values, such as numbers or structures like lists and dictionaries, have the same representation using either function. Strings, in particular, have two distinct representations.

Some examples:

```
>>> s = 'Hello, world.'
>>> str(s)
'Hello, world.'
>>> repr(s)
"'Hello, world.'"
>>> str(1/7)
'0.14285714285714285'
>>> x = 10 * 3.25
>>> y = 200 * 200
>>> s = 'The value of x is ' + repr(x) + ', and y is ' + repr(y) + '...'
>>> print(s)
The value of x is 32.5, and y is 40000...
>>> # The repr() of a string adds string quotes and backslashes:
... hello = 'hello, world\n'
```

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```
>>> hellos = repr(hello)
>>> print(hellos)
'hello, world\n'
>>> # The argument to repr() may be any Python object:
... repr((x, y, ('spam', 'eggs')))
"(32.5, 40000, ('spam', 'eggs'))"
```

Here are two ways to write a table of squares and cubes:

```
>>> for x in range(1, 11):
...     print(repr(x).rjust(2), repr(x*x).rjust(3), end=' ')
...     # Note use of 'end' on previous line
...     print(repr(x*x*x).rjust(4))
...
 1   1    1
 2   4    8
 3   9   27
 4  16   64
 5  25  125
 6  36  216
 7  49  343
 8  64  512
 9  81  729
10 100 1000

>>> for x in range(1, 11):
...     print('{0:2d} {1:3d} {2:4d}'.format(x, x*x, x*x*x))
...
 1   1    1
 2   4    8
 3   9   27
 4  16   64
 5  25  125
 6  36  216
 7  49  343
 8  64  512
 9  81  729
10 100 1000
```

(Note that in the first example, one space between each column was added by the way `print()` works: by default it adds spaces between its arguments.)

This example demonstrates the `str.rjust()` method of string objects, which right-justifies a string in a field of a given width by padding it with spaces on the left. There are similar methods `str.ljust()` and `str.center()`. These methods do not write anything, they just return a new string. If the input string is too long, they don't truncate it, but return it unchanged; this will mess up your column lay-out but that's usually better than the alternative, which would be lying about a value. (If you really want truncation you can always add a slice operation, as in `x.ljust(n)[:n]`.)

There is another method, `str.zfill()`, which pads a numeric string on the left with zeros. It understands about plus and minus signs:

```
>>> '12'.zfill(5)
'00012'
>>> '-3.14'.zfill(7)
'-003.14'
>>> '3.14159265359'.zfill(5)
```

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```
'3.14159265359'
```

Basic usage of the `str.format()` method looks like this:

```
>>> print('We are the {} who say "{}!"'.format('knights', 'Ni'))
We are the knights who say "Ni!"
```

The brackets and characters within them (called format fields) are replaced with the objects passed into the `str.format()` method. A number in the brackets can be used to refer to the position of the object passed into the `str.format()` method.

```
>>> print('{0} and {1}'.format('spam', 'eggs'))
spam and eggs
>>> print('{1} and {0}'.format('spam', 'eggs'))
eggs and spam
```

If keyword arguments are used in the `str.format()` method, their values are referred to by using the name of the argument.

```
>>> print('This {food} is {adjective}.'.format(
...       food='spam', adjective='absolutely horrible'))
This spam is absolutely horrible.
```

Positional and keyword arguments can be arbitrarily combined:

```
>>> print('The story of {0}, {1}, and {other}.'.format('Bill', 'Manfred',
                                                       other='Georg'))
The story of Bill, Manfred, and Georg.
```

`'!a'` (apply `ascii()`), `'!s'` (apply `str()`) and `'!r'` (apply `repr()`) can be used to convert the value before it is formatted:

```
>>> contents = 'eels'
>>> print('My hovercraft is full of {}.'.format(contents))
My hovercraft is full of eels.
>>> print('My hovercraft is full of {!r}.'.format(contents))
My hovercraft is full of 'eels'.
```

An optional `':'` and format specifier can follow the field name. This allows greater control over how the value is formatted. The following example rounds Pi to three places after the decimal.

```
>>> import math
>>> print('The value of PI is approximately {0:.3f}.'.format(math.pi))
The value of PI is approximately 3.142.
```

Passing an integer after the `':'` will cause that field to be a minimum number of characters wide. This is useful for making tables pretty.

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 7678}
>>> for name, phone in table.items():
...     print('{0:10} ==> {1:10d}'.format(name, phone))
...
Jack       ==>       4098
Dcab       ==>       7678
Sjoerd     ==>       4127
```

If you have a really long format string that you don't want to split up, it would be nice if you could reference the variables to be formatted by name instead of by position. This can be done by simply passing the dict and using square brackets `'[]'` to access the keys

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}
>>> print('Jack: {0[Jack]:d}; Sjoerd: {0[Sjoerd]:d}; '
...       'Dcab: {0[Dcab]:d}'.format(table))
Jack: 4098; Sjoerd: 4127; Dcab: 8637678
```

This could also be done by passing the table as keyword arguments with the '**' notation.

```
>>> table = {'Sjoerd': 4127, 'Jack': 4098, 'Dcab': 8637678}
>>> print('Jack: {Jack:d}; Sjoerd: {Sjoerd:d}; Dcab: {Dcab:d}'.format(**table))
Jack: 4098; Sjoerd: 4127; Dcab: 8637678
```

This is particularly useful in combination with the built-in function `vars()`, which returns a dictionary containing all local variables.

For a complete overview of string formatting with `str.format()`, see formatstrings.

7.1.1 Old string formatting

The `%` operator can also be used for string formatting. It interprets the left argument much like a `sprintf()`-style format string to be applied to the right argument, and returns the string resulting from this formatting operation. For example:

```
>>> import math
>>> print('The value of PI is approximately %5.3f.' % math.pi)
The value of PI is approximately 3.142.
```

More information can be found in the old-string-formatting section.

7.2 Reading and Writing Files

`open()` returns a *file object*, and is most commonly used with two arguments: `open(filename, mode)`.

```
>>> f = open('workfile', 'w')
```

The first argument is a string containing the filename. The second argument is another string containing a few characters describing the way in which the file will be used. *mode* can be `'r'` when the file will only be read, `'w'` for only writing (an existing file with the same name will be erased), and `'a'` opens the file for appending; any data written to the file is automatically added to the end. `'r+'` opens the file for both reading and writing. The *mode* argument is optional; `'r'` will be assumed if it's omitted.

Normally, files are opened in *text mode*, that means, you read and write strings from and to the file, which are encoded in a specific encoding. If encoding is not specified, the default is platform dependent (see `open()`). `'b'` appended to the mode opens the file in *binary mode*: now the data is read and written in the form of bytes objects. This mode should be used for all files that don't contain text.

In text mode, the default when reading is to convert platform-specific line endings (`\n` on Unix, `\r\n` on Windows) to just `\n`. When writing in text mode, the default is to convert occurrences of `\n` back to platform-specific line endings. This behind-the-scenes modification to file data is fine for text files, but will corrupt binary data like that in `JPEG` or `EXE` files. Be very careful to use binary mode when reading and writing such files.

It is good practice to use the `with` keyword when dealing with file objects. The advantage is that the file is properly closed after its suite finishes, even if an exception is raised at some point. Using `with` is also much shorter than writing equivalent `try-finally` blocks:

```
>>> with open('workfile') as f:
...     read_data = f.read()
>>> f.closed
True
```

If you're not using the `with` keyword, then you should call `f.close()` to close the file and immediately free up any system resources used by it. If you don't explicitly close a file, Python's garbage collector will eventually destroy the object and close the open file for you, but the file may stay open for a while. Another risk is that different Python implementations will do this clean-up at different times.

After a file object is closed, either by a `with` statement or by calling `f.close()`, attempts to use the file object will automatically fail.

```
>>> f.close()
>>> f.read()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: I/O operation on closed file
```

7.2.1 Methods of File Objects

The rest of the examples in this section will assume that a file object called `f` has already been created.

To read a file's contents, call `f.read(size)`, which reads some quantity of data and returns it as a string (in text mode) or bytes object (in binary mode). *size* is an optional numeric argument. When *size* is omitted or negative, the entire contents of the file will be read and returned; it's your problem if the file is twice as large as your machine's memory. Otherwise, at most *size* bytes are read and returned. If the end of the file has been reached, `f.read()` will return an empty string (`''`).

```
>>> f.read()
'This is the entire file.\n'
>>> f.read()
''
```

`f.readline()` reads a single line from the file; a newline character (`\n`) is left at the end of the string, and is only omitted on the last line of the file if the file doesn't end in a newline. This makes the return value unambiguous; if `f.readline()` returns an empty string, the end of the file has been reached, while a blank line is represented by `'\n'`, a string containing only a single newline.

```
>>> f.readline()
'This is the first line of the file.\n'
>>> f.readline()
'Second line of the file\n'
>>> f.readline()
''
```

For reading lines from a file, you can loop over the file object. This is memory efficient, fast, and leads to simple code:

```
>>> for line in f:
...     print(line, end='')
...
```

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```
This is the first line of the file.
Second line of the file
```

If you want to read all the lines of a file in a list you can also use `list(f)` or `f.readlines()`.

`f.write(string)` writes the contents of *string* to the file, returning the number of characters written.

```
>>> f.write('This is a test\n')
15
```

Other types of objects need to be converted – either to a string (in text mode) or a bytes object (in binary mode) – before writing them:

```
>>> value = ('the answer', 42)
>>> s = str(value)  # convert the tuple to string
>>> f.write(s)
18
```

`f.tell()` returns an integer giving the file object's current position in the file represented as number of bytes from the beginning of the file when in binary mode and an opaque number when in text mode.

To change the file object's position, use `f.seek(offset, from_what)`. The position is computed from adding *offset* to a reference point; the reference point is selected by the *from_what* argument. A *from_what* value of 0 measures from the beginning of the file, 1 uses the current file position, and 2 uses the end of the file as the reference point. *from_what* can be omitted and defaults to 0, using the beginning of the file as the reference point.

```
>>> f = open('workfile', 'rb+')
>>> f.write(b'0123456789abcdef')
16
>>> f.seek(5)      # Go to the 6th byte in the file
5
>>> f.read(1)
b'5'
>>> f.seek(-3, 2)  # Go to the 3rd byte before the end
13
>>> f.read(1)
b'd'
```

In text files (those opened without a `b` in the mode string), only seeks relative to the beginning of the file are allowed (the exception being seeking to the very file end with `seek(0, 2)`) and the only valid *offset* values are those returned from the `f.tell()`, or zero. Any other *offset* value produces undefined behaviour.

File objects have some additional methods, such as `isatty()` and `truncate()` which are less frequently used; consult the Library Reference for a complete guide to file objects.

7.2.2 Saving structured data with `json`

Strings can easily be written to and read from a file. Numbers take a bit more effort, since the `read()` method only returns strings, which will have to be passed to a function like `int()`, which takes a string like `'123'` and returns its numeric value 123. When you want to save more complex data types like nested lists and dictionaries, parsing and serializing by hand becomes complicated.

Rather than having users constantly writing and debugging code to save complicated data types to files, Python allows you to use the popular data interchange format called JSON (JavaScript Object Notation). The standard module called `json` can take Python data hierarchies, and convert them to string representations; this process is called *serializing*. Reconstructing the data from the string representation is called

deserializing. Between serializing and deserializing, the string representing the object may have been stored in a file or data, or sent over a network connection to some distant machine.

Note: The JSON format is commonly used by modern applications to allow for data exchange. Many programmers are already familiar with it, which makes it a good choice for interoperability.

If you have an object `x`, you can view its JSON string representation with a simple line of code:

```
>>> import json
>>> json.dumps([1, 'simple', 'list'])
'[1, "simple", "list"]'
```

Another variant of the `dumps()` function, called `dump()`, simply serializes the object to a *text file*. So if `f` is a *text file* object opened for writing, we can do this:

```
json.dump(x, f)
```

To decode the object again, if `f` is a *text file* object which has been opened for reading:

```
x = json.load(f)
```

This simple serialization technique can handle lists and dictionaries, but serializing arbitrary class instances in JSON requires a bit of extra effort. The reference for the `json` module contains an explanation of this.

See also:

`pickle` - the pickle module

Contrary to *JSON*, *pickle* is a protocol which allows the serialization of arbitrarily complex Python objects. As such, it is specific to Python and cannot be used to communicate with applications written in other languages. It is also insecure by default: deserializing pickle data coming from an untrusted source can execute arbitrary code, if the data was crafted by a skilled attacker.

CHAPTER

EIGHT

ERRORS AND EXCEPTIONS

Until now error messages haven't been more than mentioned, but if you have tried out the examples you have probably seen some. There are (at least) two distinguishable kinds of errors: *syntax errors* and *exceptions*.

8.1 Syntax Errors

Syntax errors, also known as parsing errors, are perhaps the most common kind of complaint you get while you are still learning Python:

```
>>> while True print('Hello world')
  File "<stdin>", line 1
    while True print('Hello world')
                   ^
SyntaxError: invalid syntax
```

The parser repeats the offending line and displays a little 'arrow' pointing at the earliest point in the line where the error was detected. The error is caused by (or at least detected at) the token *preceding* the arrow: in the example, the error is detected at the function `print()`, since a colon (`':'`) is missing before it. File name and line number are printed so you know where to look in case the input came from a script.

8.2 Exceptions

Even if a statement or expression is syntactically correct, it may cause an error when an attempt is made to execute it. Errors detected during execution are called *exceptions* and are not unconditionally fatal: you will soon learn how to handle them in Python programs. Most exceptions are not handled by programs, however, and result in error messages as shown here:

```
>>> 10 * (1/0)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ZeroDivisionError: division by zero
>>> 4 + spam*3
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'spam' is not defined
>>> '2' + 2
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: Can't convert 'int' object to str implicitly
```

The last line of the error message indicates what happened. Exceptions come in different types, and the type is printed as part of the message: the types in the example are `ZeroDivisionError`, `NameError` and `TypeError`. The string printed as the exception type is the name of the built-in exception that occurred. This is true for all built-in exceptions, but need not be true for user-defined exceptions (although it is a useful convention). Standard exception names are built-in identifiers (not reserved keywords).

The rest of the line provides detail based on the type of exception and what caused it.

The preceding part of the error message shows the context where the exception happened, in the form of a stack traceback. In general it contains a stack traceback listing source lines; however, it will not display lines read from standard input.

bltin-exceptions lists the built-in exceptions and their meanings.

8.3 Handling Exceptions

It is possible to write programs that handle selected exceptions. Look at the following example, which asks the user for input until a valid integer has been entered, but allows the user to interrupt the program (using `Control-C` or whatever the operating system supports); note that a user-generated interruption is signalled by raising the `KeyboardInterrupt` exception.

```
>>> while True:
...     try:
...         x = int(input("Please enter a number: "))
...         break
...     except ValueError:
...         print("Oops!  That was no valid number.  Try again...")
...
```

The `try` statement works as follows.

- First, the *try clause* (the statement(s) between the `try` and `except` keywords) is executed.
- If no exception occurs, the *except clause* is skipped and execution of the `try` statement is finished.
- If an exception occurs during execution of the try clause, the rest of the clause is skipped. Then if its type matches the exception named after the `except` keyword, the except clause is executed, and then execution continues after the `try` statement.
- If an exception occurs which does not match the exception named in the except clause, it is passed on to outer `try` statements; if no handler is found, it is an *unhandled exception* and execution stops with a message as shown above.

A `try` statement may have more than one except clause, to specify handlers for different exceptions. At most one handler will be executed. Handlers only handle exceptions that occur in the corresponding try clause, not in other handlers of the same `try` statement. An except clause may name multiple exceptions as a parenthesized tuple, for example:

```
... except (RuntimeError, TypeError, NameError):
...     pass
```

A class in an `except` clause is compatible with an exception if it is the same class or a base class thereof (but not the other way around — an except clause listing a derived class is not compatible with a base class). For example, the following code will print B, C, D in that order:

```
class B(Exception):
    pass
```

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```
class C(B):
    pass

class D(C):
    pass

for cls in [B, C, D]:
    try:
        raise cls()
    except D:
        print("D")
    except C:
        print("C")
    except B:
        print("B")
```

Note that if the except clauses were reversed (with `except B` first), it would have printed B, B, B — the first matching except clause is triggered.

The last except clause may omit the exception name(s), to serve as a wildcard. Use this with extreme caution, since it is easy to mask a real programming error in this way! It can also be used to print an error message and then re-raise the exception (allowing a caller to handle the exception as well):

```
import sys

try:
    f = open('myfile.txt')
    s = f.readline()
    i = int(s.strip())
except OSError as err:
    print("OS error: {0}".format(err))
except ValueError:
    print("Could not convert data to an integer.")
except:
    print("Unexpected error:", sys.exc_info()[0])
    raise
```

The `try` … `except` statement has an optional *else clause*, which, when present, must follow all except clauses. It is useful for code that must be executed if the try clause does not raise an exception. For example:

```
for arg in sys.argv[1:]:
    try:
        f = open(arg, 'r')
    except OSError:
        print('cannot open', arg)
    else:
        print(arg, 'has', len(f.readlines()), 'lines')
        f.close()
```

The use of the `else` clause is better than adding additional code to the `try` clause because it avoids accidentally catching an exception that wasn't raised by the code being protected by the `try` … `except` statement.

When an exception occurs, it may have an associated value, also known as the exception's *argument*. The presence and type of the argument depend on the exception type.

The except clause may specify a variable after the exception name. The variable is bound to an exception instance with the arguments stored in `instance.args`. For convenience, the exception instance defines `__str__()` so the arguments can be printed directly without having to reference `.args`. One may also

instantiate an exception first before raising it and add any attributes to it as desired.

```
>>> try:
...     raise Exception('spam', 'eggs')
... except Exception as inst:
...     print(type(inst))    # the exception instance
...     print(inst.args)     # arguments stored in .args
...     print(inst)          # __str__ allows args to be printed directly,
...                          # but may be overridden in exception subclasses
...     x, y = inst.args     # unpack args
...     print('x =', x)
...     print('y =', y)
...
<class 'Exception'>
('spam', 'eggs')
('spam', 'eggs')
x = spam
y = eggs
```

If an exception has arguments, they are printed as the last part ('detail') of the message for unhandled exceptions.

Exception handlers don't just handle exceptions if they occur immediately in the try clause, but also if they occur inside functions that are called (even indirectly) in the try clause. For example:

```
>>> def this_fails():
...     x = 1/0
...
>>> try:
...     this_fails()
... except ZeroDivisionError as err:
...     print('Handling run-time error:', err)
...
Handling run-time error: division by zero
```

8.4 Raising Exceptions

The `raise` statement allows the programmer to force a specified exception to occur. For example:

```
>>> raise NameError('HiThere')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: HiThere
```

The sole argument to `raise` indicates the exception to be raised. This must be either an exception instance or an exception class (a class that derives from `Exception`). If an exception class is passed, it will be implicitly instantiated by calling its constructor with no arguments:

```
raise ValueError  # shorthand for 'raise ValueError()'
```

If you need to determine whether an exception was raised but don't intend to handle it, a simpler form of the `raise` statement allows you to re-raise the exception:

```
>>> try:
...     raise NameError('HiThere')
... except NameError:
```

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```
...     print('An exception flew by!')
...     raise
...
An exception flew by!
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
NameError: HiThere
```

8.5 User-defined Exceptions

Programs may name their own exceptions by creating a new exception class (see *Classes* for more about Python classes). Exceptions should typically be derived from the `Exception` class, either directly or indirectly.

Exception classes can be defined which do anything any other class can do, but are usually kept simple, often only offering a number of attributes that allow information about the error to be extracted by handlers for the exception. When creating a module that can raise several distinct errors, a common practice is to create a base class for exceptions defined by that module, and subclass that to create specific exception classes for different error conditions:

```
class Error(Exception):
    """Base class for exceptions in this module."""
    pass

class InputError(Error):
    """Exception raised for errors in the input.

    Attributes:
        expression -- input expression in which the error occurred
        message -- explanation of the error
    """

    def __init__(self, expression, message):
        self.expression = expression
        self.message = message

class TransitionError(Error):
    """Raised when an operation attempts a state transition that's not
    allowed.

    Attributes:
        previous -- state at beginning of transition
        next -- attempted new state
        message -- explanation of why the specific transition is not allowed
    """

    def __init__(self, previous, next, message):
        self.previous = previous
        self.next = next
        self.message = message
```

Most exceptions are defined with names that end in “Error,” similar to the naming of the standard exceptions.

Many standard modules define their own exceptions to report errors that may occur in functions they define. More information on classes is presented in chapter *Classes*.

8.6 Defining Clean-up Actions

The `try` statement has another optional clause which is intended to define clean-up actions that must be executed under all circumstances. For example:

```
>>> try:
...     raise KeyboardInterrupt
... finally:
...     print('Goodbye, world!')
...
Goodbye, world!
KeyboardInterrupt
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
```

A *finally clause* is always executed before leaving the `try` statement, whether an exception has occurred or not. When an exception has occurred in the `try` clause and has not been handled by an `except` clause (or it has occurred in an `except` or `else` clause), it is re-raised after the `finally` clause has been executed. The `finally` clause is also executed "on the way out" when any other clause of the `try` statement is left via a `break`, `continue` or `return` statement. A more complicated example:

```
>>> def divide(x, y):
...     try:
...         result = x / y
...     except ZeroDivisionError:
...         print("division by zero!")
...     else:
...         print("result is", result)
...     finally:
...         print("executing finally clause")
...
>>> divide(2, 1)
result is 2.0
executing finally clause
>>> divide(2, 0)
division by zero!
executing finally clause
>>> divide("2", "1")
executing finally clause
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 3, in divide
TypeError: unsupported operand type(s) for /: 'str' and 'str'
```

As you can see, the `finally` clause is executed in any event. The `TypeError` raised by dividing two strings is not handled by the `except` clause and therefore re-raised after the `finally` clause has been executed.

In real world applications, the `finally` clause is useful for releasing external resources (such as files or network connections), regardless of whether the use of the resource was successful.

8.7 Predefined Clean-up Actions

Some objects define standard clean-up actions to be undertaken when the object is no longer needed, regardless of whether or not the operation using the object succeeded or failed. Look at the following example, which tries to open a file and print its contents to the screen.

```
for line in open("myfile.txt"):
    print(line, end="")
```

The problem with this code is that it leaves the file open for an indeterminate amount of time after this part of the code has finished executing. This is not an issue in simple scripts, but can be a problem for larger applications. The `with` statement allows objects like files to be used in a way that ensures they are always cleaned up promptly and correctly.

```
with open("myfile.txt") as f:
    for line in f:
        print(line, end="")
```

After the statement is executed, the file *f* is always closed, even if a problem was encountered while processing the lines. Objects which, like files, provide predefined clean-up actions will indicate this in their documentation.

CHAPTER

NINE

CLASSES

Classes provide a means of bundling data and functionality together. Creating a new class creates a new *type* of object, allowing new *instances* of that type to be made. Each class instance can have attributes attached to it for maintaining its state. Class instances can also have methods (defined by its class) for modifying its state.

Compared with other programming languages, Python's class mechanism adds classes with a minimum of new syntax and semantics. It is a mixture of the class mechanisms found in C++ and Modula-3. Python classes provide all the standard features of Object Oriented Programming: the class inheritance mechanism allows multiple base classes, a derived class can override any methods of its base class or classes, and a method can call the method of a base class with the same name. Objects can contain arbitrary amounts and kinds of data. As is true for modules, classes partake of the dynamic nature of Python: they are created at runtime, and can be modified further after creation.

In C++ terminology, normally class members (including the data members) are *public* (except see below *Private Variables*), and all member functions are *virtual*. As in Modula-3, there are no shorthands for referencing the object's members from its methods: the method function is declared with an explicit first argument representing the object, which is provided implicitly by the call. As in Smalltalk, classes themselves are objects. This provides semantics for importing and renaming. Unlike C++ and Modula-3, built-in types can be used as base classes for extension by the user. Also, like in C++, most built-in operators with special syntax (arithmetic operators, subscripting etc.) can be redefined for class instances.

(Lacking universally accepted terminology to talk about classes, I will make occasional use of Smalltalk and C++ terms. I would use Modula-3 terms, since its object-oriented semantics are closer to those of Python than C++, but I expect that few readers have heard of it.)

9.1 A Word About Names and Objects

Objects have individuality, and multiple names (in multiple scopes) can be bound to the same object. This is known as aliasing in other languages. This is usually not appreciated on a first glance at Python, and can be safely ignored when dealing with immutable basic types (numbers, strings, tuples). However, aliasing has a possibly surprising effect on the semantics of Python code involving mutable objects such as lists, dictionaries, and most other types. This is usually used to the benefit of the program, since aliases behave like pointers in some respects. For example, passing an object is cheap since only a pointer is passed by the implementation; and if a function modifies an object passed as an argument, the caller will see the change — this eliminates the need for two different argument passing mechanisms as in Pascal.

9.2 Python Scopes and Namespaces

Before introducing classes, I first have to tell you something about Python's scope rules. Class definitions play some neat tricks with namespaces, and you need to know how scopes and namespaces work to fully

understand what's going on. Incidentally, knowledge about this subject is useful for any advanced Python programmer.

Let's begin with some definitions.

A *namespace* is a mapping from names to objects. Most namespaces are currently implemented as Python dictionaries, but that's normally not noticeable in any way (except for performance), and it may change in the future. Examples of namespaces are: the set of built-in names (containing functions such as `abs()`, and built-in exception names); the global names in a module; and the local names in a function invocation. In a sense the set of attributes of an object also form a namespace. The important thing to know about namespaces is that there is absolutely no relation between names in different namespaces; for instance, two different modules may both define a function `maximize` without confusion — users of the modules must prefix it with the module name.

By the way, I use the word *attribute* for any name following a dot — for example, in the expression `z.real`, `real` is an attribute of the object `z`. Strictly speaking, references to names in modules are attribute references: in the expression `modname.funcname`, `modname` is a module object and `funcname` is an attribute of it. In this case there happens to be a straightforward mapping between the module's attributes and the global names defined in the module: they share the same namespace![1]

Attributes may be read-only or writable. In the latter case, assignment to attributes is possible. Module attributes are writable: you can write `modname.the_answer = 42`. Writable attributes may also be deleted with the `del` statement. For example, `del modname.the_answer` will remove the attribute `the_answer` from the object named by `modname`.

Namespaces are created at different moments and have different lifetimes. The namespace containing the built-in names is created when the Python interpreter starts up, and is never deleted. The global namespace for a module is created when the module definition is read in; normally, module namespaces also last until the interpreter quits. The statements executed by the top-level invocation of the interpreter, either read from a script file or interactively, are considered part of a module called `__main__`, so they have their own global namespace. (The built-in names actually also live in a module; this is called `builtins`.)

The local namespace for a function is created when the function is called, and deleted when the function returns or raises an exception that is not handled within the function. (Actually, forgetting would be a better way to describe what actually happens.) Of course, recursive invocations each have their own local namespace.

A *scope* is a textual region of a Python program where a namespace is directly accessible. "Directly accessible" here means that an unqualified reference to a name attempts to find the name in the namespace.

Although scopes are determined statically, they are used dynamically. At any time during execution, there are at least three nested scopes whose namespaces are directly accessible:

- the innermost scope, which is searched first, contains the local names
- the scopes of any enclosing functions, which are searched starting with the nearest enclosing scope, contains non-local, but also non-global names
- the next-to-last scope contains the current module's global names
- the outermost scope (searched last) is the namespace containing built-in names

If a name is declared global, then all references and assignments go directly to the middle scope containing the module's global names. To rebind variables found outside of the innermost scope, the `nonlocal` statement can be used; if not declared nonlocal, those variables are read-only (an attempt to write to such a variable will simply create a *new* local variable in the innermost scope, leaving the identically named outer variable unchanged).

[1] Except for one thing. Module objects have a secret read-only attribute called `__dict__` which returns the dictionary used to implement the module's namespace; the name `__dict__` is an attribute but not a global name. Obviously, using this violates the abstraction of namespace implementation, and should be restricted to things like post-mortem debuggers.

Usually, the local scope references the local names of the (textually) current function. Outside functions, the local scope references the same namespace as the global scope: the module's namespace. Class definitions place yet another namespace in the local scope.

It is important to realize that scopes are determined textually: the global scope of a function defined in a module is that module's namespace, no matter from where or by what alias the function is called. On the other hand, the actual search for names is done dynamically, at run time — however, the language definition is evolving towards static name resolution, at "compile" time, so don't rely on dynamic name resolution! (In fact, local variables are already determined statically.)

A special quirk of Python is that – if no `global` statement is in effect – assignments to names always go into the innermost scope. Assignments do not copy data — they just bind names to objects. The same is true for deletions: the statement `del x` removes the binding of `x` from the namespace referenced by the local scope. In fact, all operations that introduce new names use the local scope: in particular, `import` statements and function definitions bind the module or function name in the local scope.

The `global` statement can be used to indicate that particular variables live in the global scope and should be rebound there; the `nonlocal` statement indicates that particular variables live in an enclosing scope and should be rebound there.

9.2.1 Scopes and Namespaces Example

This is an example demonstrating how to reference the different scopes and namespaces, and how `global` and `nonlocal` affect variable binding:

```
def scope_test():
    def do_local():
        spam = "local spam"

    def do_nonlocal():
        nonlocal spam
        spam = "nonlocal spam"

    def do_global():
        global spam
        spam = "global spam"

    spam = "test spam"
    do_local()
    print("After local assignment:", spam)
    do_nonlocal()
    print("After nonlocal assignment:", spam)
    do_global()
    print("After global assignment:", spam)

scope_test()
print("In global scope:", spam)
```

The output of the example code is:

```
After local assignment: test spam
After nonlocal assignment: nonlocal spam
After global assignment: nonlocal spam
In global scope: global spam
```

Note how the *local* assignment (which is default) didn't change *scope_test*'s binding of *spam*. The `nonlocal` assignment changed *scope_test*'s binding of *spam*, and the `global` assignment changed the module-level binding.

You can also see that there was no previous binding for *spam* before the `global` assignment.

9.3 A First Look at Classes

Classes introduce a little bit of new syntax, three new object types, and some new semantics.

9.3.1 Class Definition Syntax

The simplest form of class definition looks like this:

```
class ClassName:
    <statement-1>
    .
    .
    .
    <statement-N>
```

Class definitions, like function definitions (`def` statements) must be executed before they have any effect. (You could conceivably place a class definition in a branch of an `if` statement, or inside a function.)

In practice, the statements inside a class definition will usually be function definitions, but other statements are allowed, and sometimes useful — we'll come back to this later. The function definitions inside a class normally have a peculiar form of argument list, dictated by the calling conventions for methods — again, this is explained later.

When a class definition is entered, a new namespace is created, and used as the local scope — thus, all assignments to local variables go into this new namespace. In particular, function definitions bind the name of the new function here.

When a class definition is left normally (via the end), a *class object* is created. This is basically a wrapper around the contents of the namespace created by the class definition; we'll learn more about class objects in the next section. The original local scope (the one in effect just before the class definition was entered) is reinstated, and the class object is bound here to the class name given in the class definition header (`ClassName` in the example).

9.3.2 Class Objects

Class objects support two kinds of operations: attribute references and instantiation.

Attribute references use the standard syntax used for all attribute references in Python: `obj.name`. Valid attribute names are all the names that were in the class's namespace when the class object was created. So, if the class definition looked like this:

```
class MyClass:
    """A simple example class"""
    i = 12345

    def f(self):
        return 'hello world'
```

then `MyClass.i` and `MyClass.f` are valid attribute references, returning an integer and a function object, respectively. Class attributes can also be assigned to, so you can change the value of `MyClass.i` by assignment. `__doc__` is also a valid attribute, returning the docstring belonging to the class: `"A simple example class"`.

Class *instantiation* uses function notation. Just pretend that the class object is a parameterless function that returns a new instance of the class. For example (assuming the above class):

```
x = MyClass()
```

creates a new *instance* of the class and assigns this object to the local variable `x`.

The instantiation operation ("calling" a class object) creates an empty object. Many classes like to create objects with instances customized to a specific initial state. Therefore a class may define a special method named `__init__()`, like this:

```
def __init__(self):
    self.data = []
```

When a class defines an `__init__()` method, class instantiation automatically invokes `__init__()` for the newly-created class instance. So in this example, a new, initialized instance can be obtained by:

```
x = MyClass()
```

Of course, the `__init__()` method may have arguments for greater flexibility. In that case, arguments given to the class instantiation operator are passed on to `__init__()`. For example,

```
>>> class Complex:
...     def __init__(self, realpart, imagpart):
...         self.r = realpart
...         self.i = imagpart
...
>>> x = Complex(3.0, -4.5)
>>> x.r, x.i
(3.0, -4.5)
```

9.3.3 Instance Objects

Now what can we do with instance objects? The only operations understood by instance objects are attribute references. There are two kinds of valid attribute names, data attributes and methods.

data attributes correspond to "instance variables" in Smalltalk, and to "data members" in C++. Data attributes need not be declared; like local variables, they spring into existence when they are first assigned to. For example, if `x` is the instance of `MyClass` created above, the following piece of code will print the value `16`, without leaving a trace:

```
x.counter = 1
while x.counter < 10:
    x.counter = x.counter * 2
print(x.counter)
del x.counter
```

The other kind of instance attribute reference is a *method*. A method is a function that "belongs to" an object. (In Python, the term method is not unique to class instances: other object types can have methods as well. For example, list objects have methods called append, insert, remove, sort, and so on. However, in the following discussion, we'll use the term method exclusively to mean methods of class instance objects, unless explicitly stated otherwise.)

Valid method names of an instance object depend on its class. By definition, all attributes of a class that are function objects define corresponding methods of its instances. So in our example, `x.f` is a valid method reference, since `MyClass.f` is a function, but `x.i` is not, since `MyClass.i` is not. But `x.f` is not the same thing as `MyClass.f` — it is a *method object*, not a function object.

9.3.4 Method Objects

Usually, a method is called right after it is bound:

```
x.f()
```

In the `MyClass` example, this will return the string `'hello world'`. However, it is not necessary to call a method right away: `x.f` is a method object, and can be stored away and called at a later time. For example:

```
xf = x.f
while True:
    print(xf())
```

will continue to print `hello world` until the end of time.

What exactly happens when a method is called? You may have noticed that `x.f()` was called without an argument above, even though the function definition for `f()` specified an argument. What happened to the argument? Surely Python raises an exception when a function that requires an argument is called without any — even if the argument isn't actually used…

Actually, you may have guessed the answer: the special thing about methods is that the instance object is passed as the first argument of the function. In our example, the call `x.f()` is exactly equivalent to `MyClass.f(x)`. In general, calling a method with a list of n arguments is equivalent to calling the corresponding function with an argument list that is created by inserting the method's instance object before the first argument.

If you still don't understand how methods work, a look at the implementation can perhaps clarify matters. When an instance attribute is referenced that isn't a data attribute, its class is searched. If the name denotes a valid class attribute that is a function object, a method object is created by packing (pointers to) the instance object and the function object just found together in an abstract object: this is the method object. When the method object is called with an argument list, a new argument list is constructed from the instance object and the argument list, and the function object is called with this new argument list.

9.3.5 Class and Instance Variables

Generally speaking, instance variables are for data unique to each instance and class variables are for attributes and methods shared by all instances of the class:

```
class Dog:

    kind = 'canine'         # class variable shared by all instances

    def __init__(self, name):
        self.name = name    # instance variable unique to each instance

>>> d = Dog('Fido')
>>> e = Dog('Buddy')
>>> d.kind                  # shared by all dogs
'canine'
>>> e.kind                  # shared by all dogs
'canine'
>>> d.name                  # unique to d
'Fido'
>>> e.name                  # unique to e
'Buddy'
```

As discussed in *A Word About Names and Objects*, shared data can have possibly surprising effects with involving *mutable* objects such as lists and dictionaries. For example, the *tricks* list in the following code should not be used as a class variable because just a single list would be shared by all *Dog* instances:

```
class Dog:

    tricks = []             # mistaken use of a class variable

    def __init__(self, name):
        self.name = name

    def add_trick(self, trick):
        self.tricks.append(trick)

>>> d = Dog('Fido')
>>> e = Dog('Buddy')
>>> d.add_trick('roll over')
>>> e.add_trick('play dead')
>>> d.tricks                # unexpectedly shared by all dogs
['roll over', 'play dead']
```

Correct design of the class should use an instance variable instead:

```
class Dog:

    def __init__(self, name):
        self.name = name
        self.tricks = []    # creates a new empty list for each dog

    def add_trick(self, trick):
        self.tricks.append(trick)

>>> d = Dog('Fido')
>>> e = Dog('Buddy')
>>> d.add_trick('roll over')
>>> e.add_trick('play dead')
>>> d.tricks
['roll over']
>>> e.tricks
['play dead']
```

9.4 Random Remarks

Data attributes override method attributes with the same name; to avoid accidental name conflicts, which may cause hard-to-find bugs in large programs, it is wise to use some kind of convention that minimizes the chance of conflicts. Possible conventions include capitalizing method names, prefixing data attribute names with a small unique string (perhaps just an underscore), or using verbs for methods and nouns for data attributes.

Data attributes may be referenced by methods as well as by ordinary users ("clients") of an object. In other words, classes are not usable to implement pure abstract data types. In fact, nothing in Python makes it possible to enforce data hiding — it is all based upon convention. (On the other hand, the Python implementation, written in C, can completely hide implementation details and control access to an object if necessary; this can be used by extensions to Python written in C.)

Clients should use data attributes with care — clients may mess up invariants maintained by the methods

by stamping on their data attributes. Note that clients may add data attributes of their own to an instance object without affecting the validity of the methods, as long as name conflicts are avoided — again, a naming convention can save a lot of headaches here.

There is no shorthand for referencing data attributes (or other methods!) from within methods. I find that this actually increases the readability of methods: there is no chance of confusing local variables and instance variables when glancing through a method.

Often, the first argument of a method is called `self`. This is nothing more than a convention: the name `self` has absolutely no special meaning to Python. Note, however, that by not following the convention your code may be less readable to other Python programmers, and it is also conceivable that a *class browser* program might be written that relies upon such a convention.

Any function object that is a class attribute defines a method for instances of that class. It is not necessary that the function definition is textually enclosed in the class definition: assigning a function object to a local variable in the class is also ok. For example:

```
# Function defined outside the class
def f1(self, x, y):
    return min(x, x+y)

class C:
    f = f1

    def g(self):
        return 'hello world'

    h = g
```

Now `f`, `g` and `h` are all attributes of class `C` that refer to function objects, and consequently they are all methods of instances of `C` — `h` being exactly equivalent to `g`. Note that this practice usually only serves to confuse the reader of a program.

Methods may call other methods by using method attributes of the `self` argument:

```
class Bag:
    def __init__(self):
        self.data = []

    def add(self, x):
        self.data.append(x)

    def addtwice(self, x):
        self.add(x)
        self.add(x)
```

Methods may reference global names in the same way as ordinary functions. The global scope associated with a method is the module containing its definition. (A class is never used as a global scope.) While one rarely encounters a good reason for using global data in a method, there are many legitimate uses of the global scope: for one thing, functions and modules imported into the global scope can be used by methods, as well as functions and classes defined in it. Usually, the class containing the method is itself defined in this global scope, and in the next section we'll find some good reasons why a method would want to reference its own class.

Each value is an object, and therefore has a *class* (also called its *type*). It is stored as `object.__class__`.

9.5 Inheritance

Of course, a language feature would not be worthy of the name "class" without supporting inheritance. The syntax for a derived class definition looks like this:

```
class DerivedClassName(BaseClassName):
    <statement-1>
    .
    .
    .
    <statement-N>
```

The name `BaseClassName` must be defined in a scope containing the derived class definition. In place of a base class name, other arbitrary expressions are also allowed. This can be useful, for example, when the base class is defined in another module:

```
class DerivedClassName(modname.BaseClassName):
```

Execution of a derived class definition proceeds the same as for a base class. When the class object is constructed, the base class is remembered. This is used for resolving attribute references: if a requested attribute is not found in the class, the search proceeds to look in the base class. This rule is applied recursively if the base class itself is derived from some other class.

There's nothing special about instantiation of derived classes: `DerivedClassName()` creates a new instance of the class. Method references are resolved as follows: the corresponding class attribute is searched, descending down the chain of base classes if necessary, and the method reference is valid if this yields a function object.

Derived classes may override methods of their base classes. Because methods have no special privileges when calling other methods of the same object, a method of a base class that calls another method defined in the same base class may end up calling a method of a derived class that overrides it. (For C++ programmers: all methods in Python are effectively `virtual`.)

An overriding method in a derived class may in fact want to extend rather than simply replace the base class method of the same name. There is a simple way to call the base class method directly: just call `BaseClassName.methodname(self, arguments)`. This is occasionally useful to clients as well. (Note that this only works if the base class is accessible as `BaseClassName` in the global scope.)

Python has two built-in functions that work with inheritance:

- Use `isinstance()` to check an instance's type: `isinstance(obj, int)` will be `True` only if `obj.__class__` is `int` or some class derived from `int`.
- Use `issubclass()` to check class inheritance: `issubclass(bool, int)` is `True` since `bool` is a subclass of `int`. However, `issubclass(float, int)` is `False` since `float` is not a subclass of `int`.

9.5.1 Multiple Inheritance

Python supports a form of multiple inheritance as well. A class definition with multiple base classes looks like this:

```
class DerivedClassName(Base1, Base2, Base3):
    <statement-1>
    .
    .
    .
    <statement-N>
```

For most purposes, in the simplest cases, you can think of the search for attributes inherited from a parent class as depth-first, left-to-right, not searching twice in the same class where there is an overlap in the hierarchy. Thus, if an attribute is not found in `DerivedClassName`, it is searched for in `Base1`, then (recursively) in the base classes of `Base1`, and if it was not found there, it was searched for in `Base2`, and so on.

In fact, it is slightly more complex than that; the method resolution order changes dynamically to support cooperative calls to `super()`. This approach is known in some other multiple-inheritance languages as call-next-method and is more powerful than the super call found in single-inheritance languages.

Dynamic ordering is necessary because all cases of multiple inheritance exhibit one or more diamond relationships (where at least one of the parent classes can be accessed through multiple paths from the bottommost class). For example, all classes inherit from `object`, so any case of multiple inheritance provides more than one path to reach `object`. To keep the base classes from being accessed more than once, the dynamic algorithm linearizes the search order in a way that preserves the left-to-right ordering specified in each class, that calls each parent only once, and that is monotonic (meaning that a class can be subclassed without affecting the precedence order of its parents). Taken together, these properties make it possible to design reliable and extensible classes with multiple inheritance. For more detail, see https://www.python.org/download/releases/2.3/mro/.

9.6 Private Variables

"Private" instance variables that cannot be accessed except from inside an object don't exist in Python. However, there is a convention that is followed by most Python code: a name prefixed with an underscore (e.g. `_spam`) should be treated as a non-public part of the API (whether it is a function, a method or a data member). It should be considered an implementation detail and subject to change without notice.

Since there is a valid use-case for class-private members (namely to avoid name clashes of names with names defined by subclasses), there is limited support for such a mechanism, called *name mangling*. Any identifier of the form `__spam` (at least two leading underscores, at most one trailing underscore) is textually replaced with `_classname__spam`, where `classname` is the current class name with leading underscore(s) stripped. This mangling is done without regard to the syntactic position of the identifier, as long as it occurs within the definition of a class.

Name mangling is helpful for letting subclasses override methods without breaking intraclass method calls. For example:

```
class Mapping:
    def __init__(self, iterable):
        self.items_list = []
        self.__update(iterable)

    def update(self, iterable):
        for item in iterable:
            self.items_list.append(item)

    __update = update   # private copy of original update() method

class MappingSubclass(Mapping):

    def update(self, keys, values):
        # provides new signature for update()
        # but does not break __init__()
        for item in zip(keys, values):
            self.items_list.append(item)
```

Note that the mangling rules are designed mostly to avoid accidents; it still is possible to access or modify a variable that is considered private. This can even be useful in special circumstances, such as in the debugger.

Notice that code passed to `exec()` or `eval()` does not consider the classname of the invoking class to be the current class; this is similar to the effect of the `global` statement, the effect of which is likewise restricted to code that is byte-compiled together. The same restriction applies to `getattr()`, `setattr()` and `delattr()`, as well as when referencing `__dict__` directly.

9.7 Odds and Ends

Sometimes it is useful to have a data type similar to the Pascal "record" or C "struct", bundling together a few named data items. An empty class definition will do nicely:

```
class Employee:
    pass

john = Employee()  # Create an empty employee record

# Fill the fields of the record
john.name = 'John Doe'
john.dept = 'computer lab'
john.salary = 1000
```

A piece of Python code that expects a particular abstract data type can often be passed a class that emulates the methods of that data type instead. For instance, if you have a function that formats some data from a file object, you can define a class with methods `read()` and `readline()` that get the data from a string buffer instead, and pass it as an argument.

Instance method objects have attributes, too: `m.__self__` is the instance object with the method `m()`, and `m.__func__` is the function object corresponding to the method.

9.8 Iterators

By now you have probably noticed that most container objects can be looped over using a `for` statement:

```
for element in [1, 2, 3]:
    print(element)
for element in (1, 2, 3):
    print(element)
for key in {'one':1, 'two':2}:
    print(key)
for char in "123":
    print(char)
for line in open("myfile.txt"):
    print(line, end='')
```

This style of access is clear, concise, and convenient. The use of iterators pervades and unifies Python. Behind the scenes, the `for` statement calls `iter()` on the container object. The function returns an iterator object that defines the method `__next__()` which accesses elements in the container one at a time. When there are no more elements, `__next__()` raises a `StopIteration` exception which tells the `for` loop to terminate. You can call the `__next__()` method using the `next()` built-in function; this example shows how it all works:

```
>>> s = 'abc'
>>> it = iter(s)
>>> it
```

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```
<iterator object at 0x00A1DB50>
>>> next(it)
'a'
>>> next(it)
'b'
>>> next(it)
'c'
>>> next(it)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    next(it)
StopIteration
```

Having seen the mechanics behind the iterator protocol, it is easy to add iterator behavior to your classes. Define an `__iter__()` method which returns an object with a `__next__()` method. If the class defines `__next__()`, then `__iter__()` can just return `self`:

```
class Reverse:
    """Iterator for looping over a sequence backwards."""
    def __init__(self, data):
        self.data = data
        self.index = len(data)

    def __iter__(self):
        return self

    def __next__(self):
        if self.index == 0:
            raise StopIteration
        self.index = self.index - 1
        return self.data[self.index]
```

```
>>> rev = Reverse('spam')
>>> iter(rev)
<__main__.Reverse object at 0x00A1DB50>
>>> for char in rev:
...     print(char)
...
m
a
p
s
```

9.9 Generators

*Generator*s are a simple and powerful tool for creating iterators. They are written like regular functions but use the `yield` statement whenever they want to return data. Each time `next()` is called on it, the generator resumes where it left off (it remembers all the data values and which statement was last executed). An example shows that generators can be trivially easy to create:

```
def reverse(data):
    for index in range(len(data)-1, -1, -1):
        yield data[index]
```

```
>>> for char in reverse('golf'):
...     print(char)
...
f
l
o
g
```

Anything that can be done with generators can also be done with class-based iterators as described in the previous section. What makes generators so compact is that the `__iter__()` and `__next__()` methods are created automatically.

Another key feature is that the local variables and execution state are automatically saved between calls. This made the function easier to write and much more clear than an approach using instance variables like `self.index` and `self.data`.

In addition to automatic method creation and saving program state, when generators terminate, they automatically raise `StopIteration`. In combination, these features make it easy to create iterators with no more effort than writing a regular function.

9.10 Generator Expressions

Some simple generators can be coded succinctly as expressions using a syntax similar to list comprehensions but with parentheses instead of square brackets. These expressions are designed for situations where the generator is used right away by an enclosing function. Generator expressions are more compact but less versatile than full generator definitions and tend to be more memory friendly than equivalent list comprehensions.

Examples:

```
>>> sum(i*i for i in range(10))                 # sum of squares
285

>>> xvec = [10, 20, 30]
>>> yvec = [7, 5, 3]
>>> sum(x*y for x,y in zip(xvec, yvec))         # dot product
260

>>> from math import pi, sin
>>> sine_table = {x: sin(x*pi/180) for x in range(0, 91)}

>>> unique_words = set(word  for line in page  for word in line.split())

>>> valedictorian = max((student.gpa, student.name) for student in graduates)

>>> data = 'golf'
>>> list(data[i] for i in range(len(data)-1, -1, -1))
['f', 'l', 'o', 'g']
```

CHAPTER

TEN

BRIEF TOUR OF THE STANDARD LIBRARY

10.1 Operating System Interface

The `os` module provides dozens of functions for interacting with the operating system:

```
>>> import os
>>> os.getcwd()      # Return the current working directory
'C:\\Python37'
>>> os.chdir('/server/accesslogs')   # Change current working directory
>>> os.system('mkdir today')   # Run the command mkdir in the system shell
0
```

Be sure to use the `import os` style instead of `from os import *`. This will keep `os.open()` from shadowing the built-in `open()` function which operates much differently.

The built-in `dir()` and `help()` functions are useful as interactive aids for working with large modules like `os`:

```
>>> import os
>>> dir(os)
<returns a list of all module functions>
>>> help(os)
<returns an extensive manual page created from the module's docstrings>
```

For daily file and directory management tasks, the `shutil` module provides a higher level interface that is easier to use:

```
>>> import shutil
>>> shutil.copyfile('data.db', 'archive.db')
'archive.db'
>>> shutil.move('/build/executables', 'installdir')
'installdir'
```

10.2 File Wildcards

The `glob` module provides a function for making file lists from directory wildcard searches:

```
>>> import glob
>>> glob.glob('*.py')
['primes.py', 'random.py', 'quote.py']
```

10.3 Command Line Arguments

Common utility scripts often need to process command line arguments. These arguments are stored in the `sys` module's *argv* attribute as a list. For instance the following output results from running `python demo.py one two three` at the command line:

```
>>> import sys
>>> print(sys.argv)
['demo.py', 'one', 'two', 'three']
```

The `getopt` module processes *sys.argv* using the conventions of the Unix `getopt()` function. More powerful and flexible command line processing is provided by the `argparse` module.

10.4 Error Output Redirection and Program Termination

The `sys` module also has attributes for *stdin*, *stdout*, and *stderr*. The latter is useful for emitting warnings and error messages to make them visible even when *stdout* has been redirected:

```
>>> sys.stderr.write('Warning, log file not found starting a new one\n')
Warning, log file not found starting a new one
```

The most direct way to terminate a script is to use `sys.exit()`.

10.5 String Pattern Matching

The `re` module provides regular expression tools for advanced string processing. For complex matching and manipulation, regular expressions offer succinct, optimized solutions:

```
>>> import re
>>> re.findall(r'\bf[a-z]*', 'which foot or hand fell fastest')
['foot', 'fell', 'fastest']
>>> re.sub(r'(\b[a-z]+) \1', r'\1', 'cat in the the hat')
'cat in the hat'
```

When only simple capabilities are needed, string methods are preferred because they are easier to read and debug:

```
>>> 'tea for too'.replace('too', 'two')
'tea for two'
```

10.6 Mathematics

The `math` module gives access to the underlying C library functions for floating point math:

```
>>> import math
>>> math.cos(math.pi / 4)
0.70710678118654757
>>> math.log(1024, 2)
10.0
```

The `random` module provides tools for making random selections:

```
>>> import random
>>> random.choice(['apple', 'pear', 'banana'])
'apple'
>>> random.sample(range(100), 10)   # sampling without replacement
[30, 83, 16, 4, 8, 81, 41, 50, 18, 33]
>>> random.random()    # random float
0.17970987693706186
>>> random.randrange(6)    # random integer chosen from range(6)
4
```

The `statistics` module calculates basic statistical properties (the mean, median, variance, etc.) of numeric data:

```
>>> import statistics
>>> data = [2.75, 1.75, 1.25, 0.25, 0.5, 1.25, 3.5]
>>> statistics.mean(data)
1.6071428571428572
>>> statistics.median(data)
1.25
>>> statistics.variance(data)
1.3720238095238095
```

The SciPy project <https://scipy.org> has many other modules for numerical computations.

10.7 Internet Access

There are a number of modules for accessing the internet and processing internet protocols. Two of the simplest are `urllib.request` for retrieving data from URLs and `smtplib` for sending mail:

```
>>> from urllib.request import urlopen
>>> with urlopen('http://tycho.usno.navy.mil/cgi-bin/timer.pl') as response:
...     for line in response:
...         line = line.decode('utf-8')  # Decoding the binary data to text.
...         if 'EST' in line or 'EDT' in line:  # look for Eastern Time
...             print(line)

<BR>Nov. 25, 09:43:32 PM EST

>>> import smtplib
>>> server = smtplib.SMTP('localhost')
>>> server.sendmail('soothsayer@example.org', 'jcaesar@example.org',
... """To: jcaesar@example.org
... From: soothsayer@example.org
...
... Beware the Ides of March.
... """)
>>> server.quit()
```

(Note that the second example needs a mailserver running on localhost.)

10.8 Dates and Times

The `datetime` module supplies classes for manipulating dates and times in both simple and complex ways. While date and time arithmetic is supported, the focus of the implementation is on efficient member extrac-

tion for output formatting and manipulation. The module also supports objects that are timezone aware.

```
>>> # dates are easily constructed and formatted
>>> from datetime import date
>>> now = date.today()
>>> now
datetime.date(2003, 12, 2)
>>> now.strftime("%m-%d-%y. %d %b %Y is a %A on the %d day of %B.")
'12-02-03. 02 Dec 2003 is a Tuesday on the 02 day of December.'

>>> # dates support calendar arithmetic
>>> birthday = date(1964, 7, 31)
>>> age = now - birthday
>>> age.days
14368
```

10.9 Data Compression

Common data archiving and compression formats are directly supported by modules including: `zlib`, `gzip`, `bz2`, `lzma`, `zipfile` and `tarfile`.

```
>>> import zlib
>>> s = b'witch which has which witches wrist watch'
>>> len(s)
41
>>> t = zlib.compress(s)
>>> len(t)
37
>>> zlib.decompress(t)
b'witch which has which witches wrist watch'
>>> zlib.crc32(s)
226805979
```

10.10 Performance Measurement

Some Python users develop a deep interest in knowing the relative performance of different approaches to the same problem. Python provides a measurement tool that answers those questions immediately.

For example, it may be tempting to use the tuple packing and unpacking feature instead of the traditional approach to swapping arguments. The `timeit` module quickly demonstrates a modest performance advantage:

```
>>> from timeit import Timer
>>> Timer('t=a; a=b; b=t', 'a=1; b=2').timeit()
0.57535828626024577
>>> Timer('a,b = b,a', 'a=1; b=2').timeit()
0.54962537085770791
```

In contrast to `timeit`'s fine level of granularity, the `profile` and `pstats` modules provide tools for identifying time critical sections in larger blocks of code.

10.11 Quality Control

One approach for developing high quality software is to write tests for each function as it is developed and to run those tests frequently during the development process.

The `doctest` module provides a tool for scanning a module and validating tests embedded in a program's docstrings. Test construction is as simple as cutting-and-pasting a typical call along with its results into the docstring. This improves the documentation by providing the user with an example and it allows the doctest module to make sure the code remains true to the documentation:

```
def average(values):
    """Computes the arithmetic mean of a list of numbers.

    >>> print(average([20, 30, 70]))
    40.0
    """
    return sum(values) / len(values)

import doctest
doctest.testmod()   # automatically validate the embedded tests
```

The `unittest` module is not as effortless as the `doctest` module, but it allows a more comprehensive set of tests to be maintained in a separate file:

```
import unittest

class TestStatisticalFunctions(unittest.TestCase):

    def test_average(self):
        self.assertEqual(average([20, 30, 70]), 40.0)
        self.assertEqual(round(average([1, 5, 7]), 1), 4.3)
        with self.assertRaises(ZeroDivisionError):
            average([])
        with self.assertRaises(TypeError):
            average(20, 30, 70)

unittest.main()  # Calling from the command line invokes all tests
```

10.12 Batteries Included

Python has a "batteries included" philosophy. This is best seen through the sophisticated and robust capabilities of its larger packages. For example:

- The `xmlrpc.client` and `xmlrpc.server` modules make implementing remote procedure calls into an almost trivial task. Despite the modules names, no direct knowledge or handling of XML is needed.
- The `email` package is a library for managing email messages, including MIME and other **RFC 2822**-based message documents. Unlike `smtplib` and `poplib` which actually send and receive messages, the email package has a complete toolset for building or decoding complex message structures (including attachments) and for implementing internet encoding and header protocols.
- The `json` package provides robust support for parsing this popular data interchange format. The `csv` module supports direct reading and writing of files in Comma-Separated Value format, commonly supported by databases and spreadsheets. XML processing is supported by the `xml.etree.ElementTree`, `xml.dom` and `xml.sax` packages. Together, these modules and packages greatly simplify data interchange between Python applications and other tools.

- The `sqlite3` module is a wrapper for the SQLite database library, providing a persistent database that can be updated and accessed using slightly nonstandard SQL syntax.
- Internationalization is supported by a number of modules including `gettext`, `locale`, and the `codecs` package.

CHAPTER

ELEVEN

BRIEF TOUR OF THE STANDARD LIBRARY — PART II

This second tour covers more advanced modules that support professional programming needs. These modules rarely occur in small scripts.

11.1 Output Formatting

The `reprlib` module provides a version of `repr()` customized for abbreviated displays of large or deeply nested containers:

```
>>> import reprlib
>>> reprlib.repr(set('supercalifragilisticexpialidocious'))
"{'a', 'c', 'd', 'e', 'f', 'g', ...}"
```

The `pprint` module offers more sophisticated control over printing both built-in and user defined objects in a way that is readable by the interpreter. When the result is longer than one line, the "pretty printer" adds line breaks and indentation to more clearly reveal data structure:

```
>>> import pprint
>>> t = [[[['black', 'cyan'], 'white', ['green', 'red']], [['magenta',
...     'yellow'], 'blue']]]
...
>>> pprint.pprint(t, width=30)
[[[['black', 'cyan'],
   'white',
   ['green', 'red']],
  [['magenta', 'yellow'],
   'blue']]]
```

The `textwrap` module formats paragraphs of text to fit a given screen width:

```
>>> import textwrap
>>> doc = """The wrap() method is just like fill() except that it returns
... a list of strings instead of one big string with newlines to separate
... the wrapped lines."""
...
>>> print(textwrap.fill(doc, width=40))
The wrap() method is just like fill()
except that it returns a list of strings
instead of one big string with newlines
to separate the wrapped lines.
```

The `locale` module accesses a database of culture specific data formats. The grouping attribute of locale's format function provides a direct way of formatting numbers with group separators:

```
>>> import locale
>>> locale.setlocale(locale.LC_ALL, 'English_United States.1252')
'English_United States.1252'
>>> conv = locale.localeconv()          # get a mapping of conventions
>>> x = 1234567.8
>>> locale.format("%d", x, grouping=True)
'1,234,567'
>>> locale.format_string("%s%.*f", (conv['currency_symbol'],
...                      conv['frac_digits'], x), grouping=True)
'$1,234,567.80'
```

11.2 Templating

The `string` module includes a versatile `Template` class with a simplified syntax suitable for editing by end-users. This allows users to customize their applications without having to alter the application.

The format uses placeholder names formed by `$` with valid Python identifiers (alphanumeric characters and underscores). Surrounding the placeholder with braces allows it to be followed by more alphanumeric letters with no intervening spaces. Writing `$$` creates a single escaped `$`:

```
>>> from string import Template
>>> t = Template('${village}folk send $$10 to $cause.')
>>> t.substitute(village='Nottingham', cause='the ditch fund')
'Nottinghamfolk send $10 to the ditch fund.'
```

The `substitute()` method raises a `KeyError` when a placeholder is not supplied in a dictionary or a keyword argument. For mail-merge style applications, user supplied data may be incomplete and the `safe_substitute()` method may be more appropriate — it will leave placeholders unchanged if data is missing:

```
>>> t = Template('Return the $item to $owner.')
>>> d = dict(item='unladen swallow')
>>> t.substitute(d)
Traceback (most recent call last):
  ...
KeyError: 'owner'
>>> t.safe_substitute(d)
'Return the unladen swallow to $owner.'
```

Template subclasses can specify a custom delimiter. For example, a batch renaming utility for a photo browser may elect to use percent signs for placeholders such as the current date, image sequence number, or file format:

```
>>> import time, os.path
>>> photofiles = ['img_1074.jpg', 'img_1076.jpg', 'img_1077.jpg']
>>> class BatchRename(Template):
...     delimiter = '%'
>>> fmt = input('Enter rename style (%d-date %n-seqnum %f-format):  ')
Enter rename style (%d-date %n-seqnum %f-format):  Ashley_%n%f

>>> t = BatchRename(fmt)
>>> date = time.strftime('%d%b%y')
>>> for i, filename in enumerate(photofiles):
...     base, ext = os.path.splitext(filename)
...     newname = t.substitute(d=date, n=i, f=ext)
```

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```
...     print('{0} --> {1}'.format(filename, newname))

img_1074.jpg --> Ashley_0.jpg
img_1076.jpg --> Ashley_1.jpg
img_1077.jpg --> Ashley_2.jpg
```

Another application for templating is separating program logic from the details of multiple output formats. This makes it possible to substitute custom templates for XML files, plain text reports, and HTML web reports.

11.3 Working with Binary Data Record Layouts

The `struct` module provides `pack()` and `unpack()` functions for working with variable length binary record formats. The following example shows how to loop through header information in a ZIP file without using the `zipfile` module. Pack codes `"H"` and `"I"` represent two and four byte unsigned numbers respectively. The `"<"` indicates that they are standard size and in little-endian byte order:

```
import struct

with open('myfile.zip', 'rb') as f:
    data = f.read()

start = 0
for i in range(3):                      # show the first 3 file headers
    start += 14
    fields = struct.unpack('<IIIHH', data[start:start+16])
    crc32, comp_size, uncomp_size, filenamesize, extra_size = fields

    start += 16
    filename = data[start:start+filenamesize]
    start += filenamesize
    extra = data[start:start+extra_size]
    print(filename, hex(crc32), comp_size, uncomp_size)

    start += extra_size + comp_size     # skip to the next header
```

11.4 Multi-threading

Threading is a technique for decoupling tasks which are not sequentially dependent. Threads can be used to improve the responsiveness of applications that accept user input while other tasks run in the background. A related use case is running I/O in parallel with computations in another thread.

The following code shows how the high level `threading` module can run tasks in background while the main program continues to run:

```
import threading, zipfile

class AsyncZip(threading.Thread):
    def __init__(self, infile, outfile):
        threading.Thread.__init__(self)
        self.infile = infile
        self.outfile = outfile
```

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```
    def run(self):
        f = zipfile.ZipFile(self.outfile, 'w', zipfile.ZIP_DEFLATED)
        f.write(self.infile)
        f.close()
        print('Finished background zip of:', self.infile)

background = AsyncZip('mydata.txt', 'myarchive.zip')
background.start()
print('The main program continues to run in foreground.')

background.join()    # Wait for the background task to finish
print('Main program waited until background was done.')
```

The principal challenge of multi-threaded applications is coordinating threads that share data or other resources. To that end, the threading module provides a number of synchronization primitives including locks, events, condition variables, and semaphores.

While those tools are powerful, minor design errors can result in problems that are difficult to reproduce. So, the preferred approach to task coordination is to concentrate all access to a resource in a single thread and then use the `queue` module to feed that thread with requests from other threads. Applications using `Queue` objects for inter-thread communication and coordination are easier to design, more readable, and more reliable.

11.5 Logging

The `logging` module offers a full featured and flexible logging system. At its simplest, log messages are sent to a file or to `sys.stderr`:

```
import logging
logging.debug('Debugging information')
logging.info('Informational message')
logging.warning('Warning:config file %s not found', 'server.conf')
logging.error('Error occurred')
logging.critical('Critical error -- shutting down')
```

This produces the following output:

```
WARNING:root:Warning:config file server.conf not found
ERROR:root:Error occurred
CRITICAL:root:Critical error -- shutting down
```

By default, informational and debugging messages are suppressed and the output is sent to standard error. Other output options include routing messages through email, datagrams, sockets, or to an HTTP Server. New filters can select different routing based on message priority: `DEBUG`, `INFO`, `WARNING`, `ERROR`, and `CRITICAL`.

The logging system can be configured directly from Python or can be loaded from a user editable configuration file for customized logging without altering the application.

11.6 Weak References

Python does automatic memory management (reference counting for most objects and *garbage collection* to eliminate cycles). The memory is freed shortly after the last reference to it has been eliminated.

This approach works fine for most applications but occasionally there is a need to track objects only as long as they are being used by something else. Unfortunately, just tracking them creates a reference that makes them permanent. The `weakref` module provides tools for tracking objects without creating a reference. When the object is no longer needed, it is automatically removed from a weakref table and a callback is triggered for weakref objects. Typical applications include caching objects that are expensive to create:

```
>>> import weakref, gc
>>> class A:
...     def __init__(self, value):
...         self.value = value
...     def __repr__(self):
...         return str(self.value)
...
>>> a = A(10)                   # create a reference
>>> d = weakref.WeakValueDictionary()
>>> d['primary'] = a            # does not create a reference
>>> d['primary']                # fetch the object if it is still alive
10
>>> del a                       # remove the one reference
>>> gc.collect()                # run garbage collection right away
0
>>> d['primary']                # entry was automatically removed
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    d['primary']                # entry was automatically removed
  File "C:/python37/lib/weakref.py", line 46, in __getitem__
    o = self.data[key]()
KeyError: 'primary'
```

11.7 Tools for Working with Lists

Many data structure needs can be met with the built-in list type. However, sometimes there is a need for alternative implementations with different performance trade-offs.

The `array` module provides an `array()` object that is like a list that stores only homogeneous data and stores it more compactly. The following example shows an array of numbers stored as two byte unsigned binary numbers (typecode `"H"`) rather than the usual 16 bytes per entry for regular lists of Python int objects:

```
>>> from array import array
>>> a = array('H', [4000, 10, 700, 22222])
>>> sum(a)
26932
>>> a[1:3]
array('H', [10, 700])
```

The `collections` module provides a `deque()` object that is like a list with faster appends and pops from the left side but slower lookups in the middle. These objects are well suited for implementing queues and breadth first tree searches:

```
>>> from collections import deque
>>> d = deque(["task1", "task2", "task3"])
>>> d.append("task4")
>>> print("Handling", d.popleft())
Handling task1
```

```
unsearched = deque([starting_node])
def breadth_first_search(unsearched):
    node = unsearched.popleft()
    for m in gen_moves(node):
        if is_goal(m):
            return m
        unsearched.append(m)
```

In addition to alternative list implementations, the library also offers other tools such as the `bisect` module with functions for manipulating sorted lists:

```
>>> import bisect
>>> scores = [(100, 'perl'), (200, 'tcl'), (400, 'lua'), (500, 'python')]
>>> bisect.insort(scores, (300, 'ruby'))
>>> scores
[(100, 'perl'), (200, 'tcl'), (300, 'ruby'), (400, 'lua'), (500, 'python')]
```

The `heapq` module provides functions for implementing heaps based on regular lists. The lowest valued entry is always kept at position zero. This is useful for applications which repeatedly access the smallest element but do not want to run a full list sort:

```
>>> from heapq import heapify, heappop, heappush
>>> data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]
>>> heapify(data)                      # rearrange the list into heap order
>>> heappush(data, -5)                 # add a new entry
>>> [heappop(data) for i in range(3)]  # fetch the three smallest entries
[-5, 0, 1]
```

11.8 Decimal Floating Point Arithmetic

The `decimal` module offers a `Decimal` datatype for decimal floating point arithmetic. Compared to the built-in `float` implementation of binary floating point, the class is especially helpful for

- financial applications and other uses which require exact decimal representation,
- control over precision,
- control over rounding to meet legal or regulatory requirements,
- tracking of significant decimal places, or
- applications where the user expects the results to match calculations done by hand.

For example, calculating a 5% tax on a 70 cent phone charge gives different results in decimal floating point and binary floating point. The difference becomes significant if the results are rounded to the nearest cent:

```
>>> from decimal import *
>>> round(Decimal('0.70') * Decimal('1.05'), 2)
Decimal('0.74')
>>> round(.70 * 1.05, 2)
0.73
```

The `Decimal` result keeps a trailing zero, automatically inferring four place significance from multiplicands with two place significance. Decimal reproduces mathematics as done by hand and avoids issues that can arise when binary floating point cannot exactly represent decimal quantities.

Exact representation enables the `Decimal` class to perform modulo calculations and equality tests that are unsuitable for binary floating point:

```
>>> Decimal('1.00') % Decimal('.10')
Decimal('0.00')
>>> 1.00 % 0.10
0.09999999999999995

>>> sum([Decimal('0.1')]*10) == Decimal('1.0')
True
>>> sum([0.1]*10) == 1.0
False
```

The `decimal` module provides arithmetic with as much precision as needed:

```
>>> getcontext().prec = 36
>>> Decimal(1) / Decimal(7)
Decimal('0.142857142857142857142857142857142857')
```

CHAPTER

TWELVE

VIRTUAL ENVIRONMENTS AND PACKAGES

12.1 Introduction

Python applications will often use packages and modules that don't come as part of the standard library. Applications will sometimes need a specific version of a library, because the application may require that a particular bug has been fixed or the application may be written using an obsolete version of the library's interface.

This means it may not be possible for one Python installation to meet the requirements of every application. If application A needs version 1.0 of a particular module but application B needs version 2.0, then the requirements are in conflict and installing either version 1.0 or 2.0 will leave one application unable to run.

The solution for this problem is to create a *virtual environment*, a self-contained directory tree that contains a Python installation for a particular version of Python, plus a number of additional packages.

Different applications can then use different virtual environments. To resolve the earlier example of conflicting requirements, application A can have its own virtual environment with version 1.0 installed while application B has another virtual environment with version 2.0. If application B requires a library be upgraded to version 3.0, this will not affect application A's environment.

12.2 Creating Virtual Environments

The module used to create and manage virtual environments is called `venv`. `venv` will usually install the most recent version of Python that you have available. If you have multiple versions of Python on your system, you can select a specific Python version by running `python3` or whichever version you want.

To create a virtual environment, decide upon a directory where you want to place it, and run the `venv` module as a script with the directory path:

```
python3 -m venv tutorial-env
```

This will create the `tutorial-env` directory if it doesn't exist, and also create directories inside it containing a copy of the Python interpreter, the standard library, and various supporting files.

Once you've created a virtual environment, you may activate it.

On Windows, run:

```
tutorial-env\Scripts\activate.bat
```

On Unix or MacOS, run:

```
source tutorial-env/bin/activate
```

(This script is written for the bash shell. If you use the **csh** or **fish** shells, there are alternate `activate.csh` and `activate.fish` scripts you should use instead.)

Activating the virtual environment will change your shell's prompt to show what virtual environment you're using, and modify the environment so that running `python` will get you that particular version and installation of Python. For example:

```
$ source ~/envs/tutorial-env/bin/activate
(tutorial-env) $ python
Python 3.5.1 (default, May  6 2016, 10:59:36)
  ...
>>> import sys
>>> sys.path
['', '/usr/local/lib/python35.zip', ...,
'~/envs/tutorial-env/lib/python3.5/site-packages']
>>>
```

12.3 Managing Packages with pip

You can install, upgrade, and remove packages using a program called **pip**. By default `pip` will install packages from the Python Package Index, <https://pypi.org>. You can browse the Python Package Index by going to it in your web browser, or you can use `pip`'s limited search feature:

```
(tutorial-env) $ pip search astronomy
skyfield               - Elegant astronomy for Python
gary                   - Galactic astronomy and gravitational dynamics.
novas                  - The United States Naval Observatory NOVAS astronomy library
astroobs               - Provides astronomy ephemeris to plan telescope observations
PyAstronomy            - A collection of astronomy related tools for Python.
...
```

`pip` has a number of subcommands: "search", "install", "uninstall", "freeze", etc. (Consult the installing-index guide for complete documentation for `pip`.)

You can install the latest version of a package by specifying a package's name:

```
(tutorial-env) $ pip install novas
Collecting novas
  Downloading novas-3.1.1.3.tar.gz (136kB)
Installing collected packages: novas
  Running setup.py install for novas
Successfully installed novas-3.1.1.3
```

You can also install a specific version of a package by giving the package name followed by `==` and the version number:

```
(tutorial-env) $ pip install requests==2.6.0
Collecting requests==2.6.0
  Using cached requests-2.6.0-py2.py3-none-any.whl
Installing collected packages: requests
Successfully installed requests-2.6.0
```

If you re-run this command, `pip` will notice that the requested version is already installed and do nothing. You can supply a different version number to get that version, or you can run `pip install --upgrade` to upgrade the package to the latest version:

```
(tutorial-env) $ pip install --upgrade requests
Collecting requests
Installing collected packages: requests
  Found existing installation: requests 2.6.0
    Uninstalling requests-2.6.0:
      Successfully uninstalled requests-2.6.0
Successfully installed requests-2.7.0
```

`pip uninstall` followed by one or more package names will remove the packages from the virtual environment.

`pip show` will display information about a particular package:

```
(tutorial-env) $ pip show requests
---
Metadata-Version: 2.0
Name: requests
Version: 2.7.0
Summary: Python HTTP for Humans.
Home-page: http://python-requests.org
Author: Kenneth Reitz
Author-email: me@kennethreitz.com
License: Apache 2.0
Location: /Users/akuchling/envs/tutorial-env/lib/python3.4/site-packages
Requires:
```

`pip list` will display all of the packages installed in the virtual environment:

```
(tutorial-env) $ pip list
novas (3.1.1.3)
numpy (1.9.2)
pip (7.0.3)
requests (2.7.0)
setuptools (16.0)
```

`pip freeze` will produce a similar list of the installed packages, but the output uses the format that `pip install` expects. A common convention is to put this list in a `requirements.txt` file:

```
(tutorial-env) $ pip freeze > requirements.txt
(tutorial-env) $ cat requirements.txt
novas==3.1.1.3
numpy==1.9.2
requests==2.7.0
```

The `requirements.txt` can then be committed to version control and shipped as part of an application. Users can then install all the necessary packages with `install -r`:

```
(tutorial-env) $ pip install -r requirements.txt
Collecting novas==3.1.1.3 (from -r requirements.txt (line 1))
  ...
Collecting numpy==1.9.2 (from -r requirements.txt (line 2))
  ...
Collecting requests==2.7.0 (from -r requirements.txt (line 3))
  ...
Installing collected packages: novas, numpy, requests
  Running setup.py install for novas
Successfully installed novas-3.1.1.3 numpy-1.9.2 requests-2.7.0
```

`pip` has many more options. Consult the installing-index guide for complete documentation for `pip`. When you've written a package and want to make it available on the Python Package Index, consult the distributing-index guide.

CHAPTER

THIRTEEN

WHAT NOW?

Reading this tutorial has probably reinforced your interest in using Python — you should be eager to apply Python to solving your real-world problems. Where should you go to learn more?

This tutorial is part of Python's documentation set. Some other documents in the set are:

- library-index:

  You should browse through this manual, which gives complete (though terse) reference material about types, functions, and the modules in the standard library. The standard Python distribution includes a *lot* of additional code. There are modules to read Unix mailboxes, retrieve documents via HTTP, generate random numbers, parse command-line options, write CGI programs, compress data, and many other tasks. Skimming through the Library Reference will give you an idea of what's available.

- installing-index explains how to install additional modules written by other Python users.
- reference-index: A detailed explanation of Python's syntax and semantics. It's heavy reading, but is useful as a complete guide to the language itself.

More Python resources:

- https://www.python.org: The major Python Web site. It contains code, documentation, and pointers to Python-related pages around the Web. This Web site is mirrored in various places around the world, such as Europe, Japan, and Australia; a mirror may be faster than the main site, depending on your geographical location.
- https://docs.python.org: Fast access to Python's documentation.
- https://pypi.org: The Python Package Index, previously also nicknamed the Cheese Shop, is an index of user-created Python modules that are available for download. Once you begin releasing code, you can register it here so that others can find it.
- https://code.activestate.com/recipes/langs/python/: The Python Cookbook is a sizable collection of code examples, larger modules, and useful scripts. Particularly notable contributions are collected in a book also titled Python Cookbook (O'Reilly & Associates, ISBN 0-596-00797-3.)
- http://www.pyvideo.org collects links to Python-related videos from conferences and user-group meetings.
- https://scipy.org: The Scientific Python project includes modules for fast array computations and manipulations plus a host of packages for such things as linear algebra, Fourier transforms, non-linear solvers, random number distributions, statistical analysis and the like.

For Python-related questions and problem reports, you can post to the newsgroup *comp.lang.python*, or send them to the mailing list at python-list@python.org. The newsgroup and mailing list are gatewayed, so messages posted to one will automatically be forwarded to the other. There are hundreds of postings a day, asking (and answering) questions, suggesting new features, and announcing new modules. Mailing list archives are available at https://mail.python.org/pipermail/.

Before posting, be sure to check the list of Frequently Asked Questions (also called the FAQ). The FAQ answers many of the questions that come up again and again, and may already contain the solution for your problem.

CHAPTER

FOURTEEN

INTERACTIVE INPUT EDITING AND HISTORY SUBSTITUTION

Some versions of the Python interpreter support editing of the current input line and history substitution, similar to facilities found in the Korn shell and the GNU Bash shell. This is implemented using the GNU Readline library, which supports various styles of editing. This library has its own documentation which we won't duplicate here.

14.1 Tab Completion and History Editing

Completion of variable and module names is automatically enabled at interpreter startup so that the `Tab` key invokes the completion function; it looks at Python statement names, the current local variables, and the available module names. For dotted expressions such as `string.a`, it will evaluate the expression up to the final `'.'` and then suggest completions from the attributes of the resulting object. Note that this may execute application-defined code if an object with a `__getattr__()` method is part of the expression. The default configuration also saves your history into a file named `.python_history` in your user directory. The history will be available again during the next interactive interpreter session.

14.2 Alternatives to the Interactive Interpreter

This facility is an enormous step forward compared to earlier versions of the interpreter; however, some wishes are left: It would be nice if the proper indentation were suggested on continuation lines (the parser knows if an indent token is required next). The completion mechanism might use the interpreter's symbol table. A command to check (or even suggest) matching parentheses, quotes, etc., would also be useful.

One alternative enhanced interactive interpreter that has been around for quite some time is IPython, which features tab completion, object exploration and advanced history management. It can also be thoroughly customized and embedded into other applications. Another similar enhanced interactive environment is bpython.

CHAPTER

FIFTEEN

FLOATING POINT ARITHMETIC: ISSUES AND LIMITATIONS

Floating-point numbers are represented in computer hardware as base 2 (binary) fractions. For example, the decimal fraction

```
0.125
```

has value 1/10 + 2/100 + 5/1000, and in the same way the binary fraction

```
0.001
```

has value 0/2 + 0/4 + 1/8. These two fractions have identical values, the only real difference being that the first is written in base 10 fractional notation, and the second in base 2.

Unfortunately, most decimal fractions cannot be represented exactly as binary fractions. A consequence is that, in general, the decimal floating-point numbers you enter are only approximated by the binary floating-point numbers actually stored in the machine.

The problem is easier to understand at first in base 10. Consider the fraction 1/3. You can approximate that as a base 10 fraction:

```
0.3
```

or, better,

```
0.33
```

or, better,

```
0.333
```

and so on. No matter how many digits you're willing to write down, the result will never be exactly 1/3, but will be an increasingly better approximation of 1/3.

In the same way, no matter how many base 2 digits you're willing to use, the decimal value 0.1 cannot be represented exactly as a base 2 fraction. In base 2, 1/10 is the infinitely repeating fraction

```
0.0001100110011001100110011001100110011001100110011001100110011...
```

Stop at any finite number of bits, and you get an approximation. On most machines today, floats are approximated using a binary fraction with the numerator using the first 53 bits starting with the most significant bit and with the denominator as a power of two. In the case of 1/10, the binary fraction is `3602879701896397 / 2 ** 55` which is close to but not exactly equal to the true value of 1/10.

Many users are not aware of the approximation because of the way values are displayed. Python only prints a decimal approximation to the true decimal value of the binary approximation stored by the machine. On most machines, if Python were to print the true decimal value of the binary approximation stored for 0.1, it would have to display

```
>>> 0.1
0.1000000000000000055511151231257827021181583404541015625
```

That is more digits than most people find useful, so Python keeps the number of digits manageable by displaying a rounded value instead

```
>>> 1 / 10
0.1
```

Just remember, even though the printed result looks like the exact value of 1/10, the actual stored value is the nearest representable binary fraction.

Interestingly, there are many different decimal numbers that share the same nearest approximate binary fraction. For example, the numbers `0.1` and `0.10000000000000001` and `0.1000000000000000055511151231257827021181583404541015625` are all approximated by `3602879701896397 / 2 ** 55`. Since all of these decimal values share the same approximation, any one of them could be displayed while still preserving the invariant `eval(repr(x)) == x`.

Historically, the Python prompt and built-in `repr()` function would choose the one with 17 significant digits, `0.10000000000000001`. Starting with Python 3.1, Python (on most systems) is now able to choose the shortest of these and simply display `0.1`.

Note that this is in the very nature of binary floating-point: this is not a bug in Python, and it is not a bug in your code either. You'll see the same kind of thing in all languages that support your hardware's floating-point arithmetic (although some languages may not *display* the difference by default, or in all output modes).

For more pleasant output, you may wish to use string formatting to produce a limited number of significant digits:

```
>>> format(math.pi, '.12g')  # give 12 significant digits
'3.14159265359'

>>> format(math.pi, '.2f')   # give 2 digits after the point
'3.14'

>>> repr(math.pi)
'3.141592653589793'
```

It's important to realize that this is, in a real sense, an illusion: you're simply rounding the *display* of the true machine value.

One illusion may beget another. For example, since 0.1 is not exactly 1/10, summing three values of 0.1 may not yield exactly 0.3, either:

```
>>> .1 + .1 + .1 == .3
False
```

Also, since the 0.1 cannot get any closer to the exact value of 1/10 and 0.3 cannot get any closer to the exact value of 3/10, then pre-rounding with `round()` function cannot help:

```
>>> round(.1, 1) + round(.1, 1) + round(.1, 1) == round(.3, 1)
False
```

Though the numbers cannot be made closer to their intended exact values, the `round()` function can be useful for post-rounding so that results with inexact values become comparable to one another:

```
>>> round(.1 + .1 + .1, 10) == round(.3, 10)
True
```

Binary floating-point arithmetic holds many surprises like this. The problem with "0.1" is explained in precise detail below, in the "Representation Error" section. See The Perils of Floating Point for a more complete account of other common surprises.

As that says near the end, "there are no easy answers." Still, don't be unduly wary of floating-point! The errors in Python float operations are inherited from the floating-point hardware, and on most machines are on the order of no more than 1 part in 2**53 per operation. That's more than adequate for most tasks, but you do need to keep in mind that it's not decimal arithmetic and that every float operation can suffer a new rounding error.

While pathological cases do exist, for most casual use of floating-point arithmetic you'll see the result you expect in the end if you simply round the display of your final results to the number of decimal digits you expect. `str()` usually suffices, and for finer control see the `str.format()` method's format specifiers in formatstrings.

For use cases which require exact decimal representation, try using the `decimal` module which implements decimal arithmetic suitable for accounting applications and high-precision applications.

Another form of exact arithmetic is supported by the `fractions` module which implements arithmetic based on rational numbers (so the numbers like 1/3 can be represented exactly).

If you are a heavy user of floating point operations you should take a look at the Numerical Python package and many other packages for mathematical and statistical operations supplied by the SciPy project. See <https://scipy.org>.

Python provides tools that may help on those rare occasions when you really *do* want to know the exact value of a float. The `float.as_integer_ratio()` method expresses the value of a float as a fraction:

```
>>> x = 3.14159
>>> x.as_integer_ratio()
(3537115888337719, 1125899906842624)
```

Since the ratio is exact, it can be used to losslessly recreate the original value:

```
>>> x == 3537115888337719 / 1125899906842624
True
```

The `float.hex()` method expresses a float in hexadecimal (base 16), again giving the exact value stored by your computer:

```
>>> x.hex()
'0x1.921f9f01b866ep+1'
```

This precise hexadecimal representation can be used to reconstruct the float value exactly:

```
>>> x == float.fromhex('0x1.921f9f01b866ep+1')
True
```

Since the representation is exact, it is useful for reliably porting values across different versions of Python (platform independence) and exchanging data with other languages that support the same format (such as Java and C99).

Another helpful tool is the `math.fsum()` function which helps mitigate loss-of-precision during summation. It tracks "lost digits" as values are added onto a running total. That can make a difference in overall accuracy so that the errors do not accumulate to the point where they affect the final total:

```
>>> sum([0.1] * 10) == 1.0
False
>>> math.fsum([0.1] * 10) == 1.0
True
```

15.1 Representation Error

This section explains the "0.1" example in detail, and shows how you can perform an exact analysis of cases like this yourself. Basic familiarity with binary floating-point representation is assumed.

Representation error refers to the fact that some (most, actually) decimal fractions cannot be represented exactly as binary (base 2) fractions. This is the chief reason why Python (or Perl, C, C++, Java, Fortran, and many others) often won't display the exact decimal number you expect.

Why is that? 1/10 is not exactly representable as a binary fraction. Almost all machines today (November 2000) use IEEE-754 floating point arithmetic, and almost all platforms map Python floats to IEEE-754 "double precision". 754 doubles contain 53 bits of precision, so on input the computer strives to convert 0.1 to the closest fraction it can of the form $J/2**N$ where J is an integer containing exactly 53 bits. Rewriting

```
1 / 10 ~= J / (2**N)
```

as

```
J ~= 2**N / 10
```

and recalling that J has exactly 53 bits (is `>= 2**52` but `< 2**53`), the best value for N is 56:

```
>>> 2**52 <=  2**56 // 10  < 2**53
True
```

That is, 56 is the only value for N that leaves J with exactly 53 bits. The best possible value for J is then that quotient rounded:

```
>>> q, r = divmod(2**56, 10)
>>> r
6
```

Since the remainder is more than half of 10, the best approximation is obtained by rounding up:

```
>>> q+1
7205759403792794
```

Therefore the best possible approximation to 1/10 in 754 double precision is:

```
7205759403792794 / 2 ** 56
```

Dividing both the numerator and denominator by two reduces the fraction to:

```
3602879701896397 / 2 ** 55
```

Note that since we rounded up, this is actually a little bit larger than 1/10; if we had not rounded up, the quotient would have been a little bit smaller than 1/10. But in no case can it be *exactly* 1/10!

So the computer never "sees" 1/10: what it sees is the exact fraction given above, the best 754 double approximation it can get:

```
>>> 0.1 * 2 ** 55
3602879701896397.0
```

If we multiply that fraction by 10**55, we can see the value out to 55 decimal digits:

```
>>> 3602879701896397 * 10 ** 55 // 2 ** 55
1000000000000000055511151231257827021181583404541015625
```

meaning that the exact number stored in the computer is equal to the decimal value 0.1000000000000000055511151231257827021181583404541015625. Instead of displaying the full decimal value, many languages (including older versions of Python), round the result to 17 significant digits:

```
>>> format(0.1, '.17f')
'0.10000000000000001'
```

The `fractions` and `decimal` modules make these calculations easy:

```
>>> from decimal import Decimal
>>> from fractions import Fraction

>>> Fraction.from_float(0.1)
Fraction(3602879701896397, 36028797018963968)

>>> (0.1).as_integer_ratio()
(3602879701896397, 36028797018963968)

>>> Decimal.from_float(0.1)
Decimal('0.1000000000000000055511151231257827021181583404541015625')

>>> format(Decimal.from_float(0.1), '.17')
'0.10000000000000001'
```

CHAPTER

SIXTEEN

APPENDIX

16.1 Interactive Mode

16.1.1 Error Handling

When an error occurs, the interpreter prints an error message and a stack trace. In interactive mode, it then returns to the primary prompt; when input came from a file, it exits with a nonzero exit status after printing the stack trace. (Exceptions handled by an `except` clause in a `try` statement are not errors in this context.) Some errors are unconditionally fatal and cause an exit with a nonzero exit; this applies to internal inconsistencies and some cases of running out of memory. All error messages are written to the standard error stream; normal output from executed commands is written to standard output.

Typing the interrupt character (usually `Control-C` or `Delete`) to the primary or secondary prompt cancels the input and returns to the primary prompt.[1] Typing an interrupt while a command is executing raises the `KeyboardInterrupt` exception, which may be handled by a `try` statement.

16.1.2 Executable Python Scripts

On BSD'ish Unix systems, Python scripts can be made directly executable, like shell scripts, by putting the line

```
#!/usr/bin/env python3.5
```

(assuming that the interpreter is on the user's `PATH`) at the beginning of the script and giving the file an executable mode. The `#!` must be the first two characters of the file. On some platforms, this first line must end with a Unix-style line ending (`'\n'`), not a Windows (`'\r\n'`) line ending. Note that the hash, or pound, character, `'#'`, is used to start a comment in Python.

The script can be given an executable mode, or permission, using the **`chmod`** command.

```
$ chmod +x myscript.py
```

On Windows systems, there is no notion of an "executable mode". The Python installer automatically associates `.py` files with `python.exe` so that a double-click on a Python file will run it as a script. The extension can also be `.pyw`, in that case, the console window that normally appears is suppressed.

16.1.3 The Interactive Startup File

When you use Python interactively, it is frequently handy to have some standard commands executed every time the interpreter is started. You can do this by setting an environment variable named `PYTHONSTARTUP`

[1] A problem with the GNU Readline package may prevent this.

to the name of a file containing your start-up commands. This is similar to the `.profile` feature of the Unix shells.

This file is only read in interactive sessions, not when Python reads commands from a script, and not when `/dev/tty` is given as the explicit source of commands (which otherwise behaves like an interactive session). It is executed in the same namespace where interactive commands are executed, so that objects that it defines or imports can be used without qualification in the interactive session. You can also change the prompts `sys.ps1` and `sys.ps2` in this file.

If you want to read an additional start-up file from the current directory, you can program this in the global start-up file using code like `if os.path.isfile('.pythonrc.py'): exec(open('.pythonrc.py').read())`. If you want to use the startup file in a script, you must do this explicitly in the script:

```
import os
filename = os.environ.get('PYTHONSTARTUP')
if filename and os.path.isfile(filename):
    with open(filename) as fobj:
        startup_file = fobj.read()
    exec(startup_file)
```

16.1.4 The Customization Modules

Python provides two hooks to let you customize it: `sitecustomize` and `usercustomize`. To see how it works, you need first to find the location of your user site-packages directory. Start Python and run this code:

```
>>> import site
>>> site.getusersitepackages()
'/home/user/.local/lib/python3.5/site-packages'
```

Now you can create a file named `usercustomize.py` in that directory and put anything you want in it. It will affect every invocation of Python, unless it is started with the `-s` option to disable the automatic import.

`sitecustomize` works in the same way, but is typically created by an administrator of the computer in the global site-packages directory, and is imported before `usercustomize`. See the documentation of the `site` module for more details.

APPENDIX

A

GLOSSARY

`>>>` The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

`...` The default Python prompt of the interactive shell when entering code for an indented code block, when within a pair of matching left and right delimiters (parentheses, square brackets, curly braces or triple quotes), or after specifying a decorator.

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See 2to3-reference.

abstract base class Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with magic methods). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections.abc` module), numbers (in the `numbers` module), streams (in the `io` module), import finders and loaders (in the `importlib.abc` module). You can create your own ABCs with the `abc` module.

annotation A label associated with a variable, a class attribute or a function parameter or return value, used by convention as a *type hint*.

Annotations of local variables cannot be accessed at runtime, but annotations of global variables, class attributes, and functions are stored in the `__annotations__` special attribute of modules, classes, and functions, respectively.

See *variable annotation*, *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

argument A value passed to a *function* (or *method*) when calling the function. There are two kinds of argument:

- *keyword argument*: an argument preceded by an identifier (e.g. `name=`) in a function call or passed as a value in a dictionary preceded by `**`. For example, `3` and `5` are both keyword arguments in the following calls to `complex()`:

```
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- *positional argument*: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an *iterable* preceded by `*`. For example, `3` and `5` are both positional arguments in the following calls:

```
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the calls section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the *parameter* glossary entry, the FAQ question on the difference between arguments and parameters, and **PEP 362**.

asynchronous context manager An object which controls the environment seen in an `async with` statement by defining `__aenter__()` and `__aexit__()` methods. Introduced by **PEP 492**.

asynchronous generator A function which returns an *asynchronous generator iterator*. It looks like a coroutine function defined with `async def` except that it contains `yield` expressions for producing a series of values usable in an `async for` loop.

Usually refers to a asynchronous generator function, but may refer to an *asynchronous generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

An asynchronous generator function may contain `await` expressions as well as `async for`, and `async with` statements.

asynchronous generator iterator An object created by a *asynchronous generator* function.

This is an *asynchronous iterator* which when called using the `__anext__()` method returns an awaitable object which will execute that the body of the asynchronous generator function until the next `yield` expression.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *asynchronous generator iterator* effectively resumes with another awaitable returned by `__anext__()`, it picks up where it left off. See **PEP 492** and **PEP 525**.

asynchronous iterable An object, that can be used in an `async for` statement. Must return an *asynchronous iterator* from its `__aiter__()` method. Introduced by **PEP 492**.

asynchronous iterator An object that implements `__aiter__()` and `__anext__()` methods. `__anext__` must return an *awaitable* object. `async for` resolves awaitable returned from asynchronous iterator's `__anext__()` method until it raises `StopAsyncIteration` exception. Introduced by **PEP 492**.

attribute A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

awaitable An object that can be used in an `await` expression. Can be a *coroutine* or an object with an `__await__()` method. See also **PEP 492**.

BDFL Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

binary file A *file object* able to read and write *bytes-like objects*. Examples of binary files are files opened in binary mode (`'rb'`, `'wb'` or `'rb+'`), `sys.stdin.buffer`, `sys.stdout.buffer`, and instances of `io.BytesIO` and `gzip.GzipFile`.

See also *text file* for a file object able to read and write `str` objects.

bytes-like object An object that supports the bufferobjects and can export a C-*contiguous* buffer. This includes all `bytes`, `bytearray`, and `array.array` objects, as well as many common `memoryview` objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as "read-write bytes-like objects". Example mutable buffer objects include `bytearray` and a `memoryview` of a `bytearray`. Other operations require the binary data to be stored in immutable objects ("read-only bytes-like objects"); examples of these include `bytes` and a `memoryview` of a `bytes` object.

bytecode Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for the dis module.

class A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

class variable A variable defined in a class and intended to be modified only at class level (i.e., not in an instance of the class).

coercion The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer `3`, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

complex number An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of `-1`), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

context manager An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See **PEP 343**.

contiguous A buffer is considered contiguous exactly if it is either *C-contiguous* or *Fortran contiguous*. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be laid out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

coroutine Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the `async def` statement. See also **PEP 492**.

coroutine function A function which returns a *coroutine* object. A coroutine function may be defined with the `async def` statement, and may contain `await`, `async for`, and `async with` keywords. These were introduced by **PEP 492**.

CPython The canonical implementation of the Python programming language, as distributed on python.org. The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

decorator A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)
```

(continues on next page)

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```
@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for function definitions and class definitions for more about decorators.

descriptor Any object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using *a.b* to get, set or delete an attribute looks up the object named *b* in the class dictionary for *a*, but if *b* is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see descriptors.

dictionary An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

dictionary view The objects returned from `dict.keys()`, `dict.values()`, and `dict.items()` are called dictionary views. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use `list(dictview)`. See dict-views.

docstring A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

duck-typing A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note, however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

EAFP Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

expression A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statement*s which cannot be used as expressions, such as `if`. Assignments are also statements, not expressions.

extension module A module written in C or C++, using Python's C API to interact with the core and with user code.

f-string String literals prefixed with `'f'` or `'F'` are commonly called "f-strings" which is short for formatted string literals. See also **PEP 498**.

file object An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw *binary files*, buffered *binary files* and *text files*. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the

`open()` function.

file-like object A synonym for *file object*.

finder An object that tries to find the *loader* for a module that is being imported.

Since Python 3.3, there are two types of finder: *meta path finders* for use with `sys.meta_path`, and *path entry finders* for use with `sys.path_hooks`.

See **PEP 302**, **PEP 420** and **PEP 451** for much more detail.

floor division Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See **PEP 238**.

function A series of statements which returns some value to a caller. It can also be passed zero or more *arguments* which may be used in the execution of the body. See also *parameter*, *method*, and the function section.

function annotation An *annotation* of a function parameter or return value.

Function annotations are usually used for *type hints*: for example this function is expected to take two `int` arguments and is also expected to have an `int` return value:

```
def sum_two_numbers(a: int, b: int) -> int:
   return a + b
```

Function annotation syntax is explained in section function.

See *variable annotation* and **PEP 484**, which describe this functionality.

___future___ A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

garbage collection The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles. The garbage collector can be controlled using the `gc` module.

generator A function which returns a *generator iterator*. It looks like a normal function except that it contains `yield` expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the `next()` function.

Usually refers to a generator function, but may refer to a *generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

generator iterator An object created by a *generator* function.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *generator iterator* resumes, it picks up where it left off (in contrast to functions which start fresh on every invocation).

generator expression An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))         # sum of squares 0, 1, 4, ... 81
285
```

generic function A function composed of multiple functions implementing the same operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the *single dispatch* glossary entry, the `functools.singledispatch()` decorator, and **PEP 443**.

GIL See *global interpreter lock*.

global interpreter lock The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a "free-threaded" interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

hash-based pyc A bytecode cache file that uses the hash rather than the last-modified time of the corresponding source file to determine its validity. See pyc-invalidation.

hashable An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python's immutable built-in objects are hashable; mutable containers (such as lists or dictionaries) are not. Objects which are instances of user-defined classes are hashable by default. They all compare unequal (except with themselves), and their hash value is derived from their `id()`.

IDLE An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

immutable An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

import path A list of locations (or *path entries*) that are searched by the *path based finder* for modules to import. During import, this list of locations usually comes from `sys.path`, but for subpackages it may also come from the parent package's `__path__` attribute.

importing The process by which Python code in one module is made available to Python code in another module.

importer An object that both finds and loads a module; both a *finder* and *loader* object.

interactive Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer's main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

interpreted Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically

have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the *garbage collector*. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the `__main__` module or the script being run has finished executing.

iterable An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict`, *file objects*, and objects of any classes you define with an `__iter__()` method or with a `__getitem__()` method that implements *Sequence* semantics.

Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

iterator An object representing a stream of data. Repeated calls to the iterator's `__next__()` method (or passing it to the built-in function `next()`) return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `__next__()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in typeiter.

key function A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.merge()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example. the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the Sorting HOW TO for examples of how to create and use key functions.

keyword argument See *argument*.

lambda An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [parameters]: expression`

LBYL Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between "the looking" and "the leaping". For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

list A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements is O(1).

list comprehension A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ['{:#04x}'.format(x) for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

loader An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details and `importlib.abc.Loader` for an *abstract base class*.

mapping A container object that supports arbitrary key lookups and implements the methods specified in the `Mapping` or `MutableMapping` abstract base classes. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

meta path finder A *finder* returned by a search of `sys.meta_path`. Meta path finders are related to, but different from *path entry finders*.

See `importlib.abc.MetaPathFinder` for the methods that meta path finders implement.

metaclass The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in metaclasses.

method A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

method resolution order Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order for details of the algorithm used by the Python interpreter since the 2.3 release.

module An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects. Modules are loaded into Python by the process of *importing*.

See also *package*.

module spec A namespace containing the import-related information used to load a module. An instance of `importlib.machinery.ModuleSpec`.

MRO See *method resolution order*.

mutable Mutable objects can change their value but keep their `id()`. See also *immutable*.

named tuple Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

namespace The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `builtins.open` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.islice()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

namespace package A **PEP 420** *package* which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a *regular package* because they have no `__init__.py` file.

See also *module*.

nested scope The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The `nonlocal` allows writing to outer scopes.

new-style class Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python's newer, versatile features like `__slots__`, descriptors, properties, `__getattribute__()`, class methods, and static methods.

object Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

package A Python *module* which can contain submodules or recursively, subpackages. Technically, a package is a Python module with an `__path__` attribute.

See also *regular package* and *namespace package*.

parameter A named entity in a *function* (or method) definition that specifies an *argument* (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- *positional-or-keyword*: specifies an argument that can be passed either *positionally* or as a *keyword argument*. This is the default kind of parameter, for example *foo* and *bar* in the following:

```
def func(foo, bar=None): ...
```

- *positional-only*: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. `abs()`).
- *keyword-only*: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare `*` in the parameter list of the function definition before them, for example *kw_only1* and *kw_only2* in the following:

```
def func(arg, *, kw_only1, kw_only2): ...
```

- *var-positional*: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `*`, for example *args* in the following:

```
def func(*args, **kwargs): ...
```

- *var-keyword*: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `**`, for example *kwargs* in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the *argument* glossary entry, the FAQ question on the difference between arguments and parameters, the `inspect.Parameter` class, the function section, and **PEP 362**.

path entry A single location on the *import path* which the *path based finder* consults to find modules for importing.

path entry finder A *finder* returned by a callable on `sys.path_hooks` (i.e. a *path entry hook*) which knows how to locate modules given a *path entry*.

See `importlib.abc.PathEntryFinder` for the methods that path entry finders implement.

path entry hook A callable on the `sys.path_hook` list which returns a *path entry finder* if it knows how to find modules on a specific *path entry*.

path based finder One of the default *meta path finders* which searches an *import path* for modules.

path-like object An object representing a file system path. A path-like object is either a `str` or `bytes` object representing a path, or an object implementing the `os.PathLike` protocol. An object that supports the `os.PathLike` protocol can be converted to a `str` or `bytes` file system path by calling the `os.fspath()` function; `os.fsdecode()` and `os.fsencode()` can be used to guarantee a `str` or `bytes` result instead, respectively. Introduced by **PEP 519**.

PEP Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python or its processes or environment. PEPs should provide a concise technical specification and a rationale for proposed features.

PEPs are intended to be the primary mechanisms for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible for building consensus within the community and documenting dissenting opinions.

See **PEP 1**.

portion A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in **PEP 420**.

positional argument See *argument*.

provisional API A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a "solution of last resort" - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See **PEP 411** for more details.

provisional package See *provisional API*.

Python 3000 Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

Pythonic An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print(piece)
```

qualified name A dotted name showing the "path" from a module's global scope to a class, function or method defined in that module, as defined in **PEP 3155**. For top-level functions and classes, the qualified name is the same as the object's name:

```
>>> class C:
...     class D:
...         def meth(self):
...             pass
...
>>> C.__qualname__
'C'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```

When used to refer to modules, the *fully qualified name* means the entire dotted path to the module, including any parent packages, e.g. `email.mime.text`:

```
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

reference count The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

regular package A traditional *package*, such as a directory containing an `__init__.py` file.

See also *namespace package*.

___slots___ A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

sequence An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `__len__()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `bytes`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

The `collections.abc.Sequence` abstract base class defines a much richer interface that goes beyond just `__getitem__()` and `__len__()`, adding `count()`, `index()`, `__contains__()`, and `__reversed__()`. Types that implement this expanded interface can be registered explicitly using `register()`.

single dispatch A form of *generic function* dispatch where the implementation is chosen based on the type of a single argument.

slice An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally.

special method A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in specialnames.

statement A statement is part of a suite (a "block" of code). A statement is either an *expression* or one of several constructs with a keyword, such as `if`, `while` or `for`.

struct sequence A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

text encoding A codec which encodes Unicode strings to bytes.

text file A *file object* able to read and write `str` objects. Often, a text file actually accesses a byte-oriented datastream and handles the *text encoding* automatically. Examples of text files are files opened in text mode (`'r'` or `'w'`), `sys.stdin`, `sys.stdout`, and instances of `io.StringIO`.

See also *binary file* for a file object able to read and write *bytes-like objects*.

triple-quoted string A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

type The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

type alias A synonym for a type, created by assigning the type to an identifier.

Type aliases are useful for simplifying *type hints*. For example:

```
from typing import List, Tuple

def remove_gray_shades(
        colors: List[Tuple[int, int, int]]) -> List[Tuple[int, int, int]]:
    pass
```

could be made more readable like this:

```
from typing import List, Tuple

Color = Tuple[int, int, int]

def remove_gray_shades(colors: List[Color]) -> List[Color]:
    pass
```

See `typing` and **PEP 484**, which describe this functionality.

type hint An *annotation* that specifies the expected type for a variable, a class attribute, or a function parameter or return value.

Type hints are optional and are not enforced by Python but they are useful to static type analysis tools, and aid IDEs with code completion and refactoring.

Type hints of global variables, class attributes, and functions, but not local variables, can be accessed using `typing.get_type_hints()`.

See `typing` and **PEP 484**, which describe this functionality.

universal newlines A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old

Macintosh convention `'\r'`. See **PEP 278** and **PEP 3116**, as well as `bytes.splitlines()` for an additional use.

variable annotation An *annotation* of a variable or a class attribute.

When annotating a variable or a class attribute, assignment is optional:

```
class C:
    field: 'annotation'
```

Variable annotations are usually used for *type hints*: for example this variable is expected to take `int` values:

```
count: int = 0
```

Variable annotation syntax is explained in section annassign.

See *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

virtual environment A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also `venv`.

virtual machine A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

Zen of Python Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing "`import this`" at the interactive prompt.

APPENDIX

B

ABOUT THESE DOCUMENTS

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the reporting-bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the Docutils project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.

B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See Misc/ACKS in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!

APPENDIX

C

HISTORY AND LICENSE

C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see https://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see https://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see https://opensource.org/ for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2 and above	2.1.1	2001-now	PSF	yes

Note: GPL-compatible doesn't mean that we're distributing Python under the GPL. All Python licenses, unlike the GPL, let you distribute a modified version without making your changes open source. The GPL-compatible licenses make it possible to combine Python with other software that is released under the GPL; the others don't.

Thanks to the many outside volunteers who have worked under Guido's direction to make these releases possible.

C.2 Terms and conditions for accessing or otherwise using Python

C.2.1 PSF LICENSE AGREEMENT FOR PYTHON 3.7.0

1. This LICENSE AGREEMENT is between the Python Software Foundation ("PSF"), and
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```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.

Before using, initialize the state by using init_genrand(seed)
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Any feedback is very welcome.
http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html
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```

C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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Modified by Jack Jansen, CWI, July 1995:
- Use binascii module to do the actual line-by-line conversion
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- Arguments more compliant with Python standard
```

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C.3.10 SipHash24

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Original location:
   https://github.com/majek/csiphash/

Solution inspired by code from:
   Samuel Neves (supercop/crypto_auth/siphash24/little)
   djb (supercop/crypto_auth/siphash24/little2)
   Jean-Philippe Aumasson (https://131002.net/siphash/siphash24.c)
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C.3.11 strtod and dtoa

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jloup@gzip.org          madler@alumni.caltech.edu
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The Python Language Reference

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Guido van Rossum
and the Python development team

July 07, 2018

Python Software Foundation
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Index 147

This reference manual describes the syntax and "core semantics" of the language. It is terse, but attempts to be exact and complete. The semantics of non-essential built-in object types and of the built-in functions and modules are described in library-index. For an informal introduction to the language, see tutorial-index. For C or C++ programmers, two additional manuals exist: extending-index describes the high-level picture of how to write a Python extension module, and the c-api-index describes the interfaces available to C/C++ programmers in detail.

CHAPTER

ONE

INTRODUCTION

This reference manual describes the Python programming language. It is not intended as a tutorial.

While I am trying to be as precise as possible, I chose to use English rather than formal specifications for everything except syntax and lexical analysis. This should make the document more understandable to the average reader, but will leave room for ambiguities. Consequently, if you were coming from Mars and tried to re-implement Python from this document alone, you might have to guess things and in fact you would probably end up implementing quite a different language. On the other hand, if you are using Python and wonder what the precise rules about a particular area of the language are, you should definitely be able to find them here. If you would like to see a more formal definition of the language, maybe you could volunteer your time — or invent a cloning machine :-).

It is dangerous to add too many implementation details to a language reference document — the implementation may change, and other implementations of the same language may work differently. On the other hand, CPython is the one Python implementation in widespread use (although alternate implementations continue to gain support), and its particular quirks are sometimes worth being mentioned, especially where the implementation imposes additional limitations. Therefore, you'll find short "implementation notes" sprinkled throughout the text.

Every Python implementation comes with a number of built-in and standard modules. These are documented in library-index. A few built-in modules are mentioned when they interact in a significant way with the language definition.

1.1 Alternate Implementations

Though there is one Python implementation which is by far the most popular, there are some alternate implementations which are of particular interest to different audiences.

Known implementations include:

CPython This is the original and most-maintained implementation of Python, written in C. New language features generally appear here first.

Jython Python implemented in Java. This implementation can be used as a scripting language for Java applications, or can be used to create applications using the Java class libraries. It is also often used to create tests for Java libraries. More information can be found at the Jython website.

Python for .NET This implementation actually uses the CPython implementation, but is a managed .NET application and makes .NET libraries available. It was created by Brian Lloyd. For more information, see the Python for .NET home page.

IronPython An alternate Python for .NET. Unlike Python.NET, this is a complete Python implementation that generates IL, and compiles Python code directly to .NET assemblies. It was created by Jim Hugunin, the original creator of Jython. For more information, see the IronPython website.

PyPy An implementation of Python written completely in Python. It supports several advanced features not found in other implementations like stackless support and a Just in Time compiler. One of the goals of the project is to encourage experimentation with the language itself by making it easier to modify the interpreter (since it is written in Python). Additional information is available on the PyPy project's home page.

Each of these implementations varies in some way from the language as documented in this manual, or introduces specific information beyond what's covered in the standard Python documentation. Please refer to the implementation-specific documentation to determine what else you need to know about the specific implementation you're using.

1.2 Notation

The descriptions of lexical analysis and syntax use a modified BNF grammar notation. This uses the following style of definition:

```
name        ::=   lc_letter (lc_letter | "_")*
lc_letter   ::=   "a"..."z"
```

The first line says that a `name` is an `lc_letter` followed by a sequence of zero or more `lc_letter`s and underscores. An `lc_letter` in turn is any of the single characters `'a'` through `'z'`. (This rule is actually adhered to for the names defined in lexical and grammar rules in this document.)

Each rule begins with a name (which is the name defined by the rule) and `::=`. A vertical bar (`|`) is used to separate alternatives; it is the least binding operator in this notation. A star (`*`) means zero or more repetitions of the preceding item; likewise, a plus (`+`) means one or more repetitions, and a phrase enclosed in square brackets (`[ ]`) means zero or one occurrences (in other words, the enclosed phrase is optional). The `*` and `+` operators bind as tightly as possible; parentheses are used for grouping. Literal strings are enclosed in quotes. White space is only meaningful to separate tokens. Rules are normally contained on a single line; rules with many alternatives may be formatted alternatively with each line after the first beginning with a vertical bar.

In lexical definitions (as the example above), two more conventions are used: Two literal characters separated by three dots mean a choice of any single character in the given (inclusive) range of ASCII characters. A phrase between angular brackets (`<...>`) gives an informal description of the symbol defined; e.g., this could be used to describe the notion of 'control character' if needed.

Even though the notation used is almost the same, there is a big difference between the meaning of lexical and syntactic definitions: a lexical definition operates on the individual characters of the input source, while a syntax definition operates on the stream of tokens generated by the lexical analysis. All uses of BNF in the next chapter ("Lexical Analysis") are lexical definitions; uses in subsequent chapters are syntactic definitions.

CHAPTER

TWO

LEXICAL ANALYSIS

A Python program is read by a *parser*. Input to the parser is a stream of *tokens*, generated by the *lexical analyzer*. This chapter describes how the lexical analyzer breaks a file into tokens.

Python reads program text as Unicode code points; the encoding of a source file can be given by an encoding declaration and defaults to UTF-8, see **PEP 3120** for details. If the source file cannot be decoded, a `SyntaxError` is raised.

2.1 Line structure

A Python program is divided into a number of *logical lines*.

2.1.1 Logical lines

The end of a logical line is represented by the token NEWLINE. Statements cannot cross logical line boundaries except where NEWLINE is allowed by the syntax (e.g., between statements in compound statements). A logical line is constructed from one or more *physical lines* by following the explicit or implicit *line joining* rules.

2.1.2 Physical lines

A physical line is a sequence of characters terminated by an end-of-line sequence. In source files and strings, any of the standard platform line termination sequences can be used - the Unix form using ASCII LF (linefeed), the Windows form using the ASCII sequence CR LF (return followed by linefeed), or the old Macintosh form using the ASCII CR (return) character. All of these forms can be used equally, regardless of platform. The end of input also serves as an implicit terminator for the final physical line.

When embedding Python, source code strings should be passed to Python APIs using the standard C conventions for newline characters (the `\n` character, representing ASCII LF, is the line terminator).

2.1.3 Comments

A comment starts with a hash character (`#`) that is not part of a string literal, and ends at the end of the physical line. A comment signifies the end of the logical line unless the implicit line joining rules are invoked. Comments are ignored by the syntax; they are not tokens.

2.1.4 Encoding declarations

If a comment in the first or second line of the Python script matches the regular expression `coding[=:]\s*([-\w.]+)`, this comment is processed as an encoding declaration; the first group of this expression names the encoding of the source code file. The encoding declaration must appear on a line of its own. If it is the second line, the first line must also be a comment-only line. The recommended forms of an encoding expression are

```
# -*- coding: <encoding-name> -*-
```

which is recognized also by GNU Emacs, and

```
# vim:fileencoding=<encoding-name>
```

which is recognized by Bram Moolenaar's VIM.

If no encoding declaration is found, the default encoding is UTF-8. In addition, if the first bytes of the file are the UTF-8 byte-order mark (`b'\xef\xbb\xbf'`), the declared file encoding is UTF-8 (this is supported, among others, by Microsoft's **notepad**).

If an encoding is declared, the encoding name must be recognized by Python. The encoding is used for all lexical analysis, including string literals, comments and identifiers.

2.1.5 Explicit line joining

Two or more physical lines may be joined into logical lines using backslash characters (\), as follows: when a physical line ends in a backslash that is not part of a string literal or comment, it is joined with the following forming a single logical line, deleting the backslash and the following end-of-line character. For example:

```
if 1900 < year < 2100 and 1 <= month <= 12 \
   and 1 <= day <= 31 and 0 <= hour < 24 \
   and 0 <= minute < 60 and 0 <= second < 60:   # Looks like a valid date
        return 1
```

A line ending in a backslash cannot carry a comment. A backslash does not continue a comment. A backslash does not continue a token except for string literals (i.e., tokens other than string literals cannot be split across physical lines using a backslash). A backslash is illegal elsewhere on a line outside a string literal.

2.1.6 Implicit line joining

Expressions in parentheses, square brackets or curly braces can be split over more than one physical line without using backslashes. For example:

```
month_names = ['Januari', 'Februari', 'Maart',      # These are the
               'April',   'Mei',      'Juni',       # Dutch names
               'Juli',    'Augustus', 'September',  # for the months
               'Oktober', 'November', 'December']   # of the year
```

Implicitly continued lines can carry comments. The indentation of the continuation lines is not important. Blank continuation lines are allowed. There is no NEWLINE token between implicit continuation lines. Implicitly continued lines can also occur within triple-quoted strings (see below); in that case they cannot carry comments.

2.1.7 Blank lines

A logical line that contains only spaces, tabs, formfeeds and possibly a comment, is ignored (i.e., no NEWLINE token is generated). During interactive input of statements, handling of a blank line may differ depending on the implementation of the read-eval-print loop. In the standard interactive interpreter, an entirely blank logical line (i.e. one containing not even whitespace or a comment) terminates a multi-line statement.

2.1.8 Indentation

Leading whitespace (spaces and tabs) at the beginning of a logical line is used to compute the indentation level of the line, which in turn is used to determine the grouping of statements.

Tabs are replaced (from left to right) by one to eight spaces such that the total number of characters up to and including the replacement is a multiple of eight (this is intended to be the same rule as used by Unix). The total number of spaces preceding the first non-blank character then determines the line's indentation. Indentation cannot be split over multiple physical lines using backslashes; the whitespace up to the first backslash determines the indentation.

Indentation is rejected as inconsistent if a source file mixes tabs and spaces in a way that makes the meaning dependent on the worth of a tab in spaces; a `TabError` is raised in that case.

Cross-platform compatibility note: because of the nature of text editors on non-UNIX platforms, it is unwise to use a mixture of spaces and tabs for the indentation in a single source file. It should also be noted that different platforms may explicitly limit the maximum indentation level.

A formfeed character may be present at the start of the line; it will be ignored for the indentation calculations above. Formfeed characters occurring elsewhere in the leading whitespace have an undefined effect (for instance, they may reset the space count to zero).

The indentation levels of consecutive lines are used to generate INDENT and DEDENT tokens, using a stack, as follows.

Before the first line of the file is read, a single zero is pushed on the stack; this will never be popped off again. The numbers pushed on the stack will always be strictly increasing from bottom to top. At the beginning of each logical line, the line's indentation level is compared to the top of the stack. If it is equal, nothing happens. If it is larger, it is pushed on the stack, and one INDENT token is generated. If it is smaller, it *must* be one of the numbers occurring on the stack; all numbers on the stack that are larger are popped off, and for each number popped off a DEDENT token is generated. At the end of the file, a DEDENT token is generated for each number remaining on the stack that is larger than zero.

Here is an example of a correctly (though confusingly) indented piece of Python code:

```
def perm(l):
        # Compute the list of all permutations of l
    if len(l) <= 1:
                  return [l]
    r = []
    for i in range(len(l)):
             s = l[:i] + l[i+1:]
             p = perm(s)
             for x in p:
              r.append(l[i:i+1] + x)
    return r
```

The following example shows various indentation errors:

```
 def perm(l):                        # error: first line indented
for i in range(len(l)):              # error: not indented
    s = l[:i] + l[i+1:]
        p = perm(l[:i] + l[i+1:])   # error: unexpected indent
        for x in p:
                r.append(l[i:i+1] + x)
            return r                # error: inconsistent dedent
```

(Actually, the first three errors are detected by the parser; only the last error is found by the lexical analyzer — the indentation of `return r` does not match a level popped off the stack.)

2.1.9 Whitespace between tokens

Except at the beginning of a logical line or in string literals, the whitespace characters space, tab and formfeed can be used interchangeably to separate tokens. Whitespace is needed between two tokens only if their concatenation could otherwise be interpreted as a different token (e.g., ab is one token, but a b is two tokens).

2.2 Other tokens

Besides NEWLINE, INDENT and DEDENT, the following categories of tokens exist: *identifiers*, *keywords*, *literals*, *operators*, and *delimiters*. Whitespace characters (other than line terminators, discussed earlier) are not tokens, but serve to delimit tokens. Where ambiguity exists, a token comprises the longest possible string that forms a legal token, when read from left to right.

2.3 Identifiers and keywords

Identifiers (also referred to as *names*) are described by the following lexical definitions.

The syntax of identifiers in Python is based on the Unicode standard annex UAX-31, with elaboration and changes as defined below; see also **PEP 3131** for further details.

Within the ASCII range (U+0001..U+007F), the valid characters for identifiers are the same as in Python 2.x: the uppercase and lowercase letters `A` through `Z`, the underscore `_` and, except for the first character, the digits `0` through `9`.

Python 3.0 introduces additional characters from outside the ASCII range (see **PEP 3131**). For these characters, the classification uses the version of the Unicode Character Database as included in the `unicodedata` module.

Identifiers are unlimited in length. Case is significant.

```
identifier    ::=  xid_start xid_continue*
id_start      ::=  <all characters in general categories Lu, Ll, Lt, Lm, Lo, Nl, the underscore, and
id_continue   ::=  <all characters in id_start, plus characters in the categories Mn, Mc, Nd, Pc and
xid_start     ::=  <all characters in id_start whose NFKC normalization is in "id_start xid_continue*
xid_continue  ::=  <all characters in id_continue whose NFKC normalization is in "id_continue*">
```

The Unicode category codes mentioned above stand for:

- *Lu* - uppercase letters
- *Ll* - lowercase letters

- *Lt* - titlecase letters
- *Lm* - modifier letters
- *Lo* - other letters
- *Nl* - letter numbers
- *Mn* - nonspacing marks
- *Mc* - spacing combining marks
- *Nd* - decimal numbers
- *Pc* - connector punctuations
- *Other_ID_Start* - explicit list of characters in PropList.txt to support backwards compatibility
- *Other_ID_Continue* - likewise

All identifiers are converted into the normal form NFKC while parsing; comparison of identifiers is based on NFKC.

A non-normative HTML file listing all valid identifier characters for Unicode 4.1 can be found at https://www.dcl.hpi.uni-potsdam.de/home/loewis/table-3131.html.

2.3.1 Keywords

The following identifiers are used as reserved words, or *keywords* of the language, and cannot be used as ordinary identifiers. They must be spelled exactly as written here:

```
False      await      else       import     pass
None       break      except     in         raise
True       class      finally    is         return
and        continue   for        lambda     try
as         def        from       nonlocal   while
assert     del        global     not        with
async      elif       if         or         yield
```

2.3.2 Reserved classes of identifiers

Certain classes of identifiers (besides keywords) have special meanings. These classes are identified by the patterns of leading and trailing underscore characters:

`_*` Not imported by `from module import *`. The special identifier `_` is used in the interactive interpreter to store the result of the last evaluation; it is stored in the `builtins` module. When not in interactive mode, `_` has no special meaning and is not defined. See section *The import statement*.

> **Note:** The name `_` is often used in conjunction with internationalization; refer to the documentation for the `gettext` module for more information on this convention.

`__*__` System-defined names. These names are defined by the interpreter and its implementation (including the standard library). Current system names are discussed in the *Special method names* section and elsewhere. More will likely be defined in future versions of Python. *Any* use of `__*__` names, in any context, that does not follow explicitly documented use, is subject to breakage without warning.

`__*` Class-private names. Names in this category, when used within the context of a class definition, are re-written to use a mangled form to help avoid name clashes between "private" attributes of base and derived classes. See section *Identifiers (Names)*.

2.4 Literals

Literals are notations for constant values of some built-in types.

2.4.1 String and Bytes literals

String literals are described by the following lexical definitions:

```
stringliteral     ::=   [stringprefix](shortstring | longstring)
stringprefix      ::=   "r" | "u" | "R" | "U" | "f" | "F"
                        | "fr" | "Fr" | "fR" | "FR" | "rf" | "rF" | "Rf" | "RF"
shortstring       ::=   "'" shortstringitem* "'" | '"' shortstringitem* '"'
longstring        ::=   "'''" longstringitem* "'''" | '"""' longstringitem* '"""'
shortstringitem   ::=   shortstringchar | stringescapeseq
longstringitem    ::=   longstringchar | stringescapeseq
shortstringchar   ::=   <any source character except "\" or newline or the quote>
longstringchar    ::=   <any source character except "\">
stringescapeseq   ::=   "\" <any source character>
```

```
bytesliteral     ::=   bytesprefix(shortbytes | longbytes)
bytesprefix      ::=   "b" | "B" | "br" | "Br" | "bR" | "BR" | "rb" | "rB" | "Rb" | "RB"
shortbytes       ::=   "'" shortbytesitem* "'" | '"' shortbytesitem* '"'
longbytes        ::=   "'''" longbytesitem* "'''" | '"""' longbytesitem* '"""'
shortbytesitem   ::=   shortbyteschar | bytesescapeseq
longbytesitem    ::=   longbyteschar | bytesescapeseq
shortbyteschar   ::=   <any ASCII character except "\" or newline or the quote>
longbyteschar    ::=   <any ASCII character except "\">
bytesescapeseq   ::=   "\" <any ASCII character>
```

One syntactic restriction not indicated by these productions is that whitespace is not allowed between the *stringprefix* or *bytesprefix* and the rest of the literal. The source character set is defined by the encoding declaration; it is UTF-8 if no encoding declaration is given in the source file; see section *Encoding declarations*.

In plain English: Both types of literals can be enclosed in matching single quotes (') or double quotes ("). They can also be enclosed in matching groups of three single or double quotes (these are generally referred to as *triple-quoted strings*). The backslash (\) character is used to escape characters that otherwise have a special meaning, such as newline, backslash itself, or the quote character.

Bytes literals are always prefixed with `'b'` or `'B'`; they produce an instance of the `bytes` type instead of the `str` type. They may only contain ASCII characters; bytes with a numeric value of 128 or greater must be expressed with escapes.

Both string and bytes literals may optionally be prefixed with a letter `'r'` or `'R'`; such strings are called *raw strings* and treat backslashes as literal characters. As a result, in string literals, `'\U'` and `'\u'` escapes in raw strings are not treated specially. Given that Python 2.x's raw unicode literals behave differently than Python 3.x's the `'ur'` syntax is not supported.

New in version 3.3: The `'rb'` prefix of raw bytes literals has been added as a synonym of `'br'`.

New in version 3.3: Support for the unicode legacy literal (`u'value'`) was reintroduced to simplify the maintenance of dual Python 2.x and 3.x codebases. See **PEP 414** for more information.

A string literal with `'f'` or `'F'` in its prefix is a *formatted string literal*; see *Formatted string literals*. The `'f'` may be combined with `'r'`, but not with `'b'` or `'u'`, therefore raw formatted strings are possible, but

formatted bytes literals are not.

In triple-quoted literals, unescaped newlines and quotes are allowed (and are retained), except that three unescaped quotes in a row terminate the literal. (A "quote" is the character used to open the literal, i.e. either `'` or `"`.)

Unless an `'r'` or `'R'` prefix is present, escape sequences in string and bytes literals are interpreted according to rules similar to those used by Standard C. The recognized escape sequences are:

Escape Sequence	Meaning	Notes
`\newline`	Backslash and newline ignored	
`\\`	Backslash (\)	
`\'`	Single quote (')	
`\"`	Double quote (")	
`\a`	ASCII Bell (BEL)	
`\b`	ASCII Backspace (BS)	
`\f`	ASCII Formfeed (FF)	
`\n`	ASCII Linefeed (LF)	
`\r`	ASCII Carriage Return (CR)	
`\t`	ASCII Horizontal Tab (TAB)	
`\v`	ASCII Vertical Tab (VT)	
`\ooo`	Character with octal value *ooo*	(1,3)
`\xhh`	Character with hex value *hh*	(2,3)

Escape sequences only recognized in string literals are:

Escape Sequence	Meaning	Notes
`\N{name}`	Character named *name* in the Unicode database	(4)
`\uxxxx`	Character with 16-bit hex value *xxxx*	(5)
`\Uxxxxxxxx`	Character with 32-bit hex value *xxxxxxxx*	(6)

Notes:

1. As in Standard C, up to three octal digits are accepted.
2. Unlike in Standard C, exactly two hex digits are required.
3. In a bytes literal, hexadecimal and octal escapes denote the byte with the given value. In a string literal, these escapes denote a Unicode character with the given value.
4. Changed in version 3.3: Support for name aliases[1] has been added.
5. Exactly four hex digits are required.
6. Any Unicode character can be encoded this way. Exactly eight hex digits are required.

Unlike Standard C, all unrecognized escape sequences are left in the string unchanged, i.e., *the backslash is left in the result*. (This behavior is useful when debugging: if an escape sequence is mistyped, the resulting output is more easily recognized as broken.) It is also important to note that the escape sequences only recognized in string literals fall into the category of unrecognized escapes for bytes literals.

> Changed in version 3.6: Unrecognized escape sequences produce a DeprecationWarning. In some future version of Python they will be a SyntaxError.

Even in a raw literal, quotes can be escaped with a backslash, but the backslash remains in the result; for example, `r"\""` is a valid string literal consisting of two characters: a backslash and a double quote; `r"\"` is not a valid string literal (even a raw string cannot end in an odd number of backslashes). Specifically, *a raw literal cannot end in a single backslash* (since the backslash would escape the following quote character).

[1] http://www.unicode.org/Public/11.0.0/ucd/NameAliases.txt

Note also that a single backslash followed by a newline is interpreted as those two characters as part of the literal, *not* as a line continuation.

2.4.2 String literal concatenation

Multiple adjacent string or bytes literals (delimited by whitespace), possibly using different quoting conventions, are allowed, and their meaning is the same as their concatenation. Thus, `"hello" 'world'` is equivalent to `"helloworld"`. This feature can be used to reduce the number of backslashes needed, to split long strings conveniently across long lines, or even to add comments to parts of strings, for example:

```
re.compile("[A-Za-z_]"       # letter or underscore
           "[A-Za-z0-9_]*"   # letter, digit or underscore
          )
```

Note that this feature is defined at the syntactical level, but implemented at compile time. The '+' operator must be used to concatenate string expressions at run time. Also note that literal concatenation can use different quoting styles for each component (even mixing raw strings and triple quoted strings), and formatted string literals may be concatenated with plain string literals.

2.4.3 Formatted string literals

New in version 3.6.

A *formatted string literal* or *f-string* is a string literal that is prefixed with `'f'` or `'F'`. These strings may contain replacement fields, which are expressions delimited by curly braces `{}`. While other string literals always have a constant value, formatted strings are really expressions evaluated at run time.

Escape sequences are decoded like in ordinary string literals (except when a literal is also marked as a raw string). After decoding, the grammar for the contents of the string is:

```
f_string          ::=  (literal_char | "{{" | "}}" | replacement_field)*
replacement_field ::=  "{" f_expression ["!" conversion] [":" format_spec] "}"
f_expression      ::=  (conditional_expression | "*" or_expr)
                       ("," conditional_expression | "," "*" or_expr)* [","]
                       | yield_expression
conversion        ::=  "s" | "r" | "a"
format_spec       ::=  (literal_char | NULL | replacement_field)*
literal_char      ::=  <any code point except "{", "}" or NULL>
```

The parts of the string outside curly braces are treated literally, except that any doubled curly braces `'{{'` or `'}}'` are replaced with the corresponding single curly brace. A single opening curly bracket `'{'` marks a replacement field, which starts with a Python expression. After the expression, there may be a conversion field, introduced by an exclamation point `'!'`. A format specifier may also be appended, introduced by a colon `':'`. A replacement field ends with a closing curly bracket `'}'`.

Expressions in formatted string literals are treated like regular Python expressions surrounded by parentheses, with a few exceptions. An empty expression is not allowed, and a *lambda* expression must be surrounded by explicit parentheses. Replacement expressions can contain line breaks (e.g. in triple-quoted strings), but they cannot contain comments. Each expression is evaluated in the context where the formatted string literal appears, in order from left to right.

If a conversion is specified, the result of evaluating the expression is converted before formatting. Conversion `'!s'` calls `str()` on the result, `'!r'` calls `repr()`, and `'!a'` calls `ascii()`.

The result is then formatted using the `format()` protocol. The format specifier is passed to the *__format__()*

method of the expression or conversion result. An empty string is passed when the format specifier is omitted. The formatted result is then included in the final value of the whole string.

Top-level format specifiers may include nested replacement fields. These nested fields may include their own conversion fields and format specifiers, but may not include more deeply-nested replacement fields. The format specifier mini-language is the same as that used by the string .format() method.

Formatted string literals may be concatenated, but replacement fields cannot be split across literals.

Some examples of formatted string literals:

```
>>> name = "Fred"
>>> f"He said his name is {name!r}."
"He said his name is 'Fred'."
>>> f"He said his name is {repr(name)}."  # repr() is equivalent to !r
"He said his name is 'Fred'."
>>> width = 10
>>> precision = 4
>>> value = decimal.Decimal("12.34567")
>>> f"result: {value:{width}.{precision}}"  # nested fields
'result:      12.35'
>>> today = datetime(year=2017, month=1, day=27)
>>> f"{today:%B %d, %Y}"  # using date format specifier
'January 27, 2017'
>>> number = 1024
>>> f"{number:#0x}"  # using integer format specifier
'0x400'
```

A consequence of sharing the same syntax as regular string literals is that characters in the replacement fields must not conflict with the quoting used in the outer formatted string literal:

```
f"abc {a["x"]} def"    # error: outer string literal ended prematurely
f"abc {a['x']} def"    # workaround: use different quoting
```

Backslashes are not allowed in format expressions and will raise an error:

```
f"newline: {ord('\n')}"  # raises SyntaxError
```

To include a value in which a backslash escape is required, create a temporary variable.

```
>>> newline = ord('\n')
>>> f"newline: {newline}"
'newline: 10'
```

Formatted string literals cannot be used as docstrings, even if they do not include expressions.

```
>>> def foo():
...     f"Not a docstring"
...
>>> foo.__doc__ is None
True
```

See also **PEP 498** for the proposal that added formatted string literals, and `str.format()`, which uses a related format string mechanism.

2.4.4 Numeric literals

There are three types of numeric literals: integers, floating point numbers, and imaginary numbers. There are no complex literals (complex numbers can be formed by adding a real number and an imaginary number).

Note that numeric literals do not include a sign; a phrase like `-1` is actually an expression composed of the unary operator '`-`' and the literal `1`.

2.4.5 Integer literals

Integer literals are described by the following lexical definitions:

```
integer        ::=   decinteger | bininteger | octinteger | hexinteger
decinteger     ::=   nonzerodigit (["_"] digit)* | "0"+ (["_"] "0")*
bininteger     ::=   "0" ("b" | "B") (["_"] bindigit)+
octinteger     ::=   "0" ("o" | "O") (["_"] octdigit)+
hexinteger     ::=   "0" ("x" | "X") (["_"] hexdigit)+
nonzerodigit   ::=   "1"..."9"
digit          ::=   "0"..."9"
bindigit       ::=   "0" | "1"
octdigit       ::=   "0"..."7"
hexdigit       ::=   digit | "a"..."f" | "A"..."F"
```

There is no limit for the length of integer literals apart from what can be stored in available memory.

Underscores are ignored for determining the numeric value of the literal. They can be used to group digits for enhanced readability. One underscore can occur between digits, and after base specifiers like `0x`.

Note that leading zeros in a non-zero decimal number are not allowed. This is for disambiguation with C-style octal literals, which Python used before version 3.0.

Some examples of integer literals:

```
7     2147483647                        0o177    0b100110111
3     79228162514264337593543950336     0o377    0xdeadbeef
      100_000_000_000                   0b_1110_0101
```

Changed in version 3.6: Underscores are now allowed for grouping purposes in literals.

2.4.6 Floating point literals

Floating point literals are described by the following lexical definitions:

```
floatnumber    ::=   pointfloat | exponentfloat
pointfloat     ::=   [digitpart] fraction | digitpart "."
exponentfloat  ::=   (digitpart | pointfloat) exponent
digitpart      ::=   digit (["_"] digit)*
fraction       ::=   "." digitpart
exponent       ::=   ("e" | "E") ["+" | "-"] digitpart
```

Note that the integer and exponent parts are always interpreted using radix 10. For example, `077e010` is legal, and denotes the same number as `77e10`. The allowed range of floating point literals is implementation-dependent. As in integer literals, underscores are supported for digit grouping.

Some examples of floating point literals:

```
3.14    10.    .001    1e100    3.14e-10    0e0    3.14_15_93
```

Changed in version 3.6: Underscores are now allowed for grouping purposes in literals.

2.4.7 Imaginary literals

Imaginary literals are described by the following lexical definitions:

```
imagnumber  ::=  (floatnumber | digitpart) ("j" | "J")
```

An imaginary literal yields a complex number with a real part of 0.0. Complex numbers are represented as a pair of floating point numbers and have the same restrictions on their range. To create a complex number with a nonzero real part, add a floating point number to it, e.g., `(3+4j)`. Some examples of imaginary literals:

```
3.14j   10.j    10j     .001j   1e100j   3.14e-10j   3.14_15_93j
```

2.5 Operators

The following tokens are operators:

```
+       -       *       **      /       //      %      @
<<      >>      &       |       ^       ~
<       >       <=      >=      ==      !=
```

2.6 Delimiters

The following tokens serve as delimiters in the grammar:

```
(       )       [       ]       {       }
,       :       .       ;       @       =       ->
+=      -=      *=      /=      //=     %=      @=
&=      |=      ^=      >>=     <<=     **=
```

The period can also occur in floating-point and imaginary literals. A sequence of three periods has a special meaning as an ellipsis literal. The second half of the list, the augmented assignment operators, serve lexically as delimiters, but also perform an operation.

The following printing ASCII characters have special meaning as part of other tokens or are otherwise significant to the lexical analyzer:

```
'       "       #       \
```

The following printing ASCII characters are not used in Python. Their occurrence outside string literals and comments is an unconditional error:

```
$       ?       `
```

CHAPTER

THREE

DATA MODEL

3.1 Objects, values and types

Objects are Python's abstraction for data. All data in a Python program is represented by objects or by relations between objects. (In a sense, and in conformance to Von Neumann's model of a "stored program computer," code is also represented by objects.)

Every object has an identity, a type and a value. An object's *identity* never changes once it has been created; you may think of it as the object's address in memory. The '*is*' operator compares the identity of two objects; the `id()` function returns an integer representing its identity.

CPython implementation detail: For CPython, `id(x)` is the memory address where `x` is stored.

An object's type determines the operations that the object supports (e.g., "does it have a length?") and also defines the possible values for objects of that type. The `type()` function returns an object's type (which is an object itself). Like its identity, an object's *type* is also unchangeable.[1]

The *value* of some objects can change. Objects whose value can change are said to be *mutable*; objects whose value is unchangeable once they are created are called *immutable*. (The value of an immutable container object that contains a reference to a mutable object can change when the latter's value is changed; however the container is still considered immutable, because the collection of objects it contains cannot be changed. So, immutability is not strictly the same as having an unchangeable value, it is more subtle.) An object's mutability is determined by its type; for instance, numbers, strings and tuples are immutable, while dictionaries and lists are mutable.

Objects are never explicitly destroyed; however, when they become unreachable they may be garbage-collected. An implementation is allowed to postpone garbage collection or omit it altogether — it is a matter of implementation quality how garbage collection is implemented, as long as no objects are collected that are still reachable.

CPython implementation detail: CPython currently uses a reference-counting scheme with (optional) delayed detection of cyclically linked garbage, which collects most objects as soon as they become unreachable, but is not guaranteed to collect garbage containing circular references. See the documentation of the `gc` module for information on controlling the collection of cyclic garbage. Other implementations act differently and CPython may change. Do not depend on immediate finalization of objects when they become unreachable (so you should always close files explicitly).

Note that the use of the implementation's tracing or debugging facilities may keep objects alive that would normally be collectable. Also note that catching an exception with a '*try*…*except*' statement may keep objects alive.

Some objects contain references to "external" resources such as open files or windows. It is understood that these resources are freed when the object is garbage-collected, but since garbage collection is not guaranteed to happen, such objects also provide an explicit way to release the external resource, usually a

[1] It *is* possible in some cases to change an object's type, under certain controlled conditions. It generally isn't a good idea though, since it can lead to some very strange behaviour if it is handled incorrectly.

`close()` method. Programs are strongly recommended to explicitly close such objects. The '*try*…*finally*' statement and the '*with*' statement provide convenient ways to do this.

Some objects contain references to other objects; these are called *containers*. Examples of containers are tuples, lists and dictionaries. The references are part of a container's value. In most cases, when we talk about the value of a container, we imply the values, not the identities of the contained objects; however, when we talk about the mutability of a container, only the identities of the immediately contained objects are implied. So, if an immutable container (like a tuple) contains a reference to a mutable object, its value changes if that mutable object is changed.

Types affect almost all aspects of object behavior. Even the importance of object identity is affected in some sense: for immutable types, operations that compute new values may actually return a reference to any existing object with the same type and value, while for mutable objects this is not allowed. E.g., after `a = 1; b = 1`, `a` and `b` may or may not refer to the same object with the value one, depending on the implementation, but after `c = []; d = []`, `c` and `d` are guaranteed to refer to two different, unique, newly created empty lists. (Note that `c = d = []` assigns the same object to both `c` and `d`.)

3.2 The standard type hierarchy

Below is a list of the types that are built into Python. Extension modules (written in C, Java, or other languages, depending on the implementation) can define additional types. Future versions of Python may add types to the type hierarchy (e.g., rational numbers, efficiently stored arrays of integers, etc.), although such additions will often be provided via the standard library instead.

Some of the type descriptions below contain a paragraph listing 'special attributes.' These are attributes that provide access to the implementation and are not intended for general use. Their definition may change in the future.

None This type has a single value. There is a single object with this value. This object is accessed through the built-in name `None`. It is used to signify the absence of a value in many situations, e.g., it is returned from functions that don't explicitly return anything. Its truth value is false.

NotImplemented This type has a single value. There is a single object with this value. This object is accessed through the built-in name `NotImplemented`. Numeric methods and rich comparison methods should return this value if they do not implement the operation for the operands provided. (The interpreter will then try the reflected operation, or some other fallback, depending on the operator.) Its truth value is true.

See implementing-the-arithmetic-operations for more details.

Ellipsis This type has a single value. There is a single object with this value. This object is accessed through the literal `...` or the built-in name `Ellipsis`. Its truth value is true.

`numbers.Number` These are created by numeric literals and returned as results by arithmetic operators and arithmetic built-in functions. Numeric objects are immutable; once created their value never changes. Python numbers are of course strongly related to mathematical numbers, but subject to the limitations of numerical representation in computers.

Python distinguishes between integers, floating point numbers, and complex numbers:

`numbers.Integral` These represent elements from the mathematical set of integers (positive and negative).

There are two types of integers:

Integers (`int`)

These represent numbers in an unlimited range, subject to available (virtual) memory only. For the purpose of shift and mask operations, a binary representation is assumed,

and negative numbers are represented in a variant of 2's complement which gives the illusion of an infinite string of sign bits extending to the left.

Booleans (`bool`) These represent the truth values False and True. The two objects representing the values `False` and `True` are the only Boolean objects. The Boolean type is a subtype of the integer type, and Boolean values behave like the values 0 and 1, respectively, in almost all contexts, the exception being that when converted to a string, the strings `"False"` or `"True"` are returned, respectively.

The rules for integer representation are intended to give the most meaningful interpretation of shift and mask operations involving negative integers.

`numbers.Real` (`float`) These represent machine-level double precision floating point numbers. You are at the mercy of the underlying machine architecture (and C or Java implementation) for the accepted range and handling of overflow. Python does not support single-precision floating point numbers; the savings in processor and memory usage that are usually the reason for using these are dwarfed by the overhead of using objects in Python, so there is no reason to complicate the language with two kinds of floating point numbers.

`numbers.Complex` (`complex`) These represent complex numbers as a pair of machine-level double precision floating point numbers. The same caveats apply as for floating point numbers. The real and imaginary parts of a complex number `z` can be retrieved through the read-only attributes `z.real` and `z.imag`.

Sequences These represent finite ordered sets indexed by non-negative numbers. The built-in function `len()` returns the number of items of a sequence. When the length of a sequence is n, the index set contains the numbers 0, 1, ..., n-1. Item i of sequence a is selected by `a[i]`.

Sequences also support slicing: `a[i:j]` selects all items with index k such that i `<=` k `<` j. When used as an expression, a slice is a sequence of the same type. This implies that the index set is renumbered so that it starts at 0.

Some sequences also support "extended slicing" with a third "step" parameter: `a[i:j:k]` selects all items of a with index x where `x = i + n*k`, n `>=` `0` and i `<=` x `<` j.

Sequences are distinguished according to their mutability:

Immutable sequences An object of an immutable sequence type cannot change once it is created. (If the object contains references to other objects, these other objects may be mutable and may be changed; however, the collection of objects directly referenced by an immutable object cannot change.)

The following types are immutable sequences:

Strings A string is a sequence of values that represent Unicode code points. All the code points in the range `U+0000 - U+10FFFF` can be represented in a string. Python doesn't have a `char` type; instead, every code point in the string is represented as a string object with length `1`. The built-in function `ord()` converts a code point from its string form to an integer in the range `0 - 10FFFF`; `chr()` converts an integer in the range `0 - 10FFFF` to the corresponding length `1` string object. `str.encode()` can be used to convert a `str` to `bytes` using the given text encoding, and `bytes.decode()` can be used to achieve the opposite.

Tuples The items of a tuple are arbitrary Python objects. Tuples of two or more items are formed by comma-separated lists of expressions. A tuple of one item (a 'singleton') can be formed by affixing a comma to an expression (an expression by itself does not create a tuple, since parentheses must be usable for grouping of expressions). An empty tuple can be formed by an empty pair of parentheses.

Bytes A bytes object is an immutable array. The items are 8-bit bytes, represented by integers in the range 0 <= x < 256. Bytes literals (like `b'abc'`) and the built-in `bytes()` constructor

can be used to create bytes objects. Also, bytes objects can be decoded to strings via the `decode()` method.

Mutable sequences Mutable sequences can be changed after they are created. The subscription and slicing notations can be used as the target of assignment and *del* (delete) statements.

There are currently two intrinsic mutable sequence types:

Lists The items of a list are arbitrary Python objects. Lists are formed by placing a comma-separated list of expressions in square brackets. (Note that there are no special cases needed to form lists of length 0 or 1.)

Byte Arrays A bytearray object is a mutable array. They are created by the built-in `bytearray()` constructor. Aside from being mutable (and hence unhashable), byte arrays otherwise provide the same interface and functionality as immutable `bytes` objects.

The extension module `array` provides an additional example of a mutable sequence type, as does the `collections` module.

Set types These represent unordered, finite sets of unique, immutable objects. As such, they cannot be indexed by any subscript. However, they can be iterated over, and the built-in function `len()` returns the number of items in a set. Common uses for sets are fast membership testing, removing duplicates from a sequence, and computing mathematical operations such as intersection, union, difference, and symmetric difference.

For set elements, the same immutability rules apply as for dictionary keys. Note that numeric types obey the normal rules for numeric comparison: if two numbers compare equal (e.g., `1` and `1.0`), only one of them can be contained in a set.

There are currently two intrinsic set types:

Sets These represent a mutable set. They are created by the built-in `set()` constructor and can be modified afterwards by several methods, such as `add()`.

Frozen sets These represent an immutable set. They are created by the built-in `frozenset()` constructor. As a frozenset is immutable and *hashable*, it can be used again as an element of another set, or as a dictionary key.

Mappings These represent finite sets of objects indexed by arbitrary index sets. The subscript notation `a[k]` selects the item indexed by `k` from the mapping `a`; this can be used in expressions and as the target of assignments or *del* statements. The built-in function `len()` returns the number of items in a mapping.

There is currently a single intrinsic mapping type:

Dictionaries These represent finite sets of objects indexed by nearly arbitrary values. The only types of values not acceptable as keys are values containing lists or dictionaries or other mutable types that are compared by value rather than by object identity, the reason being that the efficient implementation of dictionaries requires a key's hash value to remain constant. Numeric types used for keys obey the normal rules for numeric comparison: if two numbers compare equal (e.g., `1` and `1.0`) then they can be used interchangeably to index the same dictionary entry.

Dictionaries are mutable; they can be created by the `{...}` notation (see section *Dictionary displays*).

The extension modules `dbm.ndbm` and `dbm.gnu` provide additional examples of mapping types, as does the `collections` module.

Callable types These are the types to which the function call operation (see section *Calls*) can be applied:

User-defined functions A user-defined function object is created by a function definition (see section *Function definitions*). It should be called with an argument list containing the same number of items as the function's formal parameter list.

Special attributes:

Attribute	Meaning	
`__doc__`	The function's documentation string, or `None` if unavailable; not inherited by subclasses	Writable
`__name__`	The function's name	Writable
`__qualname__`	The function's *qualified name* New in version 3.3.	Writable
`__module__`	The name of the module the function was defined in, or `None` if unavailable.	Writable
`__defaults__`	A tuple containing default argument values for those arguments that have defaults, or `None` if no arguments have a default value	Writable
`__code__`	The code object representing the compiled function body.	Writable
`__globals__`	A reference to the dictionary that holds the function's global variables — the global namespace of the module in which the function was defined.	Read-only
`__dict__`	The namespace supporting arbitrary function attributes.	Writable
`__closure__`	`None` or a tuple of cells that contain bindings for the function's free variables. See below for information on the `cell_contents` attribute.	Read-only
`__annotations__`	A dict containing annotations of parameters. The keys of the dict are the parameter names, and `'return'` for the return annotation, if provided.	Writable
`__kwdefaults__`	A dict containing defaults for keyword-only parameters.	Writable

Most of the attributes labelled "Writable" check the type of the assigned value.

Function objects also support getting and setting arbitrary attributes, which can be used, for example, to attach metadata to functions. Regular attribute dot-notation is used to get and set such attributes. *Note that the current implementation only supports function attributes on user-defined functions. Function attributes on built-in functions may be supported in the future.*

A cell object has the attribute `cell_contents`. This can be used to get the value of the cell, as well as set the value.

Additional information about a function's definition can be retrieved from its code object; see the description of internal types below.

Instance methods An instance method object combines a class, a class instance and any callable object (normally a user-defined function).

Special read-only attributes: `__self__` is the class instance object, `__func__` is the function object; `__doc__` is the method's documentation (same as `__func__.__doc__`); `__name__` is the method name (same as `__func__.__name__`); `__module__` is the name of the module the method was defined in, or `None` if unavailable.

Methods also support accessing (but not setting) the arbitrary function attributes on the underlying function object.

User-defined method objects may be created when getting an attribute of a class (perhaps via an instance of that class), if that attribute is a user-defined function object or a class method object.

When an instance method object is created by retrieving a user-defined function object from a class via one of its instances, its `__self__` attribute is the instance, and the method object is said to be bound. The new method's `__func__` attribute is the original function object.

When a user-defined method object is created by retrieving another method object from a class or

instance, the behaviour is the same as for a function object, except that the `__func__` attribute of the new instance is not the original method object but its `__func__` attribute.

When an instance method object is created by retrieving a class method object from a class or instance, its `__self__` attribute is the class itself, and its `__func__` attribute is the function object underlying the class method.

When an instance method object is called, the underlying function (`__func__`) is called, inserting the class instance (`__self__`) in front of the argument list. For instance, when `C` is a class which contains a definition for a function `f()`, and `x` is an instance of `C`, calling `x.f(1)` is equivalent to calling `C.f(x, 1)`.

When an instance method object is derived from a class method object, the "class instance" stored in `__self__` will actually be the class itself, so that calling either `x.f(1)` or `C.f(1)` is equivalent to calling `f(C,1)` where `f` is the underlying function.

Note that the transformation from function object to instance method object happens each time the attribute is retrieved from the instance. In some cases, a fruitful optimization is to assign the attribute to a local variable and call that local variable. Also notice that this transformation only happens for user-defined functions; other callable objects (and all non-callable objects) are retrieved without transformation. It is also important to note that user-defined functions which are attributes of a class instance are not converted to bound methods; this *only* happens when the function is an attribute of the class.

Generator functions A function or method which uses the *yield* statement (see section *The yield statement*) is called a *generator function*. Such a function, when called, always returns an iterator object which can be used to execute the body of the function: calling the iterator's `iterator.__next__()` method will cause the function to execute until it provides a value using the *yield* statement. When the function executes a *return* statement or falls off the end, a `StopIteration` exception is raised and the iterator will have reached the end of the set of values to be returned.

Coroutine functions A function or method which is defined using *async def* is called a *coroutine function*. Such a function, when called, returns a *coroutine* object. It may contain *await* expressions, as well as *async with* and *async for* statements. See also the *Coroutine Objects* section.

Asynchronous generator functions A function or method which is defined using *async def* and which uses the *yield* statement is called a *asynchronous generator function*. Such a function, when called, returns an asynchronous iterator object which can be used in an *async for* statement to execute the body of the function.

Calling the asynchronous iterator's `aiterator.__anext__()` method will return an *awaitable* which when awaited will execute until it provides a value using the *yield* expression. When the function executes an empty *return* statement or falls off the end, a `StopAsyncIteration` exception is raised and the asynchronous iterator will have reached the end of the set of values to be yielded.

Built-in functions A built-in function object is a wrapper around a C function. Examples of built-in functions are `len()` and `math.sin()` (`math` is a standard built-in module). The number and type of the arguments are determined by the C function. Special read-only attributes: `__doc__` is the function's documentation string, or `None` if unavailable; `__name__` is the function's name; `__self__` is set to `None` (but see the next item); `__module__` is the name of the module the function was defined in or `None` if unavailable.

Built-in methods This is really a different disguise of a built-in function, this time containing an object passed to the C function as an implicit extra argument. An example of a built-in method is `alist.append()`, assuming *alist* is a list object. In this case, the special read-only attribute `__self__` is set to the object denoted by *alist*.

Classes Classes are callable. These objects normally act as factories for new instances of themselves,

but variations are possible for class types that override *__new__()*. The arguments of the call are passed to *__new__()* and, in the typical case, to *__init__()* to initialize the new instance.

Class Instances Instances of arbitrary classes can be made callable by defining a *__call__()* method in their class.

Modules Modules are a basic organizational unit of Python code, and are created by the *import system* as invoked either by the *import* statement (see *import*), or by calling functions such as `importlib.import_module()` and built-in `__import__()`. A module object has a namespace implemented by a dictionary object (this is the dictionary referenced by the `__globals__` attribute of functions defined in the module). Attribute references are translated to lookups in this dictionary, e.g., `m.x` is equivalent to `m.__dict__["x"]`. A module object does not contain the code object used to initialize the module (since it isn't needed once the initialization is done).

Attribute assignment updates the module's namespace dictionary, e.g., `m.x = 1` is equivalent to `m.__dict__["x"] = 1`.

Predefined (writable) attributes: *__name__* is the module's name; `__doc__` is the module's documentation string, or `None` if unavailable; `__annotations__` (optional) is a dictionary containing *variable annotations* collected during module body execution; *__file__* is the pathname of the file from which the module was loaded, if it was loaded from a file. The *__file__* attribute may be missing for certain types of modules, such as C modules that are statically linked into the interpreter; for extension modules loaded dynamically from a shared library, it is the pathname of the shared library file.

Special read-only attribute: `__dict__` is the module's namespace as a dictionary object.

CPython implementation detail: Because of the way CPython clears module dictionaries, the module dictionary will be cleared when the module falls out of scope even if the dictionary still has live references. To avoid this, copy the dictionary or keep the module around while using its dictionary directly.

Custom classes Custom class types are typically created by class definitions (see section *Class definitions*). A class has a namespace implemented by a dictionary object. Class attribute references are translated to lookups in this dictionary, e.g., `C.x` is translated to `C.__dict__["x"]` (although there are a number of hooks which allow for other means of locating attributes). When the attribute name is not found there, the attribute search continues in the base classes. This search of the base classes uses the C3 method resolution order which behaves correctly even in the presence of 'diamond' inheritance structures where there are multiple inheritance paths leading back to a common ancestor. Additional details on the C3 MRO used by Python can be found in the documentation accompanying the 2.3 release at https://www.python.org/download/releases/2.3/mro/.

When a class attribute reference (for class `C`, say) would yield a class method object, it is transformed into an instance method object whose `__self__` attribute is `C`. When it would yield a static method object, it is transformed into the object wrapped by the static method object. See section *Implementing Descriptors* for another way in which attributes retrieved from a class may differ from those actually contained in its `__dict__`.

Class attribute assignments update the class's dictionary, never the dictionary of a base class.

A class object can be called (see above) to yield a class instance (see below).

Special attributes: `__name__` is the class name; `__module__` is the module name in which the class was defined; `__dict__` is the dictionary containing the class's namespace; `__bases__` is a tuple containing the base classes, in the order of their occurrence in the base class list; `__doc__` is the class's documentation string, or `None` if undefined; `__annotations__` (optional) is a dictionary containing *variable annotations* collected during class body execution.

Class instances A class instance is created by calling a class object (see above). A class instance has a namespace implemented as a dictionary which is the first place in which attribute references are searched. When an attribute is not found there, and the instance's class has an attribute by that name, the search continues with the class attributes. If a class attribute is found that is a user-defined

function object, it is transformed into an instance method object whose `__self__` attribute is the instance. Static method and class method objects are also transformed; see above under "Classes". See section *Implementing Descriptors* for another way in which attributes of a class retrieved via its instances may differ from the objects actually stored in the class's `__dict__`. If no class attribute is found, and the object's class has a *`__getattr__()`* method, that is called to satisfy the lookup.

Attribute assignments and deletions update the instance's dictionary, never a class's dictionary. If the class has a *`__setattr__()`* or *`__delattr__()`* method, this is called instead of updating the instance dictionary directly.

Class instances can pretend to be numbers, sequences, or mappings if they have methods with certain special names. See section *Special method names*.

Special attributes: `__dict__` is the attribute dictionary; `__class__` is the instance's class.

I/O objects (also known as file objects) A *file object* represents an open file. Various shortcuts are available to create file objects: the `open()` built-in function, and also `os.popen()`, `os.fdopen()`, and the `makefile()` method of socket objects (and perhaps by other functions or methods provided by extension modules).

The objects `sys.stdin`, `sys.stdout` and `sys.stderr` are initialized to file objects corresponding to the interpreter's standard input, output and error streams; they are all open in text mode and therefore follow the interface defined by the `io.TextIOBase` abstract class.

Internal types A few types used internally by the interpreter are exposed to the user. Their definitions may change with future versions of the interpreter, but they are mentioned here for completeness.

Code objects Code objects represent *byte-compiled* executable Python code, or *bytecode*. The difference between a code object and a function object is that the function object contains an explicit reference to the function's globals (the module in which it was defined), while a code object contains no context; also the default argument values are stored in the function object, not in the code object (because they represent values calculated at run-time). Unlike function objects, code objects are immutable and contain no references (directly or indirectly) to mutable objects.

Special read-only attributes: `co_name` gives the function name; `co_argcount` is the number of positional arguments (including arguments with default values); `co_nlocals` is the number of local variables used by the function (including arguments); `co_varnames` is a tuple containing the names of the local variables (starting with the argument names); `co_cellvars` is a tuple containing the names of local variables that are referenced by nested functions; `co_freevars` is a tuple containing the names of free variables; `co_code` is a string representing the sequence of bytecode instructions; `co_consts` is a tuple containing the literals used by the bytecode; `co_names` is a tuple containing the names used by the bytecode; `co_filename` is the filename from which the code was compiled; `co_firstlineno` is the first line number of the function; `co_lnotab` is a string encoding the mapping from bytecode offsets to line numbers (for details see the source code of the interpreter); `co_stacksize` is the required stack size (including local variables); `co_flags` is an integer encoding a number of flags for the interpreter.

The following flag bits are defined for `co_flags`: bit `0x04` is set if the function uses the `*arguments` syntax to accept an arbitrary number of positional arguments; bit `0x08` is set if the function uses the `**keywords` syntax to accept arbitrary keyword arguments; bit `0x20` is set if the function is a generator.

Future feature declarations (`from __future__ import division`) also use bits in `co_flags` to indicate whether a code object was compiled with a particular feature enabled: bit `0x2000` is set if the function was compiled with future division enabled; bits `0x10` and `0x1000` were used in earlier versions of Python.

Other bits in `co_flags` are reserved for internal use.

If a code object represents a function, the first item in `co_consts` is the documentation string of the function, or `None` if undefined.

Frame objects Frame objects represent execution frames. They may occur in traceback objects (see below), and are also passed to registered trace functions.

Special read-only attributes: `f_back` is to the previous stack frame (towards the caller), or `None` if this is the bottom stack frame; `f_code` is the code object being executed in this frame; `f_locals` is the dictionary used to look up local variables; `f_globals` is used for global variables; `f_builtins` is used for built-in (intrinsic) names; `f_lasti` gives the precise instruction (this is an index into the bytecode string of the code object).

Special writable attributes: `f_trace`, if not `None`, is a function called for various events during code execution (this is used by the debugger). Normally an event is triggered for each new source line - this can be disabled by setting `f_trace_lines` to `False`.

Implementations *may* allow per-opcode events to be requested by setting `f_trace_opcodes` to `True`. Note that this may lead to undefined interpreter behaviour if exceptions raised by the trace function escape to the function being traced.

`f_lineno` is the current line number of the frame — writing to this from within a trace function jumps to the given line (only for the bottom-most frame). A debugger can implement a Jump command (aka Set Next Statement) by writing to f_lineno.

Frame objects support one method:

`frame.clear()`
This method clears all references to local variables held by the frame. Also, if the frame belonged to a generator, the generator is finalized. This helps break reference cycles involving frame objects (for example when catching an exception and storing its traceback for later use).

`RuntimeError` is raised if the frame is currently executing.

New in version 3.4.

Traceback objects

Traceback objects represent a stack trace of an exception. A traceback object is implicitly created when an exception occurs, and may also be explicitly created by calling `types.TracebackType`.

For implicitly created tracebacks, when the search for an exception handler unwinds the execution stack, at each unwound level a traceback object is inserted in front of the current traceback. When an exception handler is entered, the stack trace is made available to the program. (See section *The try statement*.) It is accessible as the third item of the tuple returned by `sys.exc_info()`, and as the `__traceback__` attribute of the caught exception.

When the program contains no suitable handler, the stack trace is written (nicely formatted) to the standard error stream; if the interpreter is interactive, it is also made available to the user as `sys.last_traceback`.

For explicitly created tracebacks, it is up to the creator of the traceback to determine how the `tb_next` attributes should be linked to form a full stack trace.

Special read-only attributes: `tb_frame` points to the execution frame of the current level; `tb_lineno` gives the line number where the exception occurred; `tb_lasti` indicates the precise instruction. The line number and last instruction in the traceback may differ from the line number of its frame object if the exception occurred in a *try* statement with no matching except clause or with a finally clause.

Special writable attribute: `tb_next` is the next level in the stack trace (towards the frame where the exception occurred), or `None` if there is no next level.

Changed in version 3.7: Traceback objects can now be explicitly instantiated from Python code, and the `tb_next` attribute of existing instances can be updated.

Slice objects Slice objects are used to represent slices for *__getitem__()* methods. They are also created by the built-in `slice()` function.

Special read-only attributes: `start` is the lower bound; `stop` is the upper bound; `step` is the step value; each is `None` if omitted. These attributes can have any type.

Slice objects support one method:

`slice.indices`(*self*, *length*)
This method takes a single integer argument *length* and computes information about the slice that the slice object would describe if applied to a sequence of *length* items. It returns a tuple of three integers; respectively these are the *start* and *stop* indices and the *step* or stride length of the slice. Missing or out-of-bounds indices are handled in a manner consistent with regular slices.

Static method objects Static method objects provide a way of defeating the transformation of function objects to method objects described above. A static method object is a wrapper around any other object, usually a user-defined method object. When a static method object is retrieved from a class or a class instance, the object actually returned is the wrapped object, which is not subject to any further transformation. Static method objects are not themselves callable, although the objects they wrap usually are. Static method objects are created by the built-in `staticmethod()` constructor.

Class method objects A class method object, like a static method object, is a wrapper around another object that alters the way in which that object is retrieved from classes and class instances. The behaviour of class method objects upon such retrieval is described above, under "User-defined methods". Class method objects are created by the built-in `classmethod()` constructor.

3.3 Special method names

A class can implement certain operations that are invoked by special syntax (such as arithmetic operations or subscripting and slicing) by defining methods with special names. This is Python's approach to *operator overloading*, allowing classes to define their own behavior with respect to language operators. For instance, if a class defines a method named *__getitem__()*, and `x` is an instance of this class, then `x[i]` is roughly equivalent to `type(x).__getitem__(x, i)`. Except where mentioned, attempts to execute an operation raise an exception when no appropriate method is defined (typically `AttributeError` or `TypeError`).

Setting a special method to `None` indicates that the corresponding operation is not available. For example, if a class sets *__iter__()* to `None`, the class is not iterable, so calling `iter()` on its instances will raise a `TypeError` (without falling back to *__getitem__()*).[2]

When implementing a class that emulates any built-in type, it is important that the emulation only be implemented to the degree that it makes sense for the object being modelled. For example, some sequences may work well with retrieval of individual elements, but extracting a slice may not make sense. (One example of this is the `NodeList` interface in the W3C's Document Object Model.)

3.3.1 Basic customization

`object.__new__`(*cls*[, ...])
Called to create a new instance of class *cls*. *__new__()* is a static method (special-cased so you need not declare it as such) that takes the class of which an instance was requested as its first argument. The remaining arguments are those passed to the object constructor expression (the call to the class). The return value of *__new__()* should be the new object instance (usually an instance of *cls*).

[2] The *__hash__()*, *__iter__()*, *__reversed__()*, and *__contains__()* methods have special handling for this; others will still raise a `TypeError`, but may do so by relying on the behavior that `None` is not callable.

Typical implementations create a new instance of the class by invoking the superclass's *__new__()* method using `super().__new__(cls[, ...])` with appropriate arguments and then modifying the newly-created instance as necessary before returning it.

If *__new__()* returns an instance of *cls*, then the new instance's *__init__()* method will be invoked like `__init__(self[, ...])`, where *self* is the new instance and the remaining arguments are the same as were passed to *__new__()*.

If *__new__()* does not return an instance of *cls*, then the new instance's *__init__()* method will not be invoked.

__new__() is intended mainly to allow subclasses of immutable types (like int, str, or tuple) to customize instance creation. It is also commonly overridden in custom metaclasses in order to customize class creation.

`object.__init__`(*self*[, *...*])
Called after the instance has been created (by *__new__()*), but before it is returned to the caller. The arguments are those passed to the class constructor expression. If a base class has an *__init__()* method, the derived class's *__init__()* method, if any, must explicitly call it to ensure proper initialization of the base class part of the instance; for example: `super().__init__([args...])`.

Because *__new__()* and *__init__()* work together in constructing objects (*__new__()* to create it, and *__init__()* to customize it), no non-`None` value may be returned by *__init__()*; doing so will cause a `TypeError` to be raised at runtime.

`object.__del__`(*self*)
Called when the instance is about to be destroyed. This is also called a finalizer or (improperly) a destructor. If a base class has a *__del__()* method, the derived class's *__del__()* method, if any, must explicitly call it to ensure proper deletion of the base class part of the instance.

It is possible (though not recommended!) for the *__del__()* method to postpone destruction of the instance by creating a new reference to it. This is called object *resurrection*. It is implementation-dependent whether *__del__()* is called a second time when a resurrected object is about to be destroyed; the current *CPython* implementation only calls it once.

It is not guaranteed that *__del__()* methods are called for objects that still exist when the interpreter exits.

Note: `del x` doesn't directly call `x.__del__()` — the former decrements the reference count for `x` by one, and the latter is only called when `x`'s reference count reaches zero.

CPython implementation detail: It is possible for a reference cycle to prevent the reference count of an object from going to zero. In this case, the cycle will be later detected and deleted by the *cyclic garbage collector*. A common cause of reference cycles is when an exception has been caught in a local variable. The frame's locals then reference the exception, which references its own traceback, which references the locals of all frames caught in the traceback.

See also:

Documentation for the `gc` module.

Warning: Due to the precarious circumstances under which *__del__()* methods are invoked, exceptions that occur during their execution are ignored, and a warning is printed to `sys.stderr` instead. In particular:

- *__del__()* can be invoked when arbitrary code is being executed, including from any arbitrary thread. If *__del__()* needs to take a lock or invoke any other blocking resource, it may

deadlock as the resource may already be taken by the code that gets interrupted to execute *__del__()*.

- *__del__()* can be executed during interpreter shutdown. As a consequence, the global variables it needs to access (including other modules) may already have been deleted or set to `None`. Python guarantees that globals whose name begins with a single underscore are deleted from their module before other globals are deleted; if no other references to such globals exist, this may help in assuring that imported modules are still available at the time when the *__del__()* method is called.

`object.__repr__`(*self*)
Called by the `repr()` built-in function to compute the "official" string representation of an object. If at all possible, this should look like a valid Python expression that could be used to recreate an object with the same value (given an appropriate environment). If this is not possible, a string of the form `<...some useful description...>` should be returned. The return value must be a string object. If a class defines *__repr__()* but not *__str__()*, then *__repr__()* is also used when an "informal" string representation of instances of that class is required.

This is typically used for debugging, so it is important that the representation is information-rich and unambiguous.

`object.__str__`(*self*)
Called by `str(object)` and the built-in functions `format()` and `print()` to compute the "informal" or nicely printable string representation of an object. The return value must be a string object.

This method differs from *object.__repr__()* in that there is no expectation that *__str__()* return a valid Python expression: a more convenient or concise representation can be used.

The default implementation defined by the built-in type `object` calls *object.__repr__()*.

`object.__bytes__`(*self*)
Called by bytes to compute a byte-string representation of an object. This should return a `bytes` object.

`object.__format__`(*self*, *format_spec*)
Called by the `format()` built-in function, and by extension, evaluation of *formatted string literals* and the `str.format()` method, to produce a "formatted" string representation of an object. The `format_spec` argument is a string that contains a description of the formatting options desired. The interpretation of the `format_spec` argument is up to the type implementing *__format__()*, however most classes will either delegate formatting to one of the built-in types, or use a similar formatting option syntax.

See formatspec for a description of the standard formatting syntax.

The return value must be a string object.

Changed in version 3.4: The ___format___ method of `object` itself raises a `TypeError` if passed any non-empty string.

Changed in version 3.7: `object.__format__(x, '')` is now equivalent to `str(x)` rather than `format(str(self), '')`.

`object.__lt__`(*self*, *other*)
`object.__le__`(*self*, *other*)
`object.__eq__`(*self*, *other*)
`object.__ne__`(*self*, *other*)
`object.__gt__`(*self*, *other*)
`object.__ge__`(*self*, *other*)
These are the so-called "rich comparison" methods. The correspondence between operator symbols and

method names is as follows: `x<y` calls `x.__lt__(y)`, `x<=y` calls `x.__le__(y)`, `x==y` calls `x.__eq__(y)`, `x!=y` calls `x.__ne__(y)`, `x>y` calls `x.__gt__(y)`, and `x>=y` calls `x.__ge__(y)`.

A rich comparison method may return the singleton `NotImplemented` if it does not implement the operation for a given pair of arguments. By convention, `False` and `True` are returned for a successful comparison. However, these methods can return any value, so if the comparison operator is used in a Boolean context (e.g., in the condition of an `if` statement), Python will call `bool()` on the value to determine if the result is true or false.

By default, *__ne__()* delegates to *__eq__()* and inverts the result unless it is `NotImplemented`. There are no other implied relationships among the comparison operators, for example, the truth of `(x<y or x==y)` does not imply `x<=y`. To automatically generate ordering operations from a single root operation, see `functools.total_ordering()`.

See the paragraph on *__hash__()* for some important notes on creating *hashable* objects which support custom comparison operations and are usable as dictionary keys.

There are no swapped-argument versions of these methods (to be used when the left argument does not support the operation but the right argument does); rather, *__lt__()* and *__gt__()* are each other's reflection, *__le__()* and *__ge__()* are each other's reflection, and *__eq__()* and *__ne__()* are their own reflection. If the operands are of different types, and right operand's type is a direct or indirect subclass of the left operand's type, the reflected method of the right operand has priority, otherwise the left operand's method has priority. Virtual subclassing is not considered.

`object.__hash__(`*self*`)`

Called by built-in function `hash()` and for operations on members of hashed collections including `set`, `frozenset`, and `dict`. *__hash__()* should return an integer. The only required property is that objects which compare equal have the same hash value; it is advised to mix together the hash values of the components of the object that also play a part in comparison of objects by packing them into a tuple and hashing the tuple. Example:

```
def __hash__(self):
    return hash((self.name, self.nick, self.color))
```

Note: `hash()` truncates the value returned from an object's custom *__hash__()* method to the size of a `Py_ssize_t`. This is typically 8 bytes on 64-bit builds and 4 bytes on 32-bit builds. If an object's *__hash__()* must interoperate on builds of different bit sizes, be sure to check the width on all supported builds. An easy way to do this is with `python -c "import sys; print(sys.hash_info.width)"`.

If a class does not define an *__eq__()* method it should not define a *__hash__()* operation either; if it defines *__eq__()* but not *__hash__()*, its instances will not be usable as items in hashable collections. If a class defines mutable objects and implements an *__eq__()* method, it should not implement *__hash__()*, since the implementation of hashable collections requires that a key's hash value is immutable (if the object's hash value changes, it will be in the wrong hash bucket).

User-defined classes have *__eq__()* and *__hash__()* methods by default; with them, all objects compare unequal (except with themselves) and `x.__hash__()` returns an appropriate value such that `x == y` implies both that `x is y` and `hash(x) == hash(y)`.

A class that overrides *__eq__()* and does not define *__hash__()* will have its *__hash__()* implicitly set to `None`. When the *__hash__()* method of a class is `None`, instances of the class will raise an appropriate `TypeError` when a program attempts to retrieve their hash value, and will also be correctly identified as unhashable when checking `isinstance(obj, collections.abc.Hashable)`.

If a class that overrides *__eq__()* needs to retain the implementation of *__hash__()* from a parent class, the interpreter must be told this explicitly by setting `__hash__ = <ParentClass>.__hash__`.

If a class that does not override *__eq__()* wishes to suppress hash support, it should include `__hash__ = None` in the class definition. A class which defines its own *__hash__()* that explicitly raises a `TypeError` would be incorrectly identified as hashable by an `isinstance(obj, collections.abc.Hashable)` call.

Note: By default, the *__hash__()* values of str, bytes and datetime objects are "salted" with an unpredictable random value. Although they remain constant within an individual Python process, they are not predictable between repeated invocations of Python.

This is intended to provide protection against a denial-of-service caused by carefully-chosen inputs that exploit the worst case performance of a dict insertion, O(n^2) complexity. See http://www.ocert.org/advisories/ocert-2011-003.html for details.

Changing hash values affects the iteration order of dicts, sets and other mappings. Python has never made guarantees about this ordering (and it typically varies between 32-bit and 64-bit builds).

See also `PYTHONHASHSEED`.

Changed in version 3.3: Hash randomization is enabled by default.

`object.__bool__(`*self*`)`
Called to implement truth value testing and the built-in operation `bool()`; should return `False` or `True`. When this method is not defined, *__len__()* is called, if it is defined, and the object is considered true if its result is nonzero. If a class defines neither *__len__()* nor *__bool__()*, all its instances are considered true.

3.3.2 Customizing attribute access

The following methods can be defined to customize the meaning of attribute access (use of, assignment to, or deletion of `x.name`) for class instances.

`object.__getattr__(`*self*, *name*`)`
Called when the default attribute access fails with an `AttributeError` (either *__getattribute__()* raises an `AttributeError` because *name* is not an instance attribute or an attribute in the class tree for `self`; or *__get__()* of a *name* property raises `AttributeError`). This method should either return the (computed) attribute value or raise an `AttributeError` exception.

Note that if the attribute is found through the normal mechanism, *__getattr__()* is not called. (This is an intentional asymmetry between *__getattr__()* and *__setattr__()*.) This is done both for efficiency reasons and because otherwise *__getattr__()* would have no way to access other attributes of the instance. Note that at least for instance variables, you can fake total control by not inserting any values in the instance attribute dictionary (but instead inserting them in another object). See the *__getattribute__()* method below for a way to actually get total control over attribute access.

`object.__getattribute__(`*self*, *name*`)`
Called unconditionally to implement attribute accesses for instances of the class. If the class also defines *__getattr__()*, the latter will not be called unless *__getattribute__()* either calls it explicitly or raises an `AttributeError`. This method should return the (computed) attribute value or raise an `AttributeError` exception. In order to avoid infinite recursion in this method, its implementation should always call the base class method with the same name to access any attributes it needs, for example, `object.__getattribute__(self, name)`.

Note: This method may still be bypassed when looking up special methods as the result of implicit invocation via language syntax or built-in functions. See *Special method lookup*.

`object.__setattr__`(*self*, *name*, *value*)
: Called when an attribute assignment is attempted. This is called instead of the normal mechanism (i.e. store the value in the instance dictionary). *name* is the attribute name, *value* is the value to be assigned to it.

  If *__setattr__()* wants to assign to an instance attribute, it should call the base class method with the same name, for example, `object.__setattr__(self, name, value)`.

`object.__delattr__`(*self*, *name*)
: Like *__setattr__()* but for attribute deletion instead of assignment. This should only be implemented if `del obj.name` is meaningful for the object.

`object.__dir__`(*self*)
: Called when `dir()` is called on the object. A sequence must be returned. `dir()` converts the returned sequence to a list and sorts it.

Customizing module attribute access

Special names `__getattr__` and `__dir__` can be also used to customize access to module attributes. The `__getattr__` function at the module level should accept one argument which is the name of an attribute and return the computed value or raise an `AttributeError`. If an attribute is not found on a module object through the normal lookup, i.e. *object.__getattribute__()*, then `__getattr__` is searched in the module `__dict__` before raising an `AttributeError`. If found, it is called with the attribute name and the result is returned.

The `__dir__` function should accept no arguments, and return a list of strings that represents the names accessible on module. If present, this function overrides the standard `dir()` search on a module.

For a more fine grained customization of the module behavior (setting attributes, properties, etc.), one can set the `__class__` attribute of a module object to a subclass of `types.ModuleType`. For example:

```
import sys
from types import ModuleType

class VerboseModule(ModuleType):
    def __repr__(self):
        return f'Verbose {self.__name__}'

    def __setattr__(self, attr, value):
        print(f'Setting {attr}...')
        setattr(self, attr, value)

sys.modules[__name__].__class__ = VerboseModule
```

Note: Defining module `__getattr__` and setting module `__class__` only affect lookups made using the attribute access syntax – directly accessing the module globals (whether by code within the module, or via a reference to the module's globals dictionary) is unaffected.

Changed in version 3.5: `__class__` module attribute is now writable.

New in version 3.7: `__getattr__` and `__dir__` module attributes.

See also:

PEP 562 - Module ___getattr___ and ___dir___ Describes the `__getattr__` and `__dir__` functions on modules.

Implementing Descriptors

The following methods only apply when an instance of the class containing the method (a so-called *descriptor* class) appears in an *owner* class (the descriptor must be in either the owner's class dictionary or in the class dictionary for one of its parents). In the examples below, "the attribute" refers to the attribute whose name is the key of the property in the owner class' `__dict__`.

`object.__get__`(*self*, *instance*, *owner*)
: Called to get the attribute of the owner class (class attribute access) or of an instance of that class (instance attribute access). *owner* is always the owner class, while *instance* is the instance that the attribute was accessed through, or `None` when the attribute is accessed through the *owner*. This method should return the (computed) attribute value or raise an `AttributeError` exception.

`object.__set__`(*self*, *instance*, *value*)
: Called to set the attribute on an instance *instance* of the owner class to a new value, *value*.

`object.__delete__`(*self*, *instance*)
: Called to delete the attribute on an instance *instance* of the owner class.

`object.__set_name__`(*self*, *owner*, *name*)
: Called at the time the owning class *owner* is created. The descriptor has been assigned to *name*.

  New in version 3.6.

The attribute `__objclass__` is interpreted by the `inspect` module as specifying the class where this object was defined (setting this appropriately can assist in runtime introspection of dynamic class attributes). For callables, it may indicate that an instance of the given type (or a subclass) is expected or required as the first positional argument (for example, CPython sets this attribute for unbound methods that are implemented in C).

Invoking Descriptors

In general, a descriptor is an object attribute with "binding behavior", one whose attribute access has been overridden by methods in the descriptor protocol: *`__get__()`*, *`__set__()`*, and *`__delete__()`*. If any of those methods are defined for an object, it is said to be a descriptor.

The default behavior for attribute access is to get, set, or delete the attribute from an object's dictionary. For instance, `a.x` has a lookup chain starting with `a.__dict__['x']`, then `type(a).__dict__['x']`, and continuing through the base classes of `type(a)` excluding metaclasses.

However, if the looked-up value is an object defining one of the descriptor methods, then Python may override the default behavior and invoke the descriptor method instead. Where this occurs in the precedence chain depends on which descriptor methods were defined and how they were called.

The starting point for descriptor invocation is a binding, `a.x`. How the arguments are assembled depends on `a`:

Direct Call The simplest and least common call is when user code directly invokes a descriptor method: `x.__get__(a)`.

Instance Binding If binding to an object instance, `a.x` is transformed into the call: `type(a).__dict__['x'].__get__(a, type(a))`.

Class Binding If binding to a class, `A.x` is transformed into the call: `A.__dict__['x'].__get__(None, A)`.

Super Binding If `a` is an instance of `super`, then the binding `super(B, obj).m()` searches `obj.__class__.__mro__` for the base class `A` immediately preceding `B` and then invokes the descriptor with the call: `A.__dict__['m'].__get__(obj, obj.__class__)`.

For instance bindings, the precedence of descriptor invocation depends on the which descriptor methods are defined. A descriptor can define any combination of *__get__()*, *__set__()* and *__delete__()*. If it does not define *__get__()*, then accessing the attribute will return the descriptor object itself unless there is a value in the object's instance dictionary. If the descriptor defines *__set__()* and/or *__delete__()*, it is a data descriptor; if it defines neither, it is a non-data descriptor. Normally, data descriptors define both *__get__()* and *__set__()*, while non-data descriptors have just the *__get__()* method. Data descriptors with *__set__()* and *__get__()* defined always override a redefinition in an instance dictionary. In contrast, non-data descriptors can be overridden by instances.

Python methods (including `staticmethod()` and `classmethod()`) are implemented as non-data descriptors. Accordingly, instances can redefine and override methods. This allows individual instances to acquire behaviors that differ from other instances of the same class.

The `property()` function is implemented as a data descriptor. Accordingly, instances cannot override the behavior of a property.

___slots___

___slots___ allow us to explicitly declare data members (like properties) and deny the creation of *___dict___* and *___weakref___* (unless explicitly declared in *___slots___* or available in a parent.)

The space saved over using *___dict___* can be significant.

`object.__slots__`
: This class variable can be assigned a string, iterable, or sequence of strings with variable names used by instances. *___slots___* reserves space for the declared variables and prevents the automatic creation of *___dict___* and *___weakref___* for each instance.

Notes on using *___slots___*

- When inheriting from a class without *___slots___*, the *___dict___* and *___weakref___* attribute of the instances will always be accessible.
- Without a *___dict___* variable, instances cannot be assigned new variables not listed in the *___slots___* definition. Attempts to assign to an unlisted variable name raises `AttributeError`. If dynamic assignment of new variables is desired, then add `'__dict__'` to the sequence of strings in the *___slots___* declaration.
- Without a *___weakref___* variable for each instance, classes defining *___slots___* do not support weak references to its instances. If weak reference support is needed, then add `'__weakref__'` to the sequence of strings in the *___slots___* declaration.
- *___slots___* are implemented at the class level by creating descriptors (*Implementing Descriptors*) for each variable name. As a result, class attributes cannot be used to set default values for instance variables defined by *___slots___*; otherwise, the class attribute would overwrite the descriptor assignment.
- The action of a *___slots___* declaration is not limited to the class where it is defined. *___slots___* declared in parents are available in child classes. However, child subclasses will get a *___dict___* and *___weakref___* unless they also define *___slots___* (which should only contain names of any *additional* slots).
- If a class defines a slot also defined in a base class, the instance variable defined by the base class slot is inaccessible (except by retrieving its descriptor directly from the base class). This renders the meaning of the program undefined. In the future, a check may be added to prevent this.
- Nonempty *___slots___* does not work for classes derived from "variable-length" built-in types such as `int`, `bytes` and `tuple`.

- Any non-string iterable may be assigned to *__slots__*. Mappings may also be used; however, in the future, special meaning may be assigned to the values corresponding to each key.
- *__class__* assignment works only if both classes have the same *__slots__*.
- Multiple inheritance with multiple slotted parent classes can be used, but only one parent is allowed to have attributes created by slots (the other bases must have empty slot layouts) - violations raise `TypeError`.

3.3.3 Customizing class creation

Whenever a class inherits from another class, *__init_subclass__* is called on that class. This way, it is possible to write classes which change the behavior of subclasses. This is closely related to class decorators, but where class decorators only affect the specific class they're applied to, `__init_subclass__` solely applies to future subclasses of the class defining the method.

`classmethod` `object.__init_subclass__`(*cls*)

This method is called whenever the containing class is subclassed. *cls* is then the new subclass. If defined as a normal instance method, this method is implicitly converted to a class method.

Keyword arguments which are given to a new class are passed to the parent's class `__init_subclass__`. For compatibility with other classes using `__init_subclass__`, one should take out the needed keyword arguments and pass the others over to the base class, as in:

```
class Philosopher:
    def __init_subclass__(cls, default_name, **kwargs):
        super().__init_subclass__(**kwargs)
        cls.default_name = default_name

class AustralianPhilosopher(Philosopher, default_name="Bruce"):
    pass
```

The default implementation `object.__init_subclass__` does nothing, but raises an error if it is called with any arguments.

Note: The metaclass hint `metaclass` is consumed by the rest of the type machinery, and is never passed to `__init_subclass__` implementations. The actual metaclass (rather than the explicit hint) can be accessed as `type(cls)`.

New in version 3.6.

Metaclasses

By default, classes are constructed using `type()`. The class body is executed in a new namespace and the class name is bound locally to the result of `type(name, bases, namespace)`.

The class creation process can be customized by passing the `metaclass` keyword argument in the class definition line, or by inheriting from an existing class that included such an argument. In the following example, both `MyClass` and `MySubclass` are instances of `Meta`:

```
class Meta(type):
    pass

class MyClass(metaclass=Meta):
    pass
```

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```
class MySubclass(MyClass):
    pass
```

Any other keyword arguments that are specified in the class definition are passed through to all metaclass operations described below.

When a class definition is executed, the following steps occur:

- MRO entries are resolved
- the appropriate metaclass is determined
- the class namespace is prepared
- the class body is executed
- the class object is created

Resolving MRO entries

If a base that appears in class definition is not an instance of `type`, then an `__mro_entries__` method is searched on it. If found, it is called with the original bases tuple. This method must return a tuple of classes that will be used instead of this base. The tuple may be empty, in such case the original base is ignored.

See also:

PEP 560 - Core support for typing module and generic types

Determining the appropriate metaclass

The appropriate metaclass for a class definition is determined as follows:

- if no bases and no explicit metaclass are given, then `type()` is used
- if an explicit metaclass is given and it is *not* an instance of `type()`, then it is used directly as the metaclass
- if an instance of `type()` is given as the explicit metaclass, or bases are defined, then the most derived metaclass is used

The most derived metaclass is selected from the explicitly specified metaclass (if any) and the metaclasses (i.e. `type(cls)`) of all specified base classes. The most derived metaclass is one which is a subtype of *all* of these candidate metaclasses. If none of the candidate metaclasses meets that criterion, then the class definition will fail with `TypeError`.

Preparing the class namespace

Once the appropriate metaclass has been identified, then the class namespace is prepared. If the metaclass has a `__prepare__` attribute, it is called as `namespace = metaclass.__prepare__(name, bases, **kwds)` (where the additional keyword arguments, if any, come from the class definition).

If the metaclass has no `__prepare__` attribute, then the class namespace is initialised as an empty ordered mapping.

See also:

PEP 3115 - Metaclasses in Python 3000 Introduced the `__prepare__` namespace hook

Executing the class body

The class body is executed (approximately) as `exec(body, globals(), namespace)`. The key difference from a normal call to `exec()` is that lexical scoping allows the class body (including any methods) to reference names from the current and outer scopes when the class definition occurs inside a function.

However, even when the class definition occurs inside the function, methods defined inside the class still cannot see names defined at the class scope. Class variables must be accessed through the first parameter of instance or class methods, or through the implicit lexically scoped `__class__` reference described in the next section.

Creating the class object

Once the class namespace has been populated by executing the class body, the class object is created by calling `metaclass(name, bases, namespace, **kwds)` (the additional keywords passed here are the same as those passed to `__prepare__`).

This class object is the one that will be referenced by the zero-argument form of `super()`. `__class__` is an implicit closure reference created by the compiler if any methods in a class body refer to either `__class__` or `super`. This allows the zero argument form of `super()` to correctly identify the class being defined based on lexical scoping, while the class or instance that was used to make the current call is identified based on the first argument passed to the method.

CPython implementation detail: In CPython 3.6 and later, the `__class__` cell is passed to the metaclass as a `__classcell__` entry in the class namespace. If present, this must be propagated up to the `type.__new__` call in order for the class to be initialised correctly. Failing to do so will result in a `DeprecationWarning` in Python 3.6, and a `RuntimeError` in Python 3.8.

When using the default metaclass `type`, or any metaclass that ultimately calls `type.__new__`, the following additional customisation steps are invoked after creating the class object:

- first, `type.__new__` collects all of the descriptors in the class namespace that define a *`__set_name__()`* method;
- second, all of these `__set_name__` methods are called with the class being defined and the assigned name of that particular descriptor; and
- finally, the *`__init_subclass__()`* hook is called on the immediate parent of the new class in its method resolution order.

After the class object is created, it is passed to the class decorators included in the class definition (if any) and the resulting object is bound in the local namespace as the defined class.

When a new class is created by `type.__new__`, the object provided as the namespace parameter is copied to a new ordered mapping and the original object is discarded. The new copy is wrapped in a read-only proxy, which becomes the `__dict__` attribute of the class object.

See also:

PEP 3135 - New super Describes the implicit `__class__` closure reference

Metaclass example

The potential uses for metaclasses are boundless. Some ideas that have been explored include enum, logging, interface checking, automatic delegation, automatic property creation, proxies, frameworks, and automatic resource locking/synchronization.

Here is an example of a metaclass that uses an `collections.OrderedDict` to remember the order that class variables are defined:

```
class OrderedClass(type):

    @classmethod
    def __prepare__(metacls, name, bases, **kwds):
        return collections.OrderedDict()

    def __new__(cls, name, bases, namespace, **kwds):
        result = type.__new__(cls, name, bases, dict(namespace))
        result.members = tuple(namespace)
        return result

class A(metaclass=OrderedClass):
    def one(self): pass
    def two(self): pass
    def three(self): pass
    def four(self): pass

>>> A.members
('__module__', 'one', 'two', 'three', 'four')
```

When the class definition for *A* gets executed, the process begins with calling the metaclass's `__prepare__()` method which returns an empty `collections.OrderedDict`. That mapping records the methods and attributes of *A* as they are defined within the body of the class statement. Once those definitions are executed, the ordered dictionary is fully populated and the metaclass's *__new__()* method gets invoked. That method builds the new type and it saves the ordered dictionary keys in an attribute called `members`.

3.3.4 Customizing instance and subclass checks

The following methods are used to override the default behavior of the `isinstance()` and `issubclass()` built-in functions.

In particular, the metaclass `abc.ABCMeta` implements these methods in order to allow the addition of Abstract Base Classes (ABCs) as "virtual base classes" to any class or type (including built-in types), including other ABCs.

`class.__instancecheck__`(*self*, *instance*)
: Return true if *instance* should be considered a (direct or indirect) instance of *class*. If defined, called to implement `isinstance(instance, class)`.

`class.__subclasscheck__`(*self*, *subclass*)
: Return true if *subclass* should be considered a (direct or indirect) subclass of *class*. If defined, called to implement `issubclass(subclass, class)`.

Note that these methods are looked up on the type (metaclass) of a class. They cannot be defined as class methods in the actual class. This is consistent with the lookup of special methods that are called on instances, only in this case the instance is itself a class.

See also:

PEP 3119 - Introducing Abstract Base Classes Includes the specification for customizing `isinstance()` and `issubclass()` behavior through *__instancecheck__()* and *__subclasscheck__()*, with motivation for this functionality in the context of adding Abstract Base Classes (see the `abc` module) to the language.

3.3.5 Emulating generic types

One can implement the generic class syntax as specified by **PEP 484** (for example `List[int]`) by defining a special method

`classmethod object.__class_getitem__(cls, key)`
Return an object representing the specialization of a generic class by type arguments found in *key*.

This method is looked up on the class object itself, and when defined in the class body, this method is implicitly a class method. Note, this mechanism is primarily reserved for use with static type hints, other usage is discouraged.

See also:

PEP 560 - Core support for typing module and generic types

3.3.6 Emulating callable objects

`object.__call__(self[, args...])`
Called when the instance is "called" as a function; if this method is defined, `x(arg1, arg2, ...)` is a shorthand for `x.__call__(arg1, arg2, ...)`.

3.3.7 Emulating container types

The following methods can be defined to implement container objects. Containers usually are sequences (such as lists or tuples) or mappings (like dictionaries), but can represent other containers as well. The first set of methods is used either to emulate a sequence or to emulate a mapping; the difference is that for a sequence, the allowable keys should be the integers k for which `0 <= k < N` where N is the length of the sequence, or slice objects, which define a range of items. It is also recommended that mappings provide the methods `keys()`, `values()`, `items()`, `get()`, `clear()`, `setdefault()`, `pop()`, `popitem()`, `copy()`, and `update()` behaving similar to those for Python's standard dictionary objects. The `collections.abc` module provides a `MutableMapping` abstract base class to help create those methods from a base set of *`__getitem__()`*, *`__setitem__()`*, *`__delitem__()`*, and `keys()`. Mutable sequences should provide methods `append()`, `count()`, `index()`, `extend()`, `insert()`, `pop()`, `remove()`, `reverse()` and `sort()`, like Python standard list objects. Finally, sequence types should implement addition (meaning concatenation) and multiplication (meaning repetition) by defining the methods *`__add__()`*, *`__radd__()`*, *`__iadd__()`*, *`__mul__()`*, *`__rmul__()`* and *`__imul__()`* described below; they should not define other numerical operators. It is recommended that both mappings and sequences implement the *`__contains__()`* method to allow efficient use of the `in` operator; for mappings, `in` should search the mapping's keys; for sequences, it should search through the values. It is further recommended that both mappings and sequences implement the *`__iter__()`* method to allow efficient iteration through the container; for mappings, *`__iter__()`* should be the same as `keys()`; for sequences, it should iterate through the values.

`object.__len__(self)`
Called to implement the built-in function `len()`. Should return the length of the object, an integer `>=` 0. Also, an object that doesn't define a *`__bool__()`* method and whose *`__len__()`* method returns zero is considered to be false in a Boolean context.

CPython implementation detail: In CPython, the length is required to be at most `sys.maxsize`. If the length is larger than `sys.maxsize` some features (such as `len()`) may raise `OverflowError`. To prevent raising `OverflowError` by truth value testing, an object must define a *`__bool__()`* method.

`object.__length_hint__(self)`
Called to implement `operator.length_hint()`. Should return an estimated length for the object (which may be greater or less than the actual length). The length must be an integer `>=` 0. This method is purely an optimization and is never required for correctness.

New in version 3.4.

Note: Slicing is done exclusively with the following three methods. A call like

```
a[1:2] = b
```

is translated to

```
a[slice(1, 2, None)] = b
```

and so forth. Missing slice items are always filled in with `None`.

`object.__getitem__`(*self*, *key*)
Called to implement evaluation of `self[key]`. For sequence types, the accepted keys should be integers and slice objects. Note that the special interpretation of negative indexes (if the class wishes to emulate a sequence type) is up to the *__getitem__()* method. If *key* is of an inappropriate type, `TypeError` may be raised; if of a value outside the set of indexes for the sequence (after any special interpretation of negative values), `IndexError` should be raised. For mapping types, if *key* is missing (not in the container), `KeyError` should be raised.

Note: *for* loops expect that an `IndexError` will be raised for illegal indexes to allow proper detection of the end of the sequence.

`object.__missing__`(*self*, *key*)
Called by `dict.`*__getitem__()* to implement `self[key]` for dict subclasses when key is not in the dictionary.

`object.__setitem__`(*self*, *key*, *value*)
Called to implement assignment to `self[key]`. Same note as for *__getitem__()*. This should only be implemented for mappings if the objects support changes to the values for keys, or if new keys can be added, or for sequences if elements can be replaced. The same exceptions should be raised for improper *key* values as for the *__getitem__()* method.

`object.__delitem__`(*self*, *key*)
Called to implement deletion of `self[key]`. Same note as for *__getitem__()*. This should only be implemented for mappings if the objects support removal of keys, or for sequences if elements can be removed from the sequence. The same exceptions should be raised for improper *key* values as for the *__getitem__()* method.

`object.__iter__`(*self*)
This method is called when an iterator is required for a container. This method should return a new iterator object that can iterate over all the objects in the container. For mappings, it should iterate over the keys of the container.

Iterator objects also need to implement this method; they are required to return themselves. For more information on iterator objects, see typeiter.

`object.__reversed__`(*self*)
Called (if present) by the `reversed()` built-in to implement reverse iteration. It should return a new iterator object that iterates over all the objects in the container in reverse order.

If the *__reversed__()* method is not provided, the `reversed()` built-in will fall back to using the sequence protocol (*__len__()* and *__getitem__()*). Objects that support the sequence protocol should only provide *__reversed__()* if they can provide an implementation that is more efficient than the one provided by `reversed()`.

The membership test operators (*in* and *not in*) are normally implemented as an iteration through a sequence. However, container objects can supply the following special method with a more efficient implementation, which also does not require the object be a sequence.

`object.__contains__`(*self*, *item*)
: Called to implement membership test operators. Should return true if *item* is in *self*, false otherwise. For mapping objects, this should consider the keys of the mapping rather than the values or the key-item pairs.

  For objects that don't define *__contains__()*, the membership test first tries iteration via *__iter__()*, then the old sequence iteration protocol via *__getitem__()*, see *this section in the language reference*.

3.3.8 Emulating numeric types

The following methods can be defined to emulate numeric objects. Methods corresponding to operations that are not supported by the particular kind of number implemented (e.g., bitwise operations for non-integral numbers) should be left undefined.

`object.__add__`(*self*, *other*)
`object.__sub__`(*self*, *other*)
`object.__mul__`(*self*, *other*)
`object.__matmul__`(*self*, *other*)
`object.__truediv__`(*self*, *other*)
`object.__floordiv__`(*self*, *other*)
`object.__mod__`(*self*, *other*)
`object.__divmod__`(*self*, *other*)
`object.__pow__`(*self*, *other*[, *modulo*])
`object.__lshift__`(*self*, *other*)
`object.__rshift__`(*self*, *other*)
`object.__and__`(*self*, *other*)
`object.__xor__`(*self*, *other*)
`object.__or__`(*self*, *other*)
: These methods are called to implement the binary arithmetic operations (`+`, `-`, `*`, `@`, `/`, `//`, `%`, `divmod()`, `pow()`, `**`, `<<`, `>>`, `&`, `^`, `|`). For instance, to evaluate the expression `x + y`, where *x* is an instance of a class that has an *__add__()* method, `x.__add__(y)` is called. The *__divmod__()* method should be the equivalent to using *__floordiv__()* and *__mod__()*; it should not be related to *__truediv__()*. Note that *__pow__()* should be defined to accept an optional third argument if the ternary version of the built-in `pow()` function is to be supported.

  If one of those methods does not support the operation with the supplied arguments, it should return `NotImplemented`.

`object.__radd__`(*self*, *other*)
`object.__rsub__`(*self*, *other*)
`object.__rmul__`(*self*, *other*)
`object.__rmatmul__`(*self*, *other*)
`object.__rtruediv__`(*self*, *other*)
`object.__rfloordiv__`(*self*, *other*)
`object.__rmod__`(*self*, *other*)
`object.__rdivmod__`(*self*, *other*)
`object.__rpow__`(*self*, *other*)
`object.__rlshift__`(*self*, *other*)
`object.__rrshift__`(*self*, *other*)
`object.__rand__`(*self*, *other*)
`object.__rxor__`(*self*, *other*)

object.__ror__(*self*, *other*)
: These methods are called to implement the binary arithmetic operations (+, -, *, @, /, //, %, divmod(), pow(), **, <<, >>, &, ^, |) with reflected (swapped) operands. These functions are only called if the left operand does not support the corresponding operation[3] and the operands are of different types.[4] For instance, to evaluate the expression x - y, where *y* is an instance of a class that has an *__rsub__()* method, y.__rsub__(x) is called if x.__sub__(y) returns *NotImplemented*.

  Note that ternary pow() will not try calling *__rpow__()* (the coercion rules would become too complicated).

  Note: If the right operand's type is a subclass of the left operand's type and that subclass provides the reflected method for the operation, this method will be called before the left operand's non-reflected method. This behavior allows subclasses to override their ancestors' operations.

  ---

object.__iadd__(*self*, *other*)
object.__isub__(*self*, *other*)
object.__imul__(*self*, *other*)
object.__imatmul__(*self*, *other*)
object.__itruediv__(*self*, *other*)
object.__ifloordiv__(*self*, *other*)
object.__imod__(*self*, *other*)
object.__ipow__(*self*, *other*[, *modulo*])
object.__ilshift__(*self*, *other*)
object.__irshift__(*self*, *other*)
object.__iand__(*self*, *other*)
object.__ixor__(*self*, *other*)
object.__ior__(*self*, *other*)
: These methods are called to implement the augmented arithmetic assignments (+=, -=, *=, @=, /=, //=, %=, **=, <<=, >>=, &=, ^=, |=). These methods should attempt to do the operation in-place (modifying *self*) and return the result (which could be, but does not have to be, *self*). If a specific method is not defined, the augmented assignment falls back to the normal methods. For instance, if *x* is an instance of a class with an *__iadd__()* method, x += y is equivalent to x = x.__iadd__(y) . Otherwise, x.__add__(y) and y.__radd__(x) are considered, as with the evaluation of x + y. In certain situations, augmented assignment can result in unexpected errors (see faq-augmented-assignment-tuple-error), but this behavior is in fact part of the data model.

object.__neg__(*self*)
object.__pos__(*self*)
object.__abs__(*self*)
object.__invert__(*self*)
: Called to implement the unary arithmetic operations (-, +, abs() and ~).

object.__complex__(*self*)
object.__int__(*self*)
object.__float__(*self*)
: Called to implement the built-in functions complex(), int() and float(). Should return a value of the appropriate type.

object.__index__(*self*)
: Called to implement operator.index(), and whenever Python needs to losslessly convert the numeric

[3] "Does not support" here means that the class has no such method, or the method returns NotImplemented. Do not set the method to None if you want to force fallback to the right operand's reflected method—that will instead have the opposite effect of explicitly *blocking* such fallback.

[4] For operands of the same type, it is assumed that if the non-reflected method (such as *__add__()*) fails the operation is not supported, which is why the reflected method is not called.

object to an integer object (such as in slicing, or in the built-in `bin()`, `hex()` and `oct()` functions). Presence of this method indicates that the numeric object is an integer type. Must return an integer.

Note: In order to have a coherent integer type class, when *__index__()* is defined *__int__()* should also be defined, and both should return the same value.

`object.__round__`(*self*[, *ndigits*])
`object.__trunc__`(*self*)
`object.__floor__`(*self*)
`object.__ceil__`(*self*)

Called to implement the built-in function `round()` and `math` functions `trunc()`, `floor()` and `ceil()`. Unless *ndigits* is passed to `__round__()` all these methods should return the value of the object truncated to an `Integral` (typically an `int`).

If *__int__()* is not defined then the built-in function `int()` falls back to *__trunc__()*.

3.3.9 With Statement Context Managers

A *context manager* is an object that defines the runtime context to be established when executing a *with* statement. The context manager handles the entry into, and the exit from, the desired runtime context for the execution of the block of code. Context managers are normally invoked using the *with* statement (described in section *The with statement*), but can also be used by directly invoking their methods.

Typical uses of context managers include saving and restoring various kinds of global state, locking and unlocking resources, closing opened files, etc.

For more information on context managers, see typecontextmanager.

`object.__enter__`(*self*)

Enter the runtime context related to this object. The *with* statement will bind this method's return value to the target(s) specified in the *as* clause of the statement, if any.

`object.__exit__`(*self*, *exc_type*, *exc_value*, *traceback*)

Exit the runtime context related to this object. The parameters describe the exception that caused the context to be exited. If the context was exited without an exception, all three arguments will be `None`.

If an exception is supplied, and the method wishes to suppress the exception (i.e., prevent it from being propagated), it should return a true value. Otherwise, the exception will be processed normally upon exit from this method.

Note that *__exit__()* methods should not reraise the passed-in exception; this is the caller's responsibility.

See also:

PEP 343 - The "with" statement The specification, background, and examples for the Python *with* statement.

3.3.10 Special method lookup

For custom classes, implicit invocations of special methods are only guaranteed to work correctly if defined on an object's type, not in the object's instance dictionary. That behaviour is the reason why the following code raises an exception:

```
>>> class C:
...     pass
...
>>> c = C()
>>> c.__len__ = lambda: 5
>>> len(c)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: object of type 'C' has no len()
```

The rationale behind this behaviour lies with a number of special methods such as *__hash__()* and *__repr__()* that are implemented by all objects, including type objects. If the implicit lookup of these methods used the conventional lookup process, they would fail when invoked on the type object itself:

```
>>> 1 .__hash__() == hash(1)
True
>>> int.__hash__() == hash(int)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: descriptor '__hash__' of 'int' object needs an argument
```

Incorrectly attempting to invoke an unbound method of a class in this way is sometimes referred to as 'metaclass confusion', and is avoided by bypassing the instance when looking up special methods:

```
>>> type(1).__hash__(1) == hash(1)
True
>>> type(int).__hash__(int) == hash(int)
True
```

In addition to bypassing any instance attributes in the interest of correctness, implicit special method lookup generally also bypasses the *__getattribute__()* method even of the object's metaclass:

```
>>> class Meta(type):
...     def __getattribute__(*args):
...         print("Metaclass getattribute invoked")
...         return type.__getattribute__(*args)
...
>>> class C(object, metaclass=Meta):
...     def __len__(self):
...         return 10
...     def __getattribute__(*args):
...         print("Class getattribute invoked")
...         return object.__getattribute__(*args)
...
>>> c = C()
>>> c.__len__()                 # Explicit lookup via instance
Class getattribute invoked
10
>>> type(c).__len__(c)          # Explicit lookup via type
Metaclass getattribute invoked
10
>>> len(c)                      # Implicit lookup
10
```

Bypassing the *__getattribute__()* machinery in this fashion provides significant scope for speed optimisations within the interpreter, at the cost of some flexibility in the handling of special methods (the special method *must* be set on the class object itself in order to be consistently invoked by the interpreter).

3.4 Coroutines

3.4.1 Awaitable Objects

An *awaitable* object generally implements an *__await__()* method. *Coroutine* objects returned from *async def* functions are awaitable.

Note: The *generator iterator* objects returned from generators decorated with `types.coroutine()` or `asyncio.coroutine()` are also awaitable, but they do not implement *__await__()*.

`object.__await__(self)`

Must return an *iterator*. Should be used to implement *awaitable* objects. For instance, `asyncio.Future` implements this method to be compatible with the *await* expression.

New in version 3.5.

See also:

PEP 492 for additional information about awaitable objects.

3.4.2 Coroutine Objects

Coroutine objects are *awaitable* objects. A coroutine's execution can be controlled by calling *__await__()* and iterating over the result. When the coroutine has finished executing and returns, the iterator raises `StopIteration`, and the exception's `value` attribute holds the return value. If the coroutine raises an exception, it is propagated by the iterator. Coroutines should not directly raise unhandled `StopIteration` exceptions.

Coroutines also have the methods listed below, which are analogous to those of generators (see *Generator-iterator methods*). However, unlike generators, coroutines do not directly support iteration.

Changed in version 3.5.2: It is a `RuntimeError` to await on a coroutine more than once.

`coroutine.send(value)`

Starts or resumes execution of the coroutine. If *value* is `None`, this is equivalent to advancing the iterator returned by *__await__()*. If *value* is not `None`, this method delegates to the *send()* method of the iterator that caused the coroutine to suspend. The result (return value, `StopIteration`, or other exception) is the same as when iterating over the *__await__()* return value, described above.

`coroutine.throw(type[, value[, traceback]])`

Raises the specified exception in the coroutine. This method delegates to the *throw()* method of the iterator that caused the coroutine to suspend, if it has such a method. Otherwise, the exception is raised at the suspension point. The result (return value, `StopIteration`, or other exception) is the same as when iterating over the *__await__()* return value, described above. If the exception is not caught in the coroutine, it propagates back to the caller.

`coroutine.close()`

Causes the coroutine to clean itself up and exit. If the coroutine is suspended, this method first delegates to the *close()* method of the iterator that caused the coroutine to suspend, if it has such a method. Then it raises `GeneratorExit` at the suspension point, causing the coroutine to immediately clean itself up. Finally, the coroutine is marked as having finished executing, even if it was never started.

Coroutine objects are automatically closed using the above process when they are about to be destroyed.

3.4.3 Asynchronous Iterators

An *asynchronous iterator* can call asynchronous code in its `__anext__` method.

Asynchronous iterators can be used in an *`async for`* statement.

`object.__aiter__`(*self*)
: Must return an *asynchronous iterator* object.

`object.__anext__`(*self*)
: Must return an *awaitable* resulting in a next value of the iterator. Should raise a `StopAsyncIteration` error when the iteration is over.

An example of an asynchronous iterable object:

```
class Reader:
    async def readline(self):
        ...

    def __aiter__(self):
        return self

    async def __anext__(self):
        val = await self.readline()
        if val == b'':
            raise StopAsyncIteration
        return val
```

New in version 3.5.

Changed in version 3.7: Prior to Python 3.7, `__aiter__` could return an *awaitable* that would resolve to an *asynchronous iterator*.

Starting with Python 3.7, `__aiter__` must return an asynchronous iterator object. Returning anything else will result in a `TypeError` error.

3.4.4 Asynchronous Context Managers

An *asynchronous context manager* is a *context manager* that is able to suspend execution in its `__aenter__` and `__aexit__` methods.

Asynchronous context managers can be used in an *`async with`* statement.

`object.__aenter__`(*self*)
: This method is semantically similar to the *`__enter__()`*, with only difference that it must return an *awaitable*.

`object.__aexit__`(*self*, *exc_type*, *exc_value*, *traceback*)
: This method is semantically similar to the *`__exit__()`*, with only difference that it must return an *awaitable*.

An example of an asynchronous context manager class:

```
class AsyncContextManager:
    async def __aenter__(self):
        await log('entering context')

    async def __aexit__(self, exc_type, exc, tb):
        await log('exiting context')
```

New in version 3.5.

CHAPTER

FOUR

EXECUTION MODEL

4.1 Structure of a program

A Python program is constructed from code blocks. A *block* is a piece of Python program text that is executed as a unit. The following are blocks: a module, a function body, and a class definition. Each command typed interactively is a block. A script file (a file given as standard input to the interpreter or specified as a command line argument to the interpreter) is a code block. A script command (a command specified on the interpreter command line with the '**-c**' option) is a code block. The string argument passed to the built-in functions `eval()` and `exec()` is a code block.

A code block is executed in an *execution frame*. A frame contains some administrative information (used for debugging) and determines where and how execution continues after the code block's execution has completed.

4.2 Naming and binding

4.2.1 Binding of names

Names refer to objects. Names are introduced by name binding operations.

The following constructs bind names: formal parameters to functions, *import* statements, class and function definitions (these bind the class or function name in the defining block), and targets that are identifiers if occurring in an assignment, *for* loop header, or after *as* in a *with* statement or *except* clause. The *import* statement of the form `from ... import *` binds all names defined in the imported module, except those beginning with an underscore. This form may only be used at the module level.

A target occurring in a *del* statement is also considered bound for this purpose (though the actual semantics are to unbind the name).

Each assignment or import statement occurs within a block defined by a class or function definition or at the module level (the top-level code block).

If a name is bound in a block, it is a local variable of that block, unless declared as *nonlocal* or *global*. If a name is bound at the module level, it is a global variable. (The variables of the module code block are local and global.) If a variable is used in a code block but not defined there, it is a *free variable*.

Each occurrence of a name in the program text refers to the *binding* of that name established by the following name resolution rules.

4.2.2 Resolution of names

A *scope* defines the visibility of a name within a block. If a local variable is defined in a block, its scope includes that block. If the definition occurs in a function block, the scope extends to any blocks contained

within the defining one, unless a contained block introduces a different binding for the name.

When a name is used in a code block, it is resolved using the nearest enclosing scope. The set of all such scopes visible to a code block is called the block's *environment*.

When a name is not found at all, a `NameError` exception is raised. If the current scope is a function scope, and the name refers to a local variable that has not yet been bound to a value at the point where the name is used, an `UnboundLocalError` exception is raised. `UnboundLocalError` is a subclass of `NameError`.

If a name binding operation occurs anywhere within a code block, all uses of the name within the block are treated as references to the current block. This can lead to errors when a name is used within a block before it is bound. This rule is subtle. Python lacks declarations and allows name binding operations to occur anywhere within a code block. The local variables of a code block can be determined by scanning the entire text of the block for name binding operations.

If the *global* statement occurs within a block, all uses of the name specified in the statement refer to the binding of that name in the top-level namespace. Names are resolved in the top-level namespace by searching the global namespace, i.e. the namespace of the module containing the code block, and the builtins namespace, the namespace of the module `builtins`. The global namespace is searched first. If the name is not found there, the builtins namespace is searched. The *global* statement must precede all uses of the name.

The *global* statement has the same scope as a name binding operation in the same block. If the nearest enclosing scope for a free variable contains a global statement, the free variable is treated as a global.

The *nonlocal* statement causes corresponding names to refer to previously bound variables in the nearest enclosing function scope. `SyntaxError` is raised at compile time if the given name does not exist in any enclosing function scope.

The namespace for a module is automatically created the first time a module is imported. The main module for a script is always called `__main__`.

Class definition blocks and arguments to `exec()` and `eval()` are special in the context of name resolution. A class definition is an executable statement that may use and define names. These references follow the normal rules for name resolution with an exception that unbound local variables are looked up in the global namespace. The namespace of the class definition becomes the attribute dictionary of the class. The scope of names defined in a class block is limited to the class block; it does not extend to the code blocks of methods – this includes comprehensions and generator expressions since they are implemented using a function scope. This means that the following will fail:

```
class A:
    a = 42
    b = list(a + i for i in range(10))
```

4.2.3 Builtins and restricted execution

CPython implementation detail: Users should not touch `__builtins__`; it is strictly an implementation detail. Users wanting to override values in the builtins namespace should *import* the `builtins` module and modify its attributes appropriately.

The builtins namespace associated with the execution of a code block is actually found by looking up the name `__builtins__` in its global namespace; this should be a dictionary or a module (in the latter case the module's dictionary is used). By default, when in the `__main__` module, `__builtins__` is the built-in module `builtins`; when in any other module, `__builtins__` is an alias for the dictionary of the `builtins` module itself.

4.2.4 Interaction with dynamic features

Name resolution of free variables occurs at runtime, not at compile time. This means that the following code will print 42:

```
i = 10
def f():
    print(i)
i = 42
f()
```

The `eval()` and `exec()` functions do not have access to the full environment for resolving names. Names may be resolved in the local and global namespaces of the caller. Free variables are not resolved in the nearest enclosing namespace, but in the global namespace.[1] The `exec()` and `eval()` functions have optional arguments to override the global and local namespace. If only one namespace is specified, it is used for both.

4.3 Exceptions

Exceptions are a means of breaking out of the normal flow of control of a code block in order to handle errors or other exceptional conditions. An exception is *raised* at the point where the error is detected; it may be *handled* by the surrounding code block or by any code block that directly or indirectly invoked the code block where the error occurred.

The Python interpreter raises an exception when it detects a run-time error (such as division by zero). A Python program can also explicitly raise an exception with the *raise* statement. Exception handlers are specified with the *try* ... *except* statement. The *finally* clause of such a statement can be used to specify cleanup code which does not handle the exception, but is executed whether an exception occurred or not in the preceding code.

Python uses the "termination" model of error handling: an exception handler can find out what happened and continue execution at an outer level, but it cannot repair the cause of the error and retry the failing operation (except by re-entering the offending piece of code from the top).

When an exception is not handled at all, the interpreter terminates execution of the program, or returns to its interactive main loop. In either case, it prints a stack backtrace, except when the exception is `SystemExit`.

Exceptions are identified by class instances. The *except* clause is selected depending on the class of the instance: it must reference the class of the instance or a base class thereof. The instance can be received by the handler and can carry additional information about the exceptional condition.

Note: Exception messages are not part of the Python API. Their contents may change from one version of Python to the next without warning and should not be relied on by code which will run under multiple versions of the interpreter.

See also the description of the *try* statement in section *The try statement* and *raise* statement in section *The raise statement*.

[1] This limitation occurs because the code that is executed by these operations is not available at the time the module is compiled.

CHAPTER

FIVE

THE IMPORT SYSTEM

Python code in one *module* gains access to the code in another module by the process of *importing* it. The *import* statement is the most common way of invoking the import machinery, but it is not the only way. Functions such as `importlib.import_module()` and built-in `__import__()` can also be used to invoke the import machinery.

The *import* statement combines two operations; it searches for the named module, then it binds the results of that search to a name in the local scope. The search operation of the *import* statement is defined as a call to the `__import__()` function, with the appropriate arguments. The return value of `__import__()` is used to perform the name binding operation of the *import* statement. See the *import* statement for the exact details of that name binding operation.

A direct call to `__import__()` performs only the module search and, if found, the module creation operation. While certain side-effects may occur, such as the importing of parent packages, and the updating of various caches (including `sys.modules`), only the *import* statement performs a name binding operation.

When an *import* statement is executed, the standard builtin `__import__()` function is called. Other mechanisms for invoking the import system (such as `importlib.import_module()`) may choose to bypass `__import__()` and use their own solutions to implement import semantics.

When a module is first imported, Python searches for the module and if found, it creates a module object[1], initializing it. If the named module cannot be found, a `ModuleNotFoundError` is raised. Python implements various strategies to search for the named module when the import machinery is invoked. These strategies can be modified and extended by using various hooks described in the sections below.

Changed in version 3.3: The import system has been updated to fully implement the second phase of **PEP 302**. There is no longer any implicit import machinery - the full import system is exposed through `sys.meta_path`. In addition, native namespace package support has been implemented (see **PEP 420**).

5.1 `importlib`

The `importlib` module provides a rich API for interacting with the import system. For example `importlib.import_module()` provides a recommended, simpler API than built-in `__import__()` for invoking the import machinery. Refer to the `importlib` library documentation for additional detail.

5.2 Packages

Python has only one type of module object, and all modules are of this type, regardless of whether the module is implemented in Python, C, or something else. To help organize modules and provide a naming hierarchy, Python has a concept of *packages*.

[1] See `types.ModuleType`.

You can think of packages as the directories on a file system and modules as files within directories, but don't take this analogy too literally since packages and modules need not originate from the file system. For the purposes of this documentation, we'll use this convenient analogy of directories and files. Like file system directories, packages are organized hierarchically, and packages may themselves contain subpackages, as well as regular modules.

It's important to keep in mind that all packages are modules, but not all modules are packages. Or put another way, packages are just a special kind of module. Specifically, any module that contains a `__path__` attribute is considered a package.

All modules have a name. Subpackage names are separated from their parent package name by dots, akin to Python's standard attribute access syntax. Thus you might have a module called `sys` and a package called `email`, which in turn has a subpackage called `email.mime` and a module within that subpackage called `email.mime.text`.

5.2.1 Regular packages

Python defines two types of packages, *regular packages* and *namespace packages*. Regular packages are traditional packages as they existed in Python 3.2 and earlier. A regular package is typically implemented as a directory containing an `__init__.py` file. When a regular package is imported, this `__init__.py` file is implicitly executed, and the objects it defines are bound to names in the package's namespace. The `__init__.py` file can contain the same Python code that any other module can contain, and Python will add some additional attributes to the module when it is imported.

For example, the following file system layout defines a top level `parent` package with three subpackages:

```
parent/
    __init__.py
    one/
        __init__.py
    two/
        __init__.py
    three/
        __init__.py
```

Importing `parent.one` will implicitly execute `parent/__init__.py` and `parent/one/__init__.py`. Subsequent imports of `parent.two` or `parent.three` will execute `parent/two/__init__.py` and `parent/three/__init__.py` respectively.

5.2.2 Namespace packages

A namespace package is a composite of various *portions*, where each portion contributes a subpackage to the parent package. Portions may reside in different locations on the file system. Portions may also be found in zip files, on the network, or anywhere else that Python searches during import. Namespace packages may or may not correspond directly to objects on the file system; they may be virtual modules that have no concrete representation.

Namespace packages do not use an ordinary list for their `__path__` attribute. They instead use a custom iterable type which will automatically perform a new search for package portions on the next import attempt within that package if the path of their parent package (or `sys.path` for a top level package) changes.

With namespace packages, there is no `parent/__init__.py` file. In fact, there may be multiple `parent` directories found during import search, where each one is provided by a different portion. Thus `parent/one` may not be physically located next to `parent/two`. In this case, Python will create a namespace package for the top-level `parent` package whenever it or one of its subpackages is imported.

See also **PEP 420** for the namespace package specification.

5.3 Searching

To begin the search, Python needs the *fully qualified* name of the module (or package, but for the purposes of this discussion, the difference is immaterial) being imported. This name may come from various arguments to the *import* statement, or from the parameters to the `importlib.import_module()` or `__import__()` functions.

This name will be used in various phases of the import search, and it may be the dotted path to a submodule, e.g. `foo.bar.baz`. In this case, Python first tries to import `foo`, then `foo.bar`, and finally `foo.bar.baz`. If any of the intermediate imports fail, a `ModuleNotFoundError` is raised.

5.3.1 The module cache

The first place checked during import search is `sys.modules`. This mapping serves as a cache of all modules that have been previously imported, including the intermediate paths. So if `foo.bar.baz` was previously imported, `sys.modules` will contain entries for `foo`, `foo.bar`, and `foo.bar.baz`. Each key will have as its value the corresponding module object.

During import, the module name is looked up in `sys.modules` and if present, the associated value is the module satisfying the import, and the process completes. However, if the value is `None`, then a `ModuleNotFoundError` is raised. If the module name is missing, Python will continue searching for the module.

`sys.modules` is writable. Deleting a key may not destroy the associated module (as other modules may hold references to it), but it will invalidate the cache entry for the named module, causing Python to search anew for the named module upon its next import. The key can also be assigned to `None`, forcing the next import of the module to result in a `ModuleNotFoundError`.

Beware though, as if you keep a reference to the module object, invalidate its cache entry in `sys.modules`, and then re-import the named module, the two module objects will *not* be the same. By contrast, `importlib.reload()` will reuse the *same* module object, and simply reinitialise the module contents by rerunning the module's code.

5.3.2 Finders and loaders

If the named module is not found in `sys.modules`, then Python's import protocol is invoked to find and load the module. This protocol consists of two conceptual objects, *finders* and *loaders*. A finder's job is to determine whether it can find the named module using whatever strategy it knows about. Objects that implement both of these interfaces are referred to as *importers* - they return themselves when they find that they can load the requested module.

Python includes a number of default finders and importers. The first one knows how to locate built-in modules, and the second knows how to locate frozen modules. A third default finder searches an *import path* for modules. The *import path* is a list of locations that may name file system paths or zip files. It can also be extended to search for any locatable resource, such as those identified by URLs.

The import machinery is extensible, so new finders can be added to extend the range and scope of module searching.

Finders do not actually load modules. If they can find the named module, they return a *module spec*, an encapsulation of the module's import-related information, which the import machinery then uses when loading the module.

The following sections describe the protocol for finders and loaders in more detail, including how you can create and register new ones to extend the import machinery.

Changed in version 3.4: In previous versions of Python, finders returned *loaders* directly, whereas now they return module specs which *contain* loaders. Loaders are still used during import but have fewer responsibilities.

5.3.3 Import hooks

The import machinery is designed to be extensible; the primary mechanism for this are the *import hooks*. There are two types of import hooks: *meta hooks* and *import path hooks*.

Meta hooks are called at the start of import processing, before any other import processing has occurred, other than `sys.modules` cache look up. This allows meta hooks to override `sys.path` processing, frozen modules, or even built-in modules. Meta hooks are registered by adding new finder objects to `sys.meta_path`, as described below.

Import path hooks are called as part of `sys.path` (or `package.__path__`) processing, at the point where their associated path item is encountered. Import path hooks are registered by adding new callables to `sys.path_hooks` as described below.

5.3.4 The meta path

When the named module is not found in `sys.modules`, Python next searches `sys.meta_path`, which contains a list of meta path finder objects. These finders are queried in order to see if they know how to handle the named module. Meta path finders must implement a method called `find_spec()` which takes three arguments: a name, an import path, and (optionally) a target module. The meta path finder can use any strategy it wants to determine whether it can handle the named module or not.

If the meta path finder knows how to handle the named module, it returns a spec object. If it cannot handle the named module, it returns `None`. If `sys.meta_path` processing reaches the end of its list without returning a spec, then a `ModuleNotFoundError` is raised. Any other exceptions raised are simply propagated up, aborting the import process.

The `find_spec()` method of meta path finders is called with two or three arguments. The first is the fully qualified name of the module being imported, for example `foo.bar.baz`. The second argument is the path entries to use for the module search. For top-level modules, the second argument is `None`, but for submodules or subpackages, the second argument is the value of the parent package's `__path__` attribute. If the appropriate `__path__` attribute cannot be accessed, a `ModuleNotFoundError` is raised. The third argument is an existing module object that will be the target of loading later. The import system passes in a target module only during reload.

The meta path may be traversed multiple times for a single import request. For example, assuming none of the modules involved has already been cached, importing `foo.bar.baz` will first perform a top level import, calling `mpf.find_spec("foo", None, None)` on each meta path finder (`mpf`). After `foo` has been imported, `foo.bar` will be imported by traversing the meta path a second time, calling `mpf.find_spec("foo.bar", foo.__path__, None)`. Once `foo.bar` has been imported, the final traversal will call `mpf.find_spec("foo.bar.baz", foo.bar.__path__, None)`.

Some meta path finders only support top level imports. These importers will always return `None` when anything other than `None` is passed as the second argument.

Python's default `sys.meta_path` has three meta path finders, one that knows how to import built-in modules, one that knows how to import frozen modules, and one that knows how to import modules from an *import path* (i.e. the *path based finder*).

Changed in version 3.4: The `find_spec()` method of meta path finders replaced `find_module()`, which is now deprecated. While it will continue to work without change, the import machinery will try it only if the finder does not implement `find_spec()`.

5.4 Loading

If and when a module spec is found, the import machinery will use it (and the loader it contains) when loading the module. Here is an approximation of what happens during the loading portion of import:

```
module = None
if spec.loader is not None and hasattr(spec.loader, 'create_module'):
    # It is assumed 'exec_module' will also be defined on the loader.
    module = spec.loader.create_module(spec)
if module is None:
    module = ModuleType(spec.name)
# The import-related module attributes get set here:
_init_module_attrs(spec, module)

if spec.loader is None:
    if spec.submodule_search_locations is not None:
        # namespace package
        sys.modules[spec.name] = module
    else:
        # unsupported
        raise ImportError
elif not hasattr(spec.loader, 'exec_module'):
    module = spec.loader.load_module(spec.name)
    # Set __loader__ and __package__ if missing.
else:
    sys.modules[spec.name] = module
    try:
        spec.loader.exec_module(module)
    except BaseException:
        try:
            del sys.modules[spec.name]
        except KeyError:
            pass
        raise
return sys.modules[spec.name]
```

Note the following details:

- If there is an existing module object with the given name in `sys.modules`, import will have already returned it.
- The module will exist in `sys.modules` before the loader executes the module code. This is crucial because the module code may (directly or indirectly) import itself; adding it to `sys.modules` beforehand prevents unbounded recursion in the worst case and multiple loading in the best.
- If loading fails, the failing module – and only the failing module – gets removed from `sys.modules`. Any module already in the `sys.modules` cache, and any module that was successfully loaded as a side-effect, must remain in the cache. This contrasts with reloading where even the failing module is left in `sys.modules`.
- After the module is created but before execution, the import machinery sets the import-related module attributes ("_init_module_attrs" in the pseudo-code example above), as summarized in a *later section*.
- Module execution is the key moment of loading in which the module's namespace gets populated. Execution is entirely delegated to the loader, which gets to decide what gets populated and how.
- The module created during loading and passed to exec_module() may not be the one returned at the end of import[2].

[2] The importlib implementation avoids using the return value directly. Instead, it gets the module object by looking the

Changed in version 3.4: The import system has taken over the boilerplate responsibilities of loaders. These were previously performed by the `importlib.abc.Loader.load_module()` method.

5.4.1 Loaders

Module loaders provide the critical function of loading: module execution. The import machinery calls the `importlib.abc.Loader.exec_module()` method with a single argument, the module object to execute. Any value returned from `exec_module()` is ignored.

Loaders must satisfy the following requirements:

- If the module is a Python module (as opposed to a built-in module or a dynamically loaded extension), the loader should execute the module's code in the module's global name space (`module.__dict__`).
- If the loader cannot execute the module, it should raise an `ImportError`, although any other exception raised during `exec_module()` will be propagated.

In many cases, the finder and loader can be the same object; in such cases the `find_spec()` method would just return a spec with the loader set to `self`.

Module loaders may opt in to creating the module object during loading by implementing a `create_module()` method. It takes one argument, the module spec, and returns the new module object to use during loading. `create_module()` does not need to set any attributes on the module object. If the method returns `None`, the import machinery will create the new module itself.

New in version 3.4: The `create_module()` method of loaders.

Changed in version 3.4: The `load_module()` method was replaced by `exec_module()` and the import machinery assumed all the boilerplate responsibilities of loading.

For compatibility with existing loaders, the import machinery will use the `load_module()` method of loaders if it exists and the loader does not also implement `exec_module()`. However, `load_module()` has been deprecated and loaders should implement `exec_module()` instead.

The `load_module()` method must implement all the boilerplate loading functionality described above in addition to executing the module. All the same constraints apply, with some additional clarification:

- If there is an existing module object with the given name in `sys.modules`, the loader must use that existing module. (Otherwise, `importlib.reload()` will not work correctly.) If the named module does not exist in `sys.modules`, the loader must create a new module object and add it to `sys.modules`.
- The module *must* exist in `sys.modules` before the loader executes the module code, to prevent unbounded recursion or multiple loading.
- If loading fails, the loader must remove any modules it has inserted into `sys.modules`, but it must remove **only** the failing module(s), and only if the loader itself has loaded the module(s) explicitly.

Changed in version 3.5: A `DeprecationWarning` is raised when `exec_module()` is defined but `create_module()` is not.

Changed in version 3.6: An `ImportError` is raised when `exec_module()` is defined but `create_module()` is not.

5.4.2 Submodules

When a submodule is loaded using any mechanism (e.g. `importlib` APIs, the `import` or `import-from` statements, or built-in `__import__()`) a binding is placed in the parent module's namespace to the submodule object. For example, if package `spam` has a submodule `foo`, after importing `spam.foo`, `spam` will have an attribute `foo` which is bound to the submodule. Let's say you have the following directory structure:

module name up in `sys.modules`. The indirect effect of this is that an imported module may replace itself in `sys.modules`. This is implementation-specific behavior that is not guaranteed to work in other Python implementations.

```
spam/
    __init__.py
    foo.py
    bar.py
```

and `spam/__init__.py` has the following lines in it:

```
from .foo import Foo
from .bar import Bar
```

then executing the following puts a name binding to `foo` and `bar` in the `spam` module:

```
>>> import spam
>>> spam.foo
<module 'spam.foo' from '/tmp/imports/spam/foo.py'>
>>> spam.bar
<module 'spam.bar' from '/tmp/imports/spam/bar.py'>
```

Given Python's familiar name binding rules this might seem surprising, but it's actually a fundamental feature of the import system. The invariant holding is that if you have `sys.modules['spam']` and `sys.modules['spam.foo']` (as you would after the above import), the latter must appear as the `foo` attribute of the former.

5.4.3 Module spec

The import machinery uses a variety of information about each module during import, especially before loading. Most of the information is common to all modules. The purpose of a module's spec is to encapsulate this import-related information on a per-module basis.

Using a spec during import allows state to be transferred between import system components, e.g. between the finder that creates the module spec and the loader that executes it. Most importantly, it allows the import machinery to perform the boilerplate operations of loading, whereas without a module spec the loader had that responsibility.

The module's spec is exposed as the `__spec__` attribute on a module object. See `ModuleSpec` for details on the contents of the module spec.

New in version 3.4.

5.4.4 Import-related module attributes

The import machinery fills in these attributes on each module object during loading, based on the module's spec, before the loader executes the module.

`__name__`
: The `__name__` attribute must be set to the fully-qualified name of the module. This name is used to uniquely identify the module in the import system.

`__loader__`
: The `__loader__` attribute must be set to the loader object that the import machinery used when loading the module. This is mostly for introspection, but can be used for additional loader-specific functionality, for example getting data associated with a loader.

`__package__`
: The module's `__package__` attribute must be set. Its value must be a string, but it can be the same value as its `__name__`. When the module is a package, its `__package__` value should be set to its

__name__. When the module is not a package, __package__ should be set to the empty string for top-level modules, or for submodules, to the parent package's name. See **PEP 366** for further details.

This attribute is used instead of __name__ to calculate explicit relative imports for main modules, as defined in **PEP 366**. It is expected to have the same value as __spec__.parent.

Changed in version 3.6: The value of __package__ is expected to be the same as __spec__.parent.

__spec__
The __spec__ attribute must be set to the module spec that was used when importing the module. Setting __spec__ appropriately applies equally to *modules initialized during interpreter startup*. The one exception is __main__, where __spec__ is *set to None in some cases*.

When __package__ is not defined, __spec__.parent is used as a fallback.

New in version 3.4.

Changed in version 3.6: __spec__.parent is used as a fallback when __package__ is not defined.

__path__
If the module is a package (either regular or namespace), the module object's __path__ attribute must be set. The value must be iterable, but may be empty if __path__ has no further significance. If __path__ is not empty, it must produce strings when iterated over. More details on the semantics of __path__ are given *below*.

Non-package modules should not have a __path__ attribute.

__file__

__cached__
__file__ is optional. If set, this attribute's value must be a string. The import system may opt to leave __file__ unset if it has no semantic meaning (e.g. a module loaded from a database).

If __file__ is set, it may also be appropriate to set the __cached__ attribute which is the path to any compiled version of the code (e.g. byte-compiled file). The file does not need to exist to set this attribute; the path can simply point to where the compiled file would exist (see **PEP 3147**).

It is also appropriate to set __cached__ when __file__ is not set. However, that scenario is quite atypical. Ultimately, the loader is what makes use of __file__ and/or __cached__. So if a loader can load from a cached module but otherwise does not load from a file, that atypical scenario may be appropriate.

5.4.5 module.__path__

By definition, if a module has a __path__ attribute, it is a package.

A package's __path__ attribute is used during imports of its subpackages. Within the import machinery, it functions much the same as sys.path, i.e. providing a list of locations to search for modules during import. However, __path__ is typically much more constrained than sys.path.

__path__ must be an iterable of strings, but it may be empty. The same rules used for sys.path also apply to a package's __path__, and sys.path_hooks (described below) are consulted when traversing a package's __path__.

A package's __init__.py file may set or alter the package's __path__ attribute, and this was typically the way namespace packages were implemented prior to **PEP 420**. With the adoption of **PEP 420**, namespace packages no longer need to supply __init__.py files containing only __path__ manipulation code; the import machinery automatically sets __path__ correctly for the namespace package.

5.4.6 Module reprs

By default, all modules have a usable repr, however depending on the attributes set above, and in the module's spec, you can more explicitly control the repr of module objects.

If the module has a spec (`__spec__`), the import machinery will try to generate a repr from it. If that fails or there is no spec, the import system will craft a default repr using whatever information is available on the module. It will try to use the `module.__name__`, `module.__file__`, and `module.__loader__` as input into the repr, with defaults for whatever information is missing.

Here are the exact rules used:

- If the module has a `__spec__` attribute, the information in the spec is used to generate the repr. The "name", "loader", "origin", and "has_location" attributes are consulted.
- If the module has a `__file__` attribute, this is used as part of the module's repr.
- If the module has no `__file__` but does have a `__loader__` that is not `None`, then the loader's repr is used as part of the module's repr.
- Otherwise, just use the module's `__name__` in the repr.

Changed in version 3.4: Use of `loader.module_repr()` has been deprecated and the module spec is now used by the import machinery to generate a module repr.

For backward compatibility with Python 3.3, the module repr will be generated by calling the loader's `module_repr()` method, if defined, before trying either approach described above. However, the method is deprecated.

5.4.7 Cached bytecode invalidation

Before Python loads cached bytecode from `.pyc` file, it checks whether the cache is up-to-date with the source `.py` file. By default, Python does this by storing the source's last-modified timestamp and size in the cache file when writing it. At runtime, the import system then validates the cache file by checking the stored metadata in the cache file against at source's metadata.

Python also supports "hash-based" cache files, which store a hash of the source file's contents rather than its metadata. There are two variants of hash-based `.pyc` files: checked and unchecked. For checked hash-based `.pyc` files, Python validates the cache file by hashing the source file and comparing the resulting hash with the hash in the cache file. If a checked hash-based cache file is found to be invalid, Python regenerates it and writes a new checked hash-based cache file. For unchecked hash-based `.pyc` files, Python simply assumes the cache file is valid if it exists. Hash-based `.pyc` files validation behavior may be overridden with the `--check-hash-based-pycs` flag.

Changed in version 3.7: Added hash-based `.pyc` files. Previously, Python only supported timestamp-based invalidation of bytecode caches.

5.5 The Path Based Finder

As mentioned previously, Python comes with several default meta path finders. One of these, called the *path based finder* (`PathFinder`), searches an *import path*, which contains a list of *path entries*. Each path entry names a location to search for modules.

The path based finder itself doesn't know how to import anything. Instead, it traverses the individual path entries, associating each of them with a path entry finder that knows how to handle that particular kind of path.

The default set of path entry finders implement all the semantics for finding modules on the file system, handling special file types such as Python source code (`.py` files), Python byte code (`.pyc` files) and shared

libraries (e.g. `.so` files). When supported by the `zipimport` module in the standard library, the default path entry finders also handle loading all of these file types (other than shared libraries) from zipfiles.

Path entries need not be limited to file system locations. They can refer to URLs, database queries, or any other location that can be specified as a string.

The path based finder provides additional hooks and protocols so that you can extend and customize the types of searchable path entries. For example, if you wanted to support path entries as network URLs, you could write a hook that implements HTTP semantics to find modules on the web. This hook (a callable) would return a *path entry finder* supporting the protocol described below, which was then used to get a loader for the module from the web.

A word of warning: this section and the previous both use the term *finder*, distinguishing between them by using the terms *meta path finder* and *path entry finder*. These two types of finders are very similar, support similar protocols, and function in similar ways during the import process, but it's important to keep in mind that they are subtly different. In particular, meta path finders operate at the beginning of the import process, as keyed off the `sys.meta_path` traversal.

By contrast, path entry finders are in a sense an implementation detail of the path based finder, and in fact, if the path based finder were to be removed from `sys.meta_path`, none of the path entry finder semantics would be invoked.

5.5.1 Path entry finders

The *path based finder* is responsible for finding and loading Python modules and packages whose location is specified with a string *path entry*. Most path entries name locations in the file system, but they need not be limited to this.

As a meta path finder, the *path based finder* implements the `find_spec()` protocol previously described, however it exposes additional hooks that can be used to customize how modules are found and loaded from the *import path*.

Three variables are used by the *path based finder*, `sys.path`, `sys.path_hooks` and `sys.path_importer_cache`. The `__path__` attributes on package objects are also used. These provide additional ways that the import machinery can be customized.

`sys.path` contains a list of strings providing search locations for modules and packages. It is initialized from the `PYTHONPATH` environment variable and various other installation- and implementation-specific defaults. Entries in `sys.path` can name directories on the file system, zip files, and potentially other "locations" (see the `site` module) that should be searched for modules, such as URLs, or database queries. Only strings and bytes should be present on `sys.path`; all other data types are ignored. The encoding of bytes entries is determined by the individual *path entry finders*.

The *path based finder* is a *meta path finder*, so the import machinery begins the *import path* search by calling the path based finder's `find_spec()` method as described previously. When the `path` argument to `find_spec()` is given, it will be a list of string paths to traverse - typically a package's `__path__` attribute for an import within that package. If the `path` argument is `None`, this indicates a top level import and `sys.path` is used.

The path based finder iterates over every entry in the search path, and for each of these, looks for an appropriate *path entry finder* (`PathEntryFinder`) for the path entry. Because this can be an expensive operation (e.g. there may be *stat()* call overheads for this search), the path based finder maintains a cache mapping path entries to path entry finders. This cache is maintained in `sys.path_importer_cache` (despite the name, this cache actually stores finder objects rather than being limited to *importer* objects). In this way, the expensive search for a particular *path entry* location's *path entry finder* need only be done once. User code is free to remove cache entries from `sys.path_importer_cache` forcing the path based finder to

perform the path entry search again[3].

If the path entry is not present in the cache, the path based finder iterates over every callable in `sys.path_hooks`. Each of the *path entry hooks* in this list is called with a single argument, the path entry to be searched. This callable may either return a *path entry finder* that can handle the path entry, or it may raise `ImportError`. An `ImportError` is used by the path based finder to signal that the hook cannot find a *path entry finder* for that *path entry*. The exception is ignored and *import path* iteration continues. The hook should expect either a string or bytes object; the encoding of bytes objects is up to the hook (e.g. it may be a file system encoding, UTF-8, or something else), and if the hook cannot decode the argument, it should raise `ImportError`.

If `sys.path_hooks` iteration ends with no *path entry finder* being returned, then the path based finder's `find_spec()` method will store `None` in `sys.path_importer_cache` (to indicate that there is no finder for this path entry) and return `None`, indicating that this *meta path finder* could not find the module.

If a *path entry finder* *is* returned by one of the *path entry hook* callables on `sys.path_hooks`, then the following protocol is used to ask the finder for a module spec, which is then used when loading the module.

The current working directory – denoted by an empty string – is handled slightly differently from other entries on `sys.path`. First, if the current working directory is found to not exist, no value is stored in `sys.path_importer_cache`. Second, the value for the current working directory is looked up fresh for each module lookup. Third, the path used for `sys.path_importer_cache` and returned by `importlib.machinery.PathFinder.find_spec()` will be the actual current working directory and not the empty string.

5.5.2 Path entry finder protocol

In order to support imports of modules and initialized packages and also to contribute portions to namespace packages, path entry finders must implement the `find_spec()` method.

`find_spec()` takes two argument, the fully qualified name of the module being imported, and the (optional) target module. `find_spec()` returns a fully populated spec for the module. This spec will always have "loader" set (with one exception).

To indicate to the import machinery that the spec represents a namespace *portion*. the path entry finder sets "loader" on the spec to `None` and "submodule_search_locations" to a list containing the portion.

Changed in version 3.4: `find_spec()` replaced `find_loader()` and `find_module()`, both of which are now deprecated, but will be used if `find_spec()` is not defined.

Older path entry finders may implement one of these two deprecated methods instead of `find_spec()`. The methods are still respected for the sake of backward compatibility. However, if `find_spec()` is implemented on the path entry finder, the legacy methods are ignored.

`find_loader()` takes one argument, the fully qualified name of the module being imported. `find_loader()` returns a 2-tuple where the first item is the loader and the second item is a namespace *portion*. When the first item (i.e. the loader) is `None`, this means that while the path entry finder does not have a loader for the named module, it knows that the path entry contributes to a namespace portion for the named module. This will almost always be the case where Python is asked to import a namespace package that has no physical presence on the file system. When a path entry finder returns `None` for the loader, the second item of the 2-tuple return value must be a sequence, although it can be empty.

If `find_loader()` returns a non-`None` loader value, the portion is ignored and the loader is returned from the path based finder, terminating the search through the path entries.

For backwards compatibility with other implementations of the import protocol, many path entry finders also support the same, traditional `find_module()` method that meta path finders support. However path

[3] In legacy code, it is possible to find instances of `imp.NullImporter` in the `sys.path_importer_cache`. It is recommended that code be changed to use `None` instead. See portingpythoncode for more details.

entry finder `find_module()` methods are never called with a `path` argument (they are expected to record the appropriate path information from the initial call to the path hook).

The `find_module()` method on path entry finders is deprecated, as it does not allow the path entry finder to contribute portions to namespace packages. If both `find_loader()` and `find_module()` exist on a path entry finder, the import system will always call `find_loader()` in preference to `find_module()`.

5.6 Replacing the standard import system

The most reliable mechanism for replacing the entire import system is to delete the default contents of `sys.meta_path`, replacing them entirely with a custom meta path hook.

If it is acceptable to only alter the behaviour of import statements without affecting other APIs that access the import system, then replacing the builtin `__import__()` function may be sufficient. This technique may also be employed at the module level to only alter the behaviour of import statements within that module.

To selectively prevent import of some modules from a hook early on the meta path (rather than disabling the standard import system entirely), it is sufficient to raise `ModuleNotFoundError` directly from `find_spec()` instead of returning `None`. The latter indicates that the meta path search should continue, while raising an exception terminates it immediately.

5.7 Special considerations for __main__

The `__main__` module is a special case relative to Python's import system. As noted *elsewhere*, the `__main__` module is directly initialized at interpreter startup, much like `sys` and `builtins`. However, unlike those two, it doesn't strictly qualify as a built-in module. This is because the manner in which `__main__` is initialized depends on the flags and other options with which the interpreter is invoked.

5.7.1 __main__.__spec__

Depending on how `__main__` is initialized, `__main__.__spec__` gets set appropriately or to `None`.

When Python is started with the `-m` option, `__spec__` is set to the module spec of the corresponding module or package. `__spec__` is also populated when the `__main__` module is loaded as part of executing a directory, zipfile or other `sys.path` entry.

In the remaining cases `__main__.__spec__` is set to `None`, as the code used to populate the `__main__` does not correspond directly with an importable module:

- interactive prompt
- -c switch
- running from stdin
- running directly from a source or bytecode file

Note that `__main__.__spec__` is always `None` in the last case, *even if* the file could technically be imported directly as a module instead. Use the `-m` switch if valid module metadata is desired in `__main__`.

Note also that even when `__main__` corresponds with an importable module and `__main__.__spec__` is set accordingly, they're still considered *distinct* modules. This is due to the fact that blocks guarded by `if __name__ == "__main__":` checks only execute when the module is used to populate the `__main__` namespace, and not during normal import.

5.8 Open issues

XXX It would be really nice to have a diagram.

XXX * (import_machinery.rst) how about a section devoted just to the attributes of modules and packages, perhaps expanding upon or supplanting the related entries in the data model reference page?

XXX runpy, pkgutil, et al in the library manual should all get "See Also" links at the top pointing to the new import system section.

XXX Add more explanation regarding the different ways in which `__main__` is initialized?

XXX Add more info on `__main__` quirks/pitfalls (i.e. copy from **PEP 395**).

5.9 References

The import machinery has evolved considerably since Python's early days. The original specification for packages is still available to read, although some details have changed since the writing of that document.

The original specification for `sys.meta_path` was **PEP 302**, with subsequent extension in **PEP 420**.

PEP 420 introduced *namespace packages* for Python 3.3. **PEP 420** also introduced the `find_loader()` protocol as an alternative to `find_module()`.

PEP 366 describes the addition of the `__package__` attribute for explicit relative imports in main modules.

PEP 328 introduced absolute and explicit relative imports and initially proposed `__name__` for semantics **PEP 366** would eventually specify for `__package__`.

PEP 338 defines executing modules as scripts.

PEP 451 adds the encapsulation of per-module import state in spec objects. It also off-loads most of the boilerplate responsibilities of loaders back onto the import machinery. These changes allow the deprecation of several APIs in the import system and also addition of new methods to finders and loaders.

CHAPTER

SIX

EXPRESSIONS

This chapter explains the meaning of the elements of expressions in Python.

Syntax Notes: In this and the following chapters, extended BNF notation will be used to describe syntax, not lexical analysis. When (one alternative of) a syntax rule has the form

```
name   ::=   othername
```

and no semantics are given, the semantics of this form of `name` are the same as for `othername`.

6.1 Arithmetic conversions

When a description of an arithmetic operator below uses the phrase "the numeric arguments are converted to a common type," this means that the operator implementation for built-in types works as follows:

- If either argument is a complex number, the other is converted to complex;
- otherwise, if either argument is a floating point number, the other is converted to floating point;
- otherwise, both must be integers and no conversion is necessary.

Some additional rules apply for certain operators (e.g., a string as a left argument to the '%' operator). Extensions must define their own conversion behavior.

6.2 Atoms

Atoms are the most basic elements of expressions. The simplest atoms are identifiers or literals. Forms enclosed in parentheses, brackets or braces are also categorized syntactically as atoms. The syntax for atoms is:

```
atom       ::=   identifier | literal | enclosure
enclosure  ::=   parenth_form | list_display | dict_display | set_display
                 | generator_expression | yield_atom
```

6.2.1 Identifiers (Names)

An identifier occurring as an atom is a name. See section *Identifiers and keywords* for lexical definition and section *Naming and binding* for documentation of naming and binding.

When the name is bound to an object, evaluation of the atom yields that object. When a name is not bound,

an attempt to evaluate it raises a `NameError` exception.

Private name mangling: When an identifier that textually occurs in a class definition begins with two or more underscore characters and does not end in two or more underscores, it is considered a *private name* of that class. Private names are transformed to a longer form before code is generated for them. The transformation inserts the class name, with leading underscores removed and a single underscore inserted, in front of the name. For example, the identifier `__spam` occurring in a class named `Ham` will be transformed to `_Ham__spam`. This transformation is independent of the syntactical context in which the identifier is used. If the transformed name is extremely long (longer than 255 characters), implementation defined truncation may happen. If the class name consists only of underscores, no transformation is done.

6.2.2 Literals

Python supports string and bytes literals and various numeric literals:

```
literal  ::=  stringliteral | bytesliteral
              | integer | floatnumber | imagnumber
```

Evaluation of a literal yields an object of the given type (string, bytes, integer, floating point number, complex number) with the given value. The value may be approximated in the case of floating point and imaginary (complex) literals. See section *Literals* for details.

All literals correspond to immutable data types, and hence the object's identity is less important than its value. Multiple evaluations of literals with the same value (either the same occurrence in the program text or a different occurrence) may obtain the same object or a different object with the same value.

6.2.3 Parenthesized forms

A parenthesized form is an optional expression list enclosed in parentheses:

```
parenth_form  ::=  "(" [starred_expression] ")"
```

A parenthesized expression list yields whatever that expression list yields: if the list contains at least one comma, it yields a tuple; otherwise, it yields the single expression that makes up the expression list.

An empty pair of parentheses yields an empty tuple object. Since tuples are immutable, the rules for literals apply (i.e., two occurrences of the empty tuple may or may not yield the same object).

Note that tuples are not formed by the parentheses, but rather by use of the comma operator. The exception is the empty tuple, for which parentheses *are* required — allowing unparenthesized "nothing" in expressions would cause ambiguities and allow common typos to pass uncaught.

6.2.4 Displays for lists, sets and dictionaries

For constructing a list, a set or a dictionary Python provides special syntax called "displays", each of them in two flavors:

- either the container contents are listed explicitly, or
- they are computed via a set of looping and filtering instructions, called a *comprehension*.

Common syntax elements for comprehensions are:

```
comprehension   ::=   expression comp_for
comp_for        ::=   ["async"] "for" target_list "in" or_test [comp_iter]
comp_iter       ::=   comp_for | comp_if
comp_if         ::=   "if" expression_nocond [comp_iter]
```

The comprehension consists of a single expression followed by at least one *for* clause and zero or more *for* or *if* clauses. In this case, the elements of the new container are those that would be produced by considering each of the *for* or *if* clauses a block, nesting from left to right, and evaluating the expression to produce an element each time the innermost block is reached.

However, aside from the iterable expression in the leftmost *for* clause, the comprehension is executed in a separate implicitly nested scope. This ensures that names assigned to in the target list don't "leak" into the enclosing scope.

The iterable expression in the leftmost *for* clause is evaluated directly in the enclosing scope and then passed as an argument to the implictly nested scope. Subsequent *for* clauses and any filter condition in the leftmost *for* clause cannot be evaluated in the enclosing scope as they may depend on the values obtained from the leftmost iterable. For example: `[x*y for x in range(10) for y in range(x, x+10)]`.

To ensure the comprehension always results in a container of the appropriate type, `yield` and `yield from` expressions are prohibited in the implicitly nested scope (in Python 3.7, such expressions emit `DeprecationWarning` when compiled, in Python 3.8+ they will emit `SyntaxError`).

Since Python 3.6, in an *async def* function, an *async for* clause may be used to iterate over a *asynchronous iterator*. A comprehension in an *async def* function may consist of either a *for* or *async for* clause following the leading expression, may contain additional *for* or *async for* clauses, and may also use *await* expressions. If a comprehension contains either *async for* clauses or *await* expressions it is called an *asynchronous comprehension*. An asynchronous comprehension may suspend the execution of the coroutine function in which it appears. See also **PEP 530**.

New in version 3.6: Asynchronous comprehensions were introduced.

Deprecated since version 3.7: `yield` and `yield from` deprecated in the implicitly nested scope.

6.2.5 List displays

A list display is a possibly empty series of expressions enclosed in square brackets:

```
list_display   ::=   "[" [starred_list | comprehension] "]"
```

A list display yields a new list object, the contents being specified by either a list of expressions or a comprehension. When a comma-separated list of expressions is supplied, its elements are evaluated from left to right and placed into the list object in that order. When a comprehension is supplied, the list is constructed from the elements resulting from the comprehension.

6.2.6 Set displays

A set display is denoted by curly braces and distinguishable from dictionary displays by the lack of colons separating keys and values:

```
set_display   ::=   "{" (starred_list | comprehension) "}"
```

A set display yields a new mutable set object, the contents being specified by either a sequence of expressions or a comprehension. When a comma-separated list of expressions is supplied, its elements are evaluated from left to right and added to the set object. When a comprehension is supplied, the set is constructed from the

elements resulting from the comprehension.

An empty set cannot be constructed with `{}`; this literal constructs an empty dictionary.

6.2.7 Dictionary displays

A dictionary display is a possibly empty series of key/datum pairs enclosed in curly braces:

```
dict_display       ::=  "{" [key_datum_list | dict_comprehension] "}"
key_datum_list     ::=  key_datum ("," key_datum)* [","]
key_datum          ::=  expression ":" expression | "**" or_expr
dict_comprehension ::=  expression ":" expression comp_for
```

A dictionary display yields a new dictionary object.

If a comma-separated sequence of key/datum pairs is given, they are evaluated from left to right to define the entries of the dictionary: each key object is used as a key into the dictionary to store the corresponding datum. This means that you can specify the same key multiple times in the key/datum list, and the final dictionary's value for that key will be the last one given.

A double asterisk `**` denotes *dictionary unpacking*. Its operand must be a *mapping*. Each mapping item is added to the new dictionary. Later values replace values already set by earlier key/datum pairs and earlier dictionary unpackings.

New in version 3.5: Unpacking into dictionary displays, originally proposed by **PEP 448**.

A dict comprehension, in contrast to list and set comprehensions, needs two expressions separated with a colon followed by the usual "for" and "if" clauses. When the comprehension is run, the resulting key and value elements are inserted in the new dictionary in the order they are produced.

Restrictions on the types of the key values are listed earlier in section *The standard type hierarchy*. (To summarize, the key type should be *hashable*, which excludes all mutable objects.) Clashes between duplicate keys are not detected; the last datum (textually rightmost in the display) stored for a given key value prevails.

6.2.8 Generator expressions

A generator expression is a compact generator notation in parentheses:

```
generator_expression  ::=  "(" expression comp_for ")"
```

A generator expression yields a new generator object. Its syntax is the same as for comprehensions, except that it is enclosed in parentheses instead of brackets or curly braces.

Variables used in the generator expression are evaluated lazily when the *`__next__()`* method is called for the generator object (in the same fashion as normal generators). However, the iterable expression in the leftmost *`for`* clause is immediately evaluated, so that an error produced by it will be emitted at the point where the generator expression is defined, rather than at the point where the first value is retrieved. Subsequent *`for`* clauses and any filter condition in the leftmost *`for`* clause cannot be evaluated in the enclosing scope as they may depend on the values obtained from the leftmost iterable. For example: `(x*y for x in range(10) for y in range(x, x+10))`.

The parentheses can be omitted on calls with only one argument. See section *Calls* for details.

To avoid interfering with the expected operation of the generator expression itself, `yield` and `yield from` expressions are prohibited in the implicitly defined generator (in Python 3.7, such expressions emit `DeprecationWarning` when compiled, in Python 3.8+ they will emit `SyntaxError`).

If a generator expression contains either *async for* clauses or *await* expressions it is called an *asynchronous generator expression*. An asynchronous generator expression returns a new asynchronous generator object, which is an asynchronous iterator (see *Asynchronous Iterators*).

New in version 3.6: Asynchronous generator expressions were introduced.

Changed in version 3.7: Prior to Python 3.7, asynchronous generator expressions could only appear in *async def* coroutines. Starting with 3.7, any function can use asynchronous generator expressions.

Deprecated since version 3.7: `yield` and `yield from` deprecated in the implicitly nested scope.

6.2.9 Yield expressions

```
yield_atom       ::=  "(" yield_expression ")"
yield_expression ::=  "yield" [expression_list | "from" expression]
```

The yield expression is used when defining a *generator* function or an *asynchronous generator* function and thus can only be used in the body of a function definition. Using a yield expression in a function's body causes that function to be a generator, and using it in an *async def* function's body causes that coroutine function to be an asynchronous generator. For example:

```
def gen():  # defines a generator function
    yield 123

async def agen(): # defines an asynchronous generator function (PEP 525)
    yield 123
```

Due to their side effects on the containing scope, `yield` expressions are not permitted as part of the implicitly defined scopes used to implement comprehensions and generator expressions (in Python 3.7, such expressions emit `DeprecationWarning` when compiled, in Python 3.8+ they will emit `SyntaxError`)..

Deprecated since version 3.7: Yield expressions deprecated in the implicitly nested scopes used to implement comprehensions and generator expressions.

Generator functions are described below, while asynchronous generator functions are described separately in section *Asynchronous generator functions*.

When a generator function is called, it returns an iterator known as a generator. That generator then controls the execution of the generator function. The execution starts when one of the generator's methods is called. At that time, the execution proceeds to the first yield expression, where it is suspended again, returning the value of *expression_list* to the generator's caller. By suspended, we mean that all local state is retained, including the current bindings of local variables, the instruction pointer, the internal evaluation stack, and the state of any exception handling. When the execution is resumed by calling one of the generator's methods, the function can proceed exactly as if the yield expression were just another external call. The value of the yield expression after resuming depends on the method which resumed the execution. If *__next__()* is used (typically via either a *for* or the `next()` builtin) then the result is `None`. Otherwise, if *send()* is used, then the result will be the value passed in to that method.

All of this makes generator functions quite similar to coroutines; they yield multiple times, they have more than one entry point and their execution can be suspended. The only difference is that a generator function cannot control where the execution should continue after it yields; the control is always transferred to the generator's caller.

Yield expressions are allowed anywhere in a *try* construct. If the generator is not resumed before it is finalized (by reaching a zero reference count or by being garbage collected), the generator-iterator's *close()* method will be called, allowing any pending *finally* clauses to execute.

When `yield from <expr>` is used, it treats the supplied expression as a subiterator. All values produced by that subiterator are passed directly to the caller of the current generator's methods. Any values passed in

with *send()* and any exceptions passed in with *throw()* are passed to the underlying iterator if it has the appropriate methods. If this is not the case, then *send()* will raise `AttributeError` or `TypeError`, while *throw()* will just raise the passed in exception immediately.

When the underlying iterator is complete, the `value` attribute of the raised `StopIteration` instance becomes the value of the yield expression. It can be either set explicitly when raising `StopIteration`, or automatically when the sub-iterator is a generator (by returning a value from the sub-generator).

Changed in version 3.3: Added `yield from <expr>` to delegate control flow to a subiterator.

The parentheses may be omitted when the yield expression is the sole expression on the right hand side of an assignment statement.

See also:

PEP 255 - Simple Generators The proposal for adding generators and the *yield* statement to Python.

PEP 342 - Coroutines via Enhanced Generators The proposal to enhance the API and syntax of generators, making them usable as simple coroutines.

PEP 380 - Syntax for Delegating to a Subgenerator The proposal to introduce the `yield_from` syntax, making delegation to sub-generators easy.

Generator-iterator methods

This subsection describes the methods of a generator iterator. They can be used to control the execution of a generator function.

Note that calling any of the generator methods below when the generator is already executing raises a `ValueError` exception.

`generator.__next__()`
Starts the execution of a generator function or resumes it at the last executed yield expression. When a generator function is resumed with a *__next__()* method, the current yield expression always evaluates to `None`. The execution then continues to the next yield expression, where the generator is suspended again, and the value of the *expression_list* is returned to *__next__()*'s caller. If the generator exits without yielding another value, a `StopIteration` exception is raised.

This method is normally called implicitly, e.g. by a *for* loop, or by the built-in `next()` function.

`generator.send(`*value*`)`
Resumes the execution and "sends" a value into the generator function. The *value* argument becomes the result of the current yield expression. The *send()* method returns the next value yielded by the generator, or raises `StopIteration` if the generator exits without yielding another value. When *send()* is called to start the generator, it must be called with `None` as the argument, because there is no yield expression that could receive the value.

`generator.throw(`*type*[, *value*[, *traceback*]]`)`
Raises an exception of type `type` at the point where the generator was paused, and returns the next value yielded by the generator function. If the generator exits without yielding another value, a `StopIteration` exception is raised. If the generator function does not catch the passed-in exception, or raises a different exception, then that exception propagates to the caller.

`generator.close()`
Raises a `GeneratorExit` at the point where the generator function was paused. If the generator function then exits gracefully, is already closed, or raises `GeneratorExit` (by not catching the exception), close returns to its caller. If the generator yields a value, a `RuntimeError` is raised. If the generator raises any other exception, it is propagated to the caller. *close()* does nothing if the generator has already exited due to an exception or normal exit.

Examples

Here is a simple example that demonstrates the behavior of generators and generator functions:

```
>>> def echo(value=None):
...     print("Execution starts when 'next()' is called for the first time.")
...     try:
...         while True:
...             try:
...                 value = (yield value)
...             except Exception as e:
...                 value = e
...     finally:
...         print("Don't forget to clean up when 'close()' is called.")
...
>>> generator = echo(1)
>>> print(next(generator))
Execution starts when 'next()' is called for the first time.
1
>>> print(next(generator))
None
>>> print(generator.send(2))
2
>>> generator.throw(TypeError, "spam")
TypeError('spam',)
>>> generator.close()
Don't forget to clean up when 'close()' is called.
```

For examples using `yield from`, see pep-380 in "What's New in Python."

Asynchronous generator functions

The presence of a yield expression in a function or method defined using *async def* further defines the function as a *asynchronous generator* function.

When an asynchronous generator function is called, it returns an asynchronous iterator known as an asynchronous generator object. That object then controls the execution of the generator function. An asynchronous generator object is typically used in an *async for* statement in a coroutine function analogously to how a generator object would be used in a *for* statement.

Calling one of the asynchronous generator's methods returns an *awaitable* object, and the execution starts when this object is awaited on. At that time, the execution proceeds to the first yield expression, where it is suspended again, returning the value of *expression_list* to the awaiting coroutine. As with a generator, suspension means that all local state is retained, including the current bindings of local variables, the instruction pointer, the internal evaluation stack, and the state of any exception handling. When the execution is resumed by awaiting on the next object returned by the asynchronous generator's methods, the function can proceed exactly as if the yield expression were just another external call. The value of the yield expression after resuming depends on the method which resumed the execution. If *__anext__()* is used then the result is `None`. Otherwise, if *asend()* is used, then the result will be the value passed in to that method.

In an asynchronous generator function, yield expressions are allowed anywhere in a *try* construct. However, if an asynchronous generator is not resumed before it is finalized (by reaching a zero reference count or by being garbage collected), then a yield expression within a *try* construct could result in a failure to execute pending *finally* clauses. In this case, it is the responsibility of the event loop or scheduler running the asynchronous generator to call the asynchronous generator-iterator's *aclose()* method and run the resulting coroutine object, thus allowing any pending *finally* clauses to execute.

To take care of finalization, an event loop should define a *finalizer* function which takes an asynchronous generator-iterator and presumably calls *aclose()* and executes the coroutine. This *finalizer* may be registered by calling `sys.set_asyncgen_hooks()`. When first iterated over, an asynchronous generator-iterator will store the registered *finalizer* to be called upon finalization. For a reference example of a *finalizer* method see the implementation of `asyncio.Loop.shutdown_asyncgens` in Lib/asyncio/base_events.py.

The expression `yield from <expr>` is a syntax error when used in an asynchronous generator function.

Asynchronous generator-iterator methods

This subsection describes the methods of an asynchronous generator iterator, which are used to control the execution of a generator function.

coroutine agen.__anext__()
: Returns an awaitable which when run starts to execute the asynchronous generator or resumes it at the last executed yield expression. When an asynchronous generator function is resumed with a *__anext__()* method, the current yield expression always evaluates to `None` in the returned awaitable, which when run will continue to the next yield expression. The value of the *expression_list* of the yield expression is the value of the `StopIteration` exception raised by the completing coroutine. If the asynchronous generator exits without yielding another value, the awaitable instead raises an `StopAsyncIteration` exception, signalling that the asynchronous iteration has completed.

  This method is normally called implicitly by a *async for* loop.

coroutine agen.asend(*value*)
: Returns an awaitable which when run resumes the execution of the asynchronous generator. As with the *send()* method for a generator, this "sends" a value into the asynchronous generator function, and the *value* argument becomes the result of the current yield expression. The awaitable returned by the *asend()* method will return the next value yielded by the generator as the value of the raised `StopIteration`, or raises `StopAsyncIteration` if the asynchronous generator exits without yielding another value. When *asend()* is called to start the asynchronous generator, it must be called with `None` as the argument, because there is no yield expression that could receive the value.

coroutine agen.athrow(*type*[, *value*[, *traceback*]])
: Returns an awaitable that raises an exception of type `type` at the point where the asynchronous generator was paused, and returns the next value yielded by the generator function as the value of the raised `StopIteration` exception. If the asynchronous generator exits without yielding another value, an `StopAsyncIteration` exception is raised by the awaitable. If the generator function does not catch the passed-in exception, or raises a different exception, then when the awaitable is run that exception propagates to the caller of the awaitable.

coroutine agen.aclose()
: Returns an awaitable that when run will throw a `GeneratorExit` into the asynchronous generator function at the point where it was paused. If the asynchronous generator function then exits gracefully, is already closed, or raises `GeneratorExit` (by not catching the exception), then the returned awaitable will raise a `StopIteration` exception. Any further awaitables returned by subsequent calls to the asynchronous generator will raise a `StopAsyncIteration` exception. If the asynchronous generator yields a value, a `RuntimeError` is raised by the awaitable. If the asynchronous generator raises any other exception, it is propagated to the caller of the awaitable. If the asynchronous generator has already exited due to an exception or normal exit, then further calls to *aclose()* will return an awaitable that does nothing.

6.3 Primaries

Primaries represent the most tightly bound operations of the language. Their syntax is:

```
primary   ::=   atom | attributeref | subscription | slicing | call
```

6.3.1 Attribute references

An attribute reference is a primary followed by a period and a name:

```
attributeref   ::=   primary "." identifier
```

The primary must evaluate to an object of a type that supports attribute references, which most objects do. This object is then asked to produce the attribute whose name is the identifier. This production can be customized by overriding the *__getattr__()* method. If this attribute is not available, the exception `AttributeError` is raised. Otherwise, the type and value of the object produced is determined by the object. Multiple evaluations of the same attribute reference may yield different objects.

6.3.2 Subscriptions

A subscription selects an item of a sequence (string, tuple or list) or mapping (dictionary) object:

```
subscription   ::=   primary "[" expression_list "]"
```

The primary must evaluate to an object that supports subscription (lists or dictionaries for example). User-defined objects can support subscription by defining a *__getitem__()* method.

For built-in objects, there are two types of objects that support subscription:

If the primary is a mapping, the expression list must evaluate to an object whose value is one of the keys of the mapping, and the subscription selects the value in the mapping that corresponds to that key. (The expression list is a tuple except if it has exactly one item.)

If the primary is a sequence, the expression list must evaluate to an integer or a slice (as discussed in the following section).

The formal syntax makes no special provision for negative indices in sequences; however, built-in sequences all provide a *__getitem__()* method that interprets negative indices by adding the length of the sequence to the index (so that `x[-1]` selects the last item of `x`). The resulting value must be a nonnegative integer less than the number of items in the sequence, and the subscription selects the item whose index is that value (counting from zero). Since the support for negative indices and slicing occurs in the object's *__getitem__()* method, subclasses overriding this method will need to explicitly add that support.

A string's items are characters. A character is not a separate data type but a string of exactly one character.

6.3.3 Slicings

A slicing selects a range of items in a sequence object (e.g., a string, tuple or list). Slicings may be used as expressions or as targets in assignment or *del* statements. The syntax for a slicing:

```
slicing      ::=   primary "[" slice_list "]"
slice_list   ::=   slice_item ("," slice_item)* [","]
slice_item   ::=   expression | proper_slice
proper_slice ::=   [lower_bound] ":" [upper_bound] [ ":" [stride] ]
```

```
lower_bound     ::=  expression
upper_bound     ::=  expression
stride          ::=  expression
```

There is ambiguity in the formal syntax here: anything that looks like an expression list also looks like a slice list, so any subscription can be interpreted as a slicing. Rather than further complicating the syntax, this is disambiguated by defining that in this case the interpretation as a subscription takes priority over the interpretation as a slicing (this is the case if the slice list contains no proper slice).

The semantics for a slicing are as follows. The primary is indexed (using the same *__getitem__()* method as normal subscription) with a key that is constructed from the slice list, as follows. If the slice list contains at least one comma, the key is a tuple containing the conversion of the slice items; otherwise, the conversion of the lone slice item is the key. The conversion of a slice item that is an expression is that expression. The conversion of a proper slice is a slice object (see section *The standard type hierarchy*) whose `start`, `stop` and `step` attributes are the values of the expressions given as lower bound, upper bound and stride, respectively, substituting `None` for missing expressions.

6.3.4 Calls

A call calls a callable object (e.g., a *function*) with a possibly empty series of *arguments*:

```
call                 ::=  primary "(" [argument_list [","] | comprehension] ")"
argument_list        ::=  positional_arguments ["," starred_and_keywords]
                          ["," keywords_arguments]
                          | starred_and_keywords ["," keywords_arguments]
                          | keywords_arguments
positional_arguments ::=  ["*"] expression ("," ["*"] expression)*
starred_and_keywords ::=  ("*" expression | keyword_item)
                          ("," "*" expression | "," keyword_item)*
keywords_arguments   ::=  (keyword_item | "**" expression)
                          ("," keyword_item | "," "**" expression)*
keyword_item         ::=  identifier "=" expression
```

An optional trailing comma may be present after the positional and keyword arguments but does not affect the semantics.

The primary must evaluate to a callable object (user-defined functions, built-in functions, methods of built-in objects, class objects, methods of class instances, and all objects having a *__call__()* method are callable). All argument expressions are evaluated before the call is attempted. Please refer to section *Function definitions* for the syntax of formal *parameter* lists.

If keyword arguments are present, they are first converted to positional arguments, as follows. First, a list of unfilled slots is created for the formal parameters. If there are N positional arguments, they are placed in the first N slots. Next, for each keyword argument, the identifier is used to determine the corresponding slot (if the identifier is the same as the first formal parameter name, the first slot is used, and so on). If the slot is already filled, a `TypeError` exception is raised. Otherwise, the value of the argument is placed in the slot, filling it (even if the expression is `None`, it fills the slot). When all arguments have been processed, the slots that are still unfilled are filled with the corresponding default value from the function definition. (Default values are calculated, once, when the function is defined; thus, a mutable object such as a list or dictionary used as default value will be shared by all calls that don't specify an argument value for the corresponding slot; this should usually be avoided.) If there are any unfilled slots for which no default value is specified, a `TypeError` exception is raised. Otherwise, the list of filled slots is used as the argument list for the call.

CPython implementation detail: An implementation may provide built-in functions whose positional parameters do not have names, even if they are 'named' for the purpose of documentation, and which

therefore cannot be supplied by keyword. In CPython, this is the case for functions implemented in C that use `PyArg_ParseTuple()` to parse their arguments.

If there are more positional arguments than there are formal parameter slots, a `TypeError` exception is raised, unless a formal parameter using the syntax `*identifier` is present; in this case, that formal parameter receives a tuple containing the excess positional arguments (or an empty tuple if there were no excess positional arguments).

If any keyword argument does not correspond to a formal parameter name, a `TypeError` exception is raised, unless a formal parameter using the syntax `**identifier` is present; in this case, that formal parameter receives a dictionary containing the excess keyword arguments (using the keywords as keys and the argument values as corresponding values), or a (new) empty dictionary if there were no excess keyword arguments.

If the syntax `*expression` appears in the function call, `expression` must evaluate to an *iterable*. Elements from these iterables are treated as if they were additional positional arguments. For the call `f(x1, x2, *y, x3, x4)`, if *y* evaluates to a sequence *y1*, ..., *yM*, this is equivalent to a call with M+4 positional arguments *x1*, *x2*, *y1*, ..., *yM*, *x3*, *x4*.

A consequence of this is that although the `*expression` syntax may appear *after* explicit keyword arguments, it is processed *before* the keyword arguments (and any `**expression` arguments – see below). So:

```
>>> def f(a, b):
...     print(a, b)
...
>>> f(b=1, *(2,))
2 1
>>> f(a=1, *(2,))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: f() got multiple values for keyword argument 'a'
>>> f(1, *(2,))
1 2
```

It is unusual for both keyword arguments and the `*expression` syntax to be used in the same call, so in practice this confusion does not arise.

If the syntax `**expression` appears in the function call, `expression` must evaluate to a *mapping*, the contents of which are treated as additional keyword arguments. If a keyword is already present (as an explicit keyword argument, or from another unpacking), a `TypeError` exception is raised.

Formal parameters using the syntax `*identifier` or `**identifier` cannot be used as positional argument slots or as keyword argument names.

Changed in version 3.5: Function calls accept any number of `*` and `**` unpackings, positional arguments may follow iterable unpackings (`*`), and keyword arguments may follow dictionary unpackings (`**`). Originally proposed by **PEP 448**.

A call always returns some value, possibly `None`, unless it raises an exception. How this value is computed depends on the type of the callable object.

If it is—

a user-defined function: The code block for the function is executed, passing it the argument list. The first thing the code block will do is bind the formal parameters to the arguments; this is described in section *Function definitions*. When the code block executes a `return` statement, this specifies the return value of the function call.

a built-in function or method: The result is up to the interpreter; see built-in-funcs for the descriptions of built-in functions and methods.

a class object: A new instance of that class is returned.

a class instance method: The corresponding user-defined function is called, with an argument list that is one longer than the argument list of the call: the instance becomes the first argument.

a class instance: The class must define a *__call__()* method; the effect is then the same as if that method was called.

6.4 Await expression

Suspend the execution of *coroutine* on an *awaitable* object. Can only be used inside a *coroutine function*.

```
await_expr   ::=   "await" primary
```

New in version 3.5.

6.5 The power operator

The power operator binds more tightly than unary operators on its left; it binds less tightly than unary operators on its right. The syntax is:

```
power   ::=   ( await_expr | primary ) ["**" u_expr]
```

Thus, in an unparenthesized sequence of power and unary operators, the operators are evaluated from right to left (this does not constrain the evaluation order for the operands): `-1**2` results in `-1`.

The power operator has the same semantics as the built-in `pow()` function, when called with two arguments: it yields its left argument raised to the power of its right argument. The numeric arguments are first converted to a common type, and the result is of that type.

For int operands, the result has the same type as the operands unless the second argument is negative; in that case, all arguments are converted to float and a float result is delivered. For example, `10**2` returns `100`, but `10**-2` returns `0.01`.

Raising `0.0` to a negative power results in a `ZeroDivisionError`. Raising a negative number to a fractional power results in a `complex` number. (In earlier versions it raised a `ValueError`.)

6.6 Unary arithmetic and bitwise operations

All unary arithmetic and bitwise operations have the same priority:

```
u_expr   ::=   power | "-" u_expr | "+" u_expr | "~" u_expr
```

The unary `-` (minus) operator yields the negation of its numeric argument.

The unary `+` (plus) operator yields its numeric argument unchanged.

The unary `~` (invert) operator yields the bitwise inversion of its integer argument. The bitwise inversion of `x` is defined as `-(x+1)`. It only applies to integral numbers.

In all three cases, if the argument does not have the proper type, a `TypeError` exception is raised.

6.7 Binary arithmetic operations

The binary arithmetic operations have the conventional priority levels. Note that some of these operations also apply to certain non-numeric types. Apart from the power operator, there are only two levels, one for multiplicative operators and one for additive operators:

```
m_expr  ::=  u_expr | m_expr "*" u_expr | m_expr "@" m_expr |
             m_expr "//" u_expr| m_expr "/" u_expr |
             m_expr "%" u_expr
a_expr  ::=  m_expr | a_expr "+" m_expr | a_expr "-" m_expr
```

The `*` (multiplication) operator yields the product of its arguments. The arguments must either both be numbers, or one argument must be an integer and the other must be a sequence. In the former case, the numbers are converted to a common type and then multiplied together. In the latter case, sequence repetition is performed; a negative repetition factor yields an empty sequence.

The `@` (at) operator is intended to be used for matrix multiplication. No builtin Python types implement this operator.

New in version 3.5.

The `/` (division) and `//` (floor division) operators yield the quotient of their arguments. The numeric arguments are first converted to a common type. Division of integers yields a float, while floor division of integers results in an integer; the result is that of mathematical division with the 'floor' function applied to the result. Division by zero raises the `ZeroDivisionError` exception.

The `%` (modulo) operator yields the remainder from the division of the first argument by the second. The numeric arguments are first converted to a common type. A zero right argument raises the `ZeroDivisionError` exception. The arguments may be floating point numbers, e.g., `3.14%0.7` equals `0.34` (since `3.14` equals `4*0.7 + 0.34`.) The modulo operator always yields a result with the same sign as its second operand (or zero); the absolute value of the result is strictly smaller than the absolute value of the second operand[1].

The floor division and modulo operators are connected by the following identity: `x == (x//y)*y + (x%y)`. Floor division and modulo are also connected with the built-in function `divmod()`: `divmod(x, y) == (x//y, x%y)`.[2].

In addition to performing the modulo operation on numbers, the `%` operator is also overloaded by string objects to perform old-style string formatting (also known as interpolation). The syntax for string formatting is described in the Python Library Reference, section old-string-formatting.

The floor division operator, the modulo operator, and the `divmod()` function are not defined for complex numbers. Instead, convert to a floating point number using the `abs()` function if appropriate.

The `+` (addition) operator yields the sum of its arguments. The arguments must either both be numbers or both be sequences of the same type. In the former case, the numbers are converted to a common type and then added together. In the latter case, the sequences are concatenated.

The `-` (subtraction) operator yields the difference of its arguments. The numeric arguments are first converted to a common type.

[1] While `abs(x%y) < abs(y)` is true mathematically, for floats it may not be true numerically due to roundoff. For example, and assuming a platform on which a Python float is an IEEE 754 double-precision number, in order that `-1e-100 % 1e100` have the same sign as `1e100`, the computed result is `-1e-100 + 1e100`, which is numerically exactly equal to `1e100`. The function `math.fmod()` returns a result whose sign matches the sign of the first argument instead, and so returns `-1e-100` in this case. Which approach is more appropriate depends on the application.

[2] If x is very close to an exact integer multiple of y, it's possible for `x//y` to be one larger than `(x-x%y)//y` due to rounding. In such cases, Python returns the latter result, in order to preserve that `divmod(x,y)[0] * y + x % y` be very close to `x`.

6.8 Shifting operations

The shifting operations have lower priority than the arithmetic operations:

```
shift_expr  ::=  a_expr | shift_expr ( "<<" | ">>" ) a_expr
```

These operators accept integers as arguments. They shift the first argument to the left or right by the number of bits given by the second argument.

A right shift by *n* bits is defined as floor division by `pow(2,n)`. A left shift by *n* bits is defined as multiplication with `pow(2,n)`.

6.9 Binary bitwise operations

Each of the three bitwise operations has a different priority level:

```
and_expr  ::=  shift_expr | and_expr "&" shift_expr
xor_expr  ::=  and_expr | xor_expr "^" and_expr
or_expr   ::=  xor_expr | or_expr "|" xor_expr
```

The `&` operator yields the bitwise AND of its arguments, which must be integers.

The `^` operator yields the bitwise XOR (exclusive OR) of its arguments, which must be integers.

The `|` operator yields the bitwise (inclusive) OR of its arguments, which must be integers.

6.10 Comparisons

Unlike C, all comparison operations in Python have the same priority, which is lower than that of any arithmetic, shifting or bitwise operation. Also unlike C, expressions like `a < b < c` have the interpretation that is conventional in mathematics:

```
comparison     ::=  or_expr ( comp_operator or_expr )*
comp_operator  ::=  "<" | ">" | "==" | ">=" | "<=" | "!="
                    | "is" ["not"] | ["not"] "in"
```

Comparisons yield boolean values: `True` or `False`.

Comparisons can be chained arbitrarily, e.g., `x < y <= z` is equivalent to `x < y and y <= z`, except that `y` is evaluated only once (but in both cases `z` is not evaluated at all when `x < y` is found to be false).

Formally, if *a*, *b*, *c*, ..., *y*, *z* are expressions and *op1*, *op2*, ..., *opN* are comparison operators, then `a op1 b op2 c ... y opN z` is equivalent to `a op1 b and b op2 c and ... y opN z`, except that each expression is evaluated at most once.

Note that `a op1 b op2 c` doesn't imply any kind of comparison between *a* and *c*, so that, e.g., `x < y > z` is perfectly legal (though perhaps not pretty).

6.10.1 Value comparisons

The operators `<`, `>`, `==`, `>=`, `<=`, and `!=` compare the values of two objects. The objects do not need to have the same type.

Chapter *Objects, values and types* states that objects have a value (in addition to type and identity). The value of an object is a rather abstract notion in Python: For example, there is no canonical access method for an object's value. Also, there is no requirement that the value of an object should be constructed in a particular way, e.g. comprised of all its data attributes. Comparison operators implement a particular notion of what the value of an object is. One can think of them as defining the value of an object indirectly, by means of their comparison implementation.

Because all types are (direct or indirect) subtypes of `object`, they inherit the default comparison behavior from `object`. Types can customize their comparison behavior by implementing *rich comparison methods* like *`__lt__()`*, described in *Basic customization*.

The default behavior for equality comparison (`==` and `!=`) is based on the identity of the objects. Hence, equality comparison of instances with the same identity results in equality, and equality comparison of instances with different identities results in inequality. A motivation for this default behavior is the desire that all objects should be reflexive (i.e. `x is y` implies `x == y`).

A default order comparison (`<`, `>`, `<=`, and `>=`) is not provided; an attempt raises `TypeError`. A motivation for this default behavior is the lack of a similar invariant as for equality.

The behavior of the default equality comparison, that instances with different identities are always unequal, may be in contrast to what types will need that have a sensible definition of object value and value-based equality. Such types will need to customize their comparison behavior, and in fact, a number of built-in types have done that.

The following list describes the comparison behavior of the most important built-in types.

- Numbers of built-in numeric types (typesnumeric) and of the standard library types `fractions.Fraction` and `decimal.Decimal` can be compared within and across their types, with the restriction that complex numbers do not support order comparison. Within the limits of the types involved, they compare mathematically (algorithmically) correct without loss of precision.

  The not-a-number values `float('NaN')` and `Decimal('NaN')` are special. They are identical to themselves (`x is x` is true) but are not equal to themselves (`x == x` is false). Additionally, comparing any number to a not-a-number value will return `False`. For example, both `3 < float('NaN')` and `float('NaN') < 3` will return `False`.

- Binary sequences (instances of `bytes` or `bytearray`) can be compared within and across their types. They compare lexicographically using the numeric values of their elements.

- Strings (instances of `str`) compare lexicographically using the numerical Unicode code points (the result of the built-in function `ord()`) of their characters.[3]

  Strings and binary sequences cannot be directly compared.

- Sequences (instances of `tuple`, `list`, or `range`) can be compared only within each of their types, with the restriction that ranges do not support order comparison. Equality comparison across these types results in inequality, and ordering comparison across these types raises `TypeError`.

[3] The Unicode standard distinguishes between *code points* (e.g. U+0041) and *abstract characters* (e.g. "LATIN CAPITAL LETTER A"). While most abstract characters in Unicode are only represented using one code point, there is a number of abstract characters that can in addition be represented using a sequence of more than one code point. For example, the abstract character "LATIN CAPITAL LETTER C WITH CEDILLA" can be represented as a single *precomposed character* at code position U+00C7, or as a sequence of a *base character* at code position U+0043 (LATIN CAPITAL LETTER C), followed by a *combining character* at code position U+0327 (COMBINING CEDILLA).

The comparison operators on strings compare at the level of Unicode code points. This may be counter-intuitive to humans. For example, `"\u00C7" == "\u0043\u0327"` is `False`, even though both strings represent the same abstract character "LATIN CAPITAL LETTER C WITH CEDILLA".

To compare strings at the level of abstract characters (that is, in a way intuitive to humans), use `unicodedata.normalize()`.

Sequences compare lexicographically using comparison of corresponding elements, whereby reflexivity of the elements is enforced.

In enforcing reflexivity of elements, the comparison of collections assumes that for a collection element `x`, `x == x` is always true. Based on that assumption, element identity is compared first, and element comparison is performed only for distinct elements. This approach yields the same result as a strict element comparison would, if the compared elements are reflexive. For non-reflexive elements, the result is different than for strict element comparison, and may be surprising: The non-reflexive not-a-number values for example result in the following comparison behavior when used in a list:

```
>>> nan = float('NaN')
>>> nan is nan
True
>>> nan == nan
False                  <-- the defined non-reflexive behavior of NaN
>>> [nan] == [nan]
True                   <-- list enforces reflexivity and tests identity first
```

Lexicographical comparison between built-in collections works as follows:

- For two collections to compare equal, they must be of the same type, have the same length, and each pair of corresponding elements must compare equal (for example, `[1,2] == (1,2)` is false because the type is not the same).
- Collections that support order comparison are ordered the same as their first unequal elements (for example, `[1,2,x] <= [1,2,y]` has the same value as `x <= y`). If a corresponding element does not exist, the shorter collection is ordered first (for example, `[1,2] < [1,2,3]` is true).

- Mappings (instances of `dict`) compare equal if and only if they have equal *(key, value)* pairs. Equality comparison of the keys and values enforces reflexivity.

  Order comparisons (`<`, `>`, `<=`, and `>=`) raise `TypeError`.

- Sets (instances of `set` or `frozenset`) can be compared within and across their types.

  They define order comparison operators to mean subset and superset tests. Those relations do not define total orderings (for example, the two sets `{1,2}` and `{2,3}` are not equal, nor subsets of one another, nor supersets of one another). Accordingly, sets are not appropriate arguments for functions which depend on total ordering (for example, `min()`, `max()`, and `sorted()` produce undefined results given a list of sets as inputs).

  Comparison of sets enforces reflexivity of its elements.

- Most other built-in types have no comparison methods implemented, so they inherit the default comparison behavior.

User-defined classes that customize their comparison behavior should follow some consistency rules, if possible:

- Equality comparison should be reflexive. In other words, identical objects should compare equal:

  `x is y` implies `x == y`

- Comparison should be symmetric. In other words, the following expressions should have the same result:

  `x == y` and `y == x`

  `x != y` and `y != x`

  `x < y` and `y > x`

  `x <= y` and `y >= x`

- Comparison should be transitive. The following (non-exhaustive) examples illustrate that:

`x > y and y > z` implies `x > z`

`x < y and y <= z` implies `x < z`

- Inverse comparison should result in the boolean negation. In other words, the following expressions should have the same result:

  `x == y` and `not x != y`

  `x < y` and `not x >= y` (for total ordering)

  `x > y` and `not x <= y` (for total ordering)

  The last two expressions apply to totally ordered collections (e.g. to sequences, but not to sets or mappings). See also the `total_ordering()` decorator.

- The `hash()` result should be consistent with equality. Objects that are equal should either have the same hash value, or be marked as unhashable.

Python does not enforce these consistency rules. In fact, the not-a-number values are an example for not following these rules.

6.10.2 Membership test operations

The operators *in* and *not in* test for membership. `x in s` evaluates to `True` if x is a member of s, and `False` otherwise. `x not in s` returns the negation of `x in s`. All built-in sequences and set types support this as well as dictionary, for which *in* tests whether the dictionary has a given key. For container types such as list, tuple, set, frozenset, dict, or collections.deque, the expression `x in y` is equivalent to `any(x is e or x == e for e in y)`.

For the string and bytes types, `x in y` is `True` if and only if x is a substring of y. An equivalent test is `y.find(x) != -1`. Empty strings are always considered to be a substring of any other string, so `"" in "abc"` will return `True`.

For user-defined classes which define the *__contains__()* method, `x in y` returns `True` if `y.__contains__(x)` returns a true value, and `False` otherwise.

For user-defined classes which do not define *__contains__()* but do define *__iter__()*, `x in y` is `True` if some value `z` with `x == z` is produced while iterating over `y`. If an exception is raised during the iteration, it is as if *in* raised that exception.

Lastly, the old-style iteration protocol is tried: if a class defines *__getitem__()*, `x in y` is `True` if and only if there is a non-negative integer index i such that `x == y[i]`, and all lower integer indices do not raise `IndexError` exception. (If any other exception is raised, it is as if *in* raised that exception).

The operator *not in* is defined to have the inverse true value of *in*.

6.10.3 Identity comparisons

The operators *is* and *is not* test for object identity: `x is y` is true if and only if x and y are the same object. Object identity is determined using the `id()` function. `x is not y` yields the inverse truth value.[4]

6.11 Boolean operations

[4] Due to automatic garbage-collection, free lists, and the dynamic nature of descriptors, you may notice seemingly unusual behaviour in certain uses of the *is* operator, like those involving comparisons between instance methods, or constants. Check their documentation for more info.

```
or_test   ::=  and_test | or_test "or" and_test
and_test  ::=  not_test | and_test "and" not_test
not_test  ::=  comparison | "not" not_test
```

In the context of Boolean operations, and also when expressions are used by control flow statements, the following values are interpreted as false: `False`, `None`, numeric zero of all types, and empty strings and containers (including strings, tuples, lists, dictionaries, sets and frozensets). All other values are interpreted as true. User-defined objects can customize their truth value by providing a *__bool__()* method.

The operator *not* yields `True` if its argument is false, `False` otherwise.

The expression `x and y` first evaluates x; if x is false, its value is returned; otherwise, y is evaluated and the resulting value is returned.

The expression `x or y` first evaluates x; if x is true, its value is returned; otherwise, y is evaluated and the resulting value is returned.

(Note that neither *and* nor *or* restrict the value and type they return to `False` and `True`, but rather return the last evaluated argument. This is sometimes useful, e.g., if `s` is a string that should be replaced by a default value if it is empty, the expression `s or 'foo'` yields the desired value. Because *not* has to create a new value, it returns a boolean value regardless of the type of its argument (for example, `not 'foo'` produces `False` rather than `''`.)

6.12 Conditional expressions

```
conditional_expression  ::=  or_test ["if" or_test "else" expression]
expression              ::=  conditional_expression | lambda_expr
expression_nocond       ::=  or_test | lambda_expr_nocond
```

Conditional expressions (sometimes called a "ternary operator") have the lowest priority of all Python operations.

The expression `x if C else y` first evaluates the condition, C rather than x. If C is true, x is evaluated and its value is returned; otherwise, y is evaluated and its value is returned.

See **PEP 308** for more details about conditional expressions.

6.13 Lambdas

```
lambda_expr         ::=  "lambda" [parameter_list]: expression
lambda_expr_nocond  ::=  "lambda" [parameter_list]: expression_nocond
```

Lambda expressions (sometimes called lambda forms) are used to create anonymous functions. The expression `lambda parameters: expression` yields a function object. The unnamed object behaves like a function object defined with:

```
def <lambda>(parameters):
    return expression
```

See section *Function definitions* for the syntax of parameter lists. Note that functions created with lambda expressions cannot contain statements or annotations.

6.14 Expression lists

```
expression_list      ::=   expression ( "," expression )* [","]
starred_list         ::=   starred_item ( "," starred_item )* [","]
starred_expression   ::=   expression | ( starred_item "," )* [starred_item]
starred_item         ::=   expression | "*" or_expr
```

Except when part of a list or set display, an expression list containing at least one comma yields a tuple. The length of the tuple is the number of expressions in the list. The expressions are evaluated from left to right.

An asterisk `*` denotes *iterable unpacking*. Its operand must be an *iterable*. The iterable is expanded into a sequence of items, which are included in the new tuple, list, or set, at the site of the unpacking.

New in version 3.5: Iterable unpacking in expression lists, originally proposed by **PEP 448**.

The trailing comma is required only to create a single tuple (a.k.a. a *singleton*); it is optional in all other cases. A single expression without a trailing comma doesn't create a tuple, but rather yields the value of that expression. (To create an empty tuple, use an empty pair of parentheses: `()`.)

6.15 Evaluation order

Python evaluates expressions from left to right. Notice that while evaluating an assignment, the right-hand side is evaluated before the left-hand side.

In the following lines, expressions will be evaluated in the arithmetic order of their suffixes:

```
expr1, expr2, expr3, expr4
(expr1, expr2, expr3, expr4)
{expr1: expr2, expr3: expr4}
expr1 + expr2 * (expr3 - expr4)
expr1(expr2, expr3, *expr4, **expr5)
expr3, expr4 = expr1, expr2
```

6.16 Operator precedence

The following table summarizes the operator precedence in Python, from lowest precedence (least binding) to highest precedence (most binding). Operators in the same box have the same precedence. Unless the syntax is explicitly given, operators are binary. Operators in the same box group left to right (except for exponentiation, which groups from right to left).

Note that comparisons, membership tests, and identity tests, all have the same precedence and have a left-to-right chaining feature as described in the *Comparisons* section.

Operator	Description
lambda	Lambda expression
if – *else*	Conditional expression
or	Boolean OR
and	Boolean AND
not x	Boolean NOT
in, *not in*, *is*, *is not*, <, <=, >, >=, !=, ==	Comparisons, including membership tests and identity tests
|	Bitwise OR
^	Bitwise XOR
&	Bitwise AND
<<, >>	Shifts
+, -	Addition and subtraction
*, @, /, //, %	Multiplication, matrix multiplication, division, floor division, remainder[5]
+x, -x, ~x	Positive, negative, bitwise NOT
**	Exponentiation[6]
await x	Await expression
x[index], x[index:index], x(arguments...), x.attribute	Subscription, slicing, call, attribute reference
(expressions...), [expressions...], {key: value...}, {expressions...}	Binding or tuple display, list display, dictionary display, set display

[5] The % operator is also used for string formatting; the same precedence applies.

[6] The power operator ** binds less tightly than an arithmetic or bitwise unary operator on its right, that is, 2**-1 is 0.5.

CHAPTER

SEVEN

SIMPLE STATEMENTS

A simple statement is comprised within a single logical line. Several simple statements may occur on a single line separated by semicolons. The syntax for simple statements is:

```
simple_stmt  ::=  expression_stmt
                | assert_stmt
                | assignment_stmt
                | augmented_assignment_stmt
                | annotated_assignment_stmt
                | pass_stmt
                | del_stmt
                | return_stmt
                | yield_stmt
                | raise_stmt
                | break_stmt
                | continue_stmt
                | import_stmt
                | global_stmt
                | nonlocal_stmt
```

7.1 Expression statements

Expression statements are used (mostly interactively) to compute and write a value, or (usually) to call a procedure (a function that returns no meaningful result; in Python, procedures return the value `None`). Other uses of expression statements are allowed and occasionally useful. The syntax for an expression statement is:

```
expression_stmt  ::=  starred_expression
```

An expression statement evaluates the expression list (which may be a single expression).

In interactive mode, if the value is not `None`, it is converted to a string using the built-in `repr()` function and the resulting string is written to standard output on a line by itself (except if the result is `None`, so that procedure calls do not cause any output.)

7.2 Assignment statements

Assignment statements are used to (re)bind names to values and to modify attributes or items of mutable objects:

```
assignment_stmt  ::=  (target_list "=")+ (starred_expression | yield_expression)
target_list      ::=  target ("," target)* [","]
target           ::=  identifier
                      | "(" [target_list] ")"
                      | "[" [target_list] "]"
                      | attributeref
                      | subscription
                      | slicing
                      | "*" target
```

(See section *Primaries* for the syntax definitions for *attributeref*, *subscription*, and *slicing*.)

An assignment statement evaluates the expression list (remember that this can be a single expression or a comma-separated list, the latter yielding a tuple) and assigns the single resulting object to each of the target lists, from left to right.

Assignment is defined recursively depending on the form of the target (list). When a target is part of a mutable object (an attribute reference, subscription or slicing), the mutable object must ultimately perform the assignment and decide about its validity, and may raise an exception if the assignment is unacceptable. The rules observed by various types and the exceptions raised are given with the definition of the object types (see section *The standard type hierarchy*).

Assignment of an object to a target list, optionally enclosed in parentheses or square brackets, is recursively defined as follows.

- If the target list is empty: The object must also be an empty iterable.
- If the target list is a single target in parentheses: The object is assigned to that target.
- If the target list is a comma-separated list of targets, or a single target in square brackets: The object must be an iterable with the same number of items as there are targets in the target list, and the items are assigned, from left to right, to the corresponding targets.
  - If the target list contains one target prefixed with an asterisk, called a "starred" target: The object must be an iterable with at least as many items as there are targets in the target list, minus one. The first items of the iterable are assigned, from left to right, to the targets before the starred target. The final items of the iterable are assigned to the targets after the starred target. A list of the remaining items in the iterable is then assigned to the starred target (the list can be empty).
  - Else: The object must be an iterable with the same number of items as there are targets in the target list, and the items are assigned, from left to right, to the corresponding targets.

Assignment of an object to a single target is recursively defined as follows.

- If the target is an identifier (name):
  - If the name does not occur in a `global` or `nonlocal` statement in the current code block: the name is bound to the object in the current local namespace.
  - Otherwise: the name is bound to the object in the global namespace or the outer namespace determined by `nonlocal`, respectively.

  The name is rebound if it was already bound. This may cause the reference count for the object previously bound to the name to reach zero, causing the object to be deallocated and its destructor (if

it has one) to be called.

- If the target is an attribute reference: The primary expression in the reference is evaluated. It should yield an object with assignable attributes; if this is not the case, `TypeError` is raised. That object is then asked to assign the assigned object to the given attribute; if it cannot perform the assignment, it raises an exception (usually but not necessarily `AttributeError`).

  Note: If the object is a class instance and the attribute reference occurs on both sides of the assignment operator, the RHS expression, `a.x` can access either an instance attribute or (if no instance attribute exists) a class attribute. The LHS target `a.x` is always set as an instance attribute, creating it if necessary. Thus, the two occurrences of `a.x` do not necessarily refer to the same attribute: if the RHS expression refers to a class attribute, the LHS creates a new instance attribute as the target of the assignment:

```
class Cls:
    x = 3             # class variable
inst = Cls()
inst.x = inst.x + 1   # writes inst.x as 4 leaving Cls.x as 3
```

  This description does not necessarily apply to descriptor attributes, such as properties created with `property()`.

- If the target is a subscription: The primary expression in the reference is evaluated. It should yield either a mutable sequence object (such as a list) or a mapping object (such as a dictionary). Next, the subscript expression is evaluated.

  If the primary is a mutable sequence object (such as a list), the subscript must yield an integer. If it is negative, the sequence's length is added to it. The resulting value must be a nonnegative integer less than the sequence's length, and the sequence is asked to assign the assigned object to its item with that index. If the index is out of range, `IndexError` is raised (assignment to a subscripted sequence cannot add new items to a list).

  If the primary is a mapping object (such as a dictionary), the subscript must have a type compatible with the mapping's key type, and the mapping is then asked to create a key/datum pair which maps the subscript to the assigned object. This can either replace an existing key/value pair with the same key value, or insert a new key/value pair (if no key with the same value existed).

  For user-defined objects, the *`__setitem__()`* method is called with appropriate arguments.

- If the target is a slicing: The primary expression in the reference is evaluated. It should yield a mutable sequence object (such as a list). The assigned object should be a sequence object of the same type. Next, the lower and upper bound expressions are evaluated, insofar they are present; defaults are zero and the sequence's length. The bounds should evaluate to integers. If either bound is negative, the sequence's length is added to it. The resulting bounds are clipped to lie between zero and the sequence's length, inclusive. Finally, the sequence object is asked to replace the slice with the items of the assigned sequence. The length of the slice may be different from the length of the assigned sequence, thus changing the length of the target sequence, if the target sequence allows it.

CPython implementation detail: In the current implementation, the syntax for targets is taken to be the same as for expressions, and invalid syntax is rejected during the code generation phase, causing less detailed error messages.

Although the definition of assignment implies that overlaps between the left-hand side and the right-hand side are 'simultaneous' (for example `a, b = b, a` swaps two variables), overlaps *within* the collection of assigned-to variables occur left-to-right, sometimes resulting in confusion. For instance, the following program prints `[0, 2]`:

```
x = [0, 1]
i = 0
```

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```
i, x[i] = 1, 2         # i is updated, then x[i] is updated
print(x)
```

See also:

PEP 3132 - Extended Iterable Unpacking The specification for the `*target` feature.

7.2.1 Augmented assignment statements

Augmented assignment is the combination, in a single statement, of a binary operation and an assignment statement:

```
augmented_assignment_stmt   ::=   augtarget augop (expression_list | yield_expression)
augtarget                   ::=   identifier | attributeref | subscription | slicing
augop                       ::=   "+=" | "-=" | "*=" | "@=" | "/=" | "//=" | "%=" | "**="
                                  | ">>=" | "<<=" | "&=" | "^=" | "|="
```

(See section *Primaries* for the syntax definitions of the last three symbols.)

An augmented assignment evaluates the target (which, unlike normal assignment statements, cannot be an unpacking) and the expression list, performs the binary operation specific to the type of assignment on the two operands, and assigns the result to the original target. The target is only evaluated once.

An augmented assignment expression like `x += 1` can be rewritten as `x = x + 1` to achieve a similar, but not exactly equal effect. In the augmented version, `x` is only evaluated once. Also, when possible, the actual operation is performed *in-place*, meaning that rather than creating a new object and assigning that to the target, the old object is modified instead.

Unlike normal assignments, augmented assignments evaluate the left-hand side *before* evaluating the right-hand side. For example, `a[i] += f(x)` first looks-up `a[i]`, then it evaluates `f(x)` and performs the addition, and lastly, it writes the result back to `a[i]`.

With the exception of assigning to tuples and multiple targets in a single statement, the assignment done by augmented assignment statements is handled the same way as normal assignments. Similarly, with the exception of the possible *in-place* behavior, the binary operation performed by augmented assignment is the same as the normal binary operations.

For targets which are attribute references, the same *caveat about class and instance attributes* applies as for regular assignments.

7.2.2 Annotated assignment statements

Annotation assignment is the combination, in a single statement, of a variable or attribute annotation and an optional assignment statement:

```
annotated_assignment_stmt   ::=   augtarget ":" expression ["=" expression]
```

The difference from normal *Assignment statements* is that only single target and only single right hand side value is allowed.

For simple names as assignment targets, if in class or module scope, the annotations are evaluated and stored in a special class or module attribute `__annotations__` that is a dictionary mapping from variable names (mangled if private) to evaluated annotations. This attribute is writable and is automatically created at the start of class or module body execution, if annotations are found statically.

For expressions as assignment targets, the annotations are evaluated if in class or module scope, but not stored.

If a name is annotated in a function scope, then this name is local for that scope. Annotations are never evaluated and stored in function scopes.

If the right hand side is present, an annotated assignment performs the actual assignment before evaluating annotations (where applicable). If the right hand side is not present for an expression target, then the interpreter evaluates the target except for the last *__setitem__()* or *__setattr__()* call.

See also:

PEP 526 - Variable and attribute annotation syntax **PEP 484** - Type hints

7.3 The `assert` statement

Assert statements are a convenient way to insert debugging assertions into a program:

```
assert_stmt  ::=  "assert" expression ["," expression]
```

The simple form, `assert expression`, is equivalent to

```
if __debug__:
    if not expression: raise AssertionError
```

The extended form, `assert expression1, expression2`, is equivalent to

```
if __debug__:
    if not expression1: raise AssertionError(expression2)
```

These equivalences assume that `__debug__` and `AssertionError` refer to the built-in variables with those names. In the current implementation, the built-in variable `__debug__` is `True` under normal circumstances, `False` when optimization is requested (command line option -O). The current code generator emits no code for an assert statement when optimization is requested at compile time. Note that it is unnecessary to include the source code for the expression that failed in the error message; it will be displayed as part of the stack trace.

Assignments to `__debug__` are illegal. The value for the built-in variable is determined when the interpreter starts.

7.4 The `pass` statement

```
pass_stmt  ::=  "pass"
```

pass is a null operation — when it is executed, nothing happens. It is useful as a placeholder when a statement is required syntactically, but no code needs to be executed, for example:

```
def f(arg): pass    # a function that does nothing (yet)

class C: pass       # a class with no methods (yet)
```

7.5 The `del` statement

```
del_stmt   ::=   "del" target_list
```

Deletion is recursively defined very similar to the way assignment is defined. Rather than spelling it out in full details, here are some hints.

Deletion of a target list recursively deletes each target, from left to right.

Deletion of a name removes the binding of that name from the local or global namespace, depending on whether the name occurs in a *global* statement in the same code block. If the name is unbound, a `NameError` exception will be raised.

Deletion of attribute references, subscriptions and slicings is passed to the primary object involved; deletion of a slicing is in general equivalent to assignment of an empty slice of the right type (but even this is determined by the sliced object).

Changed in version 3.2: Previously it was illegal to delete a name from the local namespace if it occurs as a free variable in a nested block.

7.6 The `return` statement

```
return_stmt   ::=   "return" [expression_list]
```

return may only occur syntactically nested in a function definition, not within a nested class definition.

If an expression list is present, it is evaluated, else `None` is substituted.

return leaves the current function call with the expression list (or `None`) as return value.

When *return* passes control out of a *try* statement with a *finally* clause, that *finally* clause is executed before really leaving the function.

In a generator function, the *return* statement indicates that the generator is done and will cause `StopIteration` to be raised. The returned value (if any) is used as an argument to construct `StopIteration` and becomes the `StopIteration.value` attribute.

In an asynchronous generator function, an empty *return* statement indicates that the asynchronous generator is done and will cause `StopAsyncIteration` to be raised. A non-empty *return* statement is a syntax error in an asynchronous generator function.

7.7 The `yield` statement

```
yield_stmt   ::=   yield_expression
```

A *yield* statement is semantically equivalent to a *yield expression*. The yield statement can be used to omit the parentheses that would otherwise be required in the equivalent yield expression statement. For example, the yield statements

```
yield <expr>
yield from <expr>
```

are equivalent to the yield expression statements

```
(yield <expr>)
(yield from <expr>)
```

Yield expressions and statements are only used when defining a *generator* function, and are only used in the body of the generator function. Using yield in a function definition is sufficient to cause that definition to create a generator function instead of a normal function.

For full details of *yield* semantics, refer to the *Yield expressions* section.

7.8 The raise statement

```
raise_stmt  ::=  "raise" [expression ["from" expression]]
```

If no expressions are present, *raise* re-raises the last exception that was active in the current scope. If no exception is active in the current scope, a `RuntimeError` exception is raised indicating that this is an error.

Otherwise, *raise* evaluates the first expression as the exception object. It must be either a subclass or an instance of `BaseException`. If it is a class, the exception instance will be obtained when needed by instantiating the class with no arguments.

The *type* of the exception is the exception instance's class, the *value* is the instance itself.

A traceback object is normally created automatically when an exception is raised and attached to it as the `__traceback__` attribute, which is writable. You can create an exception and set your own traceback in one step using the `with_traceback()` exception method (which returns the same exception instance, with its traceback set to its argument), like so:

```
raise Exception("foo occurred").with_traceback(tracebackobj)
```

The `from` clause is used for exception chaining: if given, the second *expression* must be another exception class or instance, which will then be attached to the raised exception as the `__cause__` attribute (which is writable). If the raised exception is not handled, both exceptions will be printed:

```
>>> try:
...     print(1 / 0)
... except Exception as exc:
...     raise RuntimeError("Something bad happened") from exc
...
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
ZeroDivisionError: division by zero

The above exception was the direct cause of the following exception:

Traceback (most recent call last):
  File "<stdin>", line 4, in <module>
RuntimeError: Something bad happened
```

A similar mechanism works implicitly if an exception is raised inside an exception handler or a *finally* clause: the previous exception is then attached as the new exception's `__context__` attribute:

```
>>> try:
...     print(1 / 0)
... except:
...     raise RuntimeError("Something bad happened")
...
```

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```
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
ZeroDivisionError: division by zero

During handling of the above exception, another exception occurred:

Traceback (most recent call last):
  File "<stdin>", line 4, in <module>
RuntimeError: Something bad happened
```

Exception chaining can be explicitly suppressed by specifying `None` in the `from` clause:

```
>>> try:
...     print(1 / 0)
... except:
...     raise RuntimeError("Something bad happened") from None
...
Traceback (most recent call last):
  File "<stdin>", line 4, in <module>
RuntimeError: Something bad happened
```

Additional information on exceptions can be found in section *Exceptions*, and information about handling exceptions is in section *The try statement*.

Changed in version 3.3: `None` is now permitted as `Y` in `raise X from Y`.

New in version 3.3: The `__suppress_context__` attribute to suppress automatic display of the exception context.

7.9 The `break` statement

```
break_stmt  ::=  "break"
```

break may only occur syntactically nested in a *for* or *while* loop, but not nested in a function or class definition within that loop.

It terminates the nearest enclosing loop, skipping the optional *else* clause if the loop has one.

If a *for* loop is terminated by *break*, the loop control target keeps its current value.

When *break* passes control out of a *try* statement with a *finally* clause, that *finally* clause is executed before really leaving the loop.

7.10 The `continue` statement

```
continue_stmt  ::=  "continue"
```

continue may only occur syntactically nested in a *for* or *while* loop, but not nested in a function or class definition or *finally* clause within that loop. It continues with the next cycle of the nearest enclosing loop.

When *continue* passes control out of a *try* statement with a *finally* clause, that *finally* clause is executed before really starting the next loop cycle.

7.11 The `import` statement

```
import_stmt      ::=  "import" module ["as" name] ( "," module ["as" name] )*
                      | "from" relative_module "import" identifier ["as" name]
                      ( "," identifier ["as" name] )*
                      | "from" relative_module "import" "(" identifier ["as" name]
                      ( "," identifier ["as" name] )* [","] ")"
                      | "from" module "import" "*"
module           ::=  (identifier ".")* identifier
relative_module  ::=  "."* module | "."+
name             ::=  identifier
```

The basic import statement (no *from* clause) is executed in two steps:

1. find a module, loading and initializing it if necessary
2. define a name or names in the local namespace for the scope where the *import* statement occurs.

When the statement contains multiple clauses (separated by commas) the two steps are carried out separately for each clause, just as though the clauses had been separated out into individual import statements.

The details of the first step, finding and loading modules are described in greater detail in the section on the *import system*, which also describes the various types of packages and modules that can be imported, as well as all the hooks that can be used to customize the import system. Note that failures in this step may indicate either that the module could not be located, *or* that an error occurred while initializing the module, which includes execution of the module's code.

If the requested module is retrieved successfully, it will be made available in the local namespace in one of three ways:

- If the module name is followed by *as*, then the name following *as* is bound directly to the imported module.
- If no other name is specified, and the module being imported is a top level module, the module's name is bound in the local namespace as a reference to the imported module
- If the module being imported is *not* a top level module, then the name of the top level package that contains the module is bound in the local namespace as a reference to the top level package. The imported module must be accessed using its full qualified name rather than directly

The *from* form uses a slightly more complex process:

1. find the module specified in the *from* clause, loading and initializing it if necessary;
2. for each of the identifiers specified in the *import* clauses:
   (a) check if the imported module has an attribute by that name
   (b) if not, attempt to import a submodule with that name and then check the imported module again for that attribute
   (c) if the attribute is not found, `ImportError` is raised.
   (d) otherwise, a reference to that value is stored in the local namespace, using the name in the *as* clause if it is present, otherwise using the attribute name

Examples:

```
import foo                 # foo imported and bound locally
import foo.bar.baz         # foo.bar.baz imported, foo bound locally
import foo.bar.baz as fbb  # foo.bar.baz imported and bound as fbb
```

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```
from foo.bar import baz     # foo.bar.baz imported and bound as baz
from foo import attr        # foo imported and foo.attr bound as attr
```

If the list of identifiers is replaced by a star (`'*'`), all public names defined in the module are bound in the local namespace for the scope where the *import* statement occurs.

The *public names* defined by a module are determined by checking the module's namespace for a variable named `__all__`; if defined, it must be a sequence of strings which are names defined or imported by that module. The names given in `__all__` are all considered public and are required to exist. If `__all__` is not defined, the set of public names includes all names found in the module's namespace which do not begin with an underscore character (`'_'`). `__all__` should contain the entire public API. It is intended to avoid accidentally exporting items that are not part of the API (such as library modules which were imported and used within the module).

The wild card form of import — `from module import *` — is only allowed at the module level. Attempting to use it in class or function definitions will raise a `SyntaxError`.

When specifying what module to import you do not have to specify the absolute name of the module. When a module or package is contained within another package it is possible to make a relative import within the same top package without having to mention the package name. By using leading dots in the specified module or package after *from* you can specify how high to traverse up the current package hierarchy without specifying exact names. One leading dot means the current package where the module making the import exists. Two dots means up one package level. Three dots is up two levels, etc. So if you execute `from . import mod` from a module in the `pkg` package then you will end up importing `pkg.mod`. If you execute `from ..subpkg2 import mod` from within `pkg.subpkg1` you will import `pkg.subpkg2.mod`. The specification for relative imports is contained within **PEP 328**.

`importlib.import_module()` is provided to support applications that determine dynamically the modules to be loaded.

7.11.1 Future statements

A *future statement* is a directive to the compiler that a particular module should be compiled using syntax or semantics that will be available in a specified future release of Python where the feature becomes standard.

The future statement is intended to ease migration to future versions of Python that introduce incompatible changes to the language. It allows use of the new features on a per-module basis before the release in which the feature becomes standard.

```
future_statement  ::=  "from" "__future__" "import" feature ["as" name]
                       ("," feature ["as" name])*
                       | "from" "__future__" "import" "(" feature ["as" name]
                       ("," feature ["as" name])* [","] ")"
feature           ::=  identifier
name              ::=  identifier
```

A future statement must appear near the top of the module. The only lines that can appear before a future statement are:

- the module docstring (if any),
- comments,
- blank lines, and
- other future statements.

The only feature in Python 3.7 that requires using the future statement is `annotations`.

All historical features enabled by the future statement are still recognized by Python 3. The list includes `absolute_import`, `division`, `generators`, `generator_stop`, `unicode_literals`, `print_function`, `nested_scopes` and `with_statement`. They are all redundant because they are always enabled, and only kept for backwards compatibility.

A future statement is recognized and treated specially at compile time: Changes to the semantics of core constructs are often implemented by generating different code. It may even be the case that a new feature introduces new incompatible syntax (such as a new reserved word), in which case the compiler may need to parse the module differently. Such decisions cannot be pushed off until runtime.

For any given release, the compiler knows which feature names have been defined, and raises a compile-time error if a future statement contains a feature not known to it.

The direct runtime semantics are the same as for any import statement: there is a standard module `__future__`, described later, and it will be imported in the usual way at the time the future statement is executed.

The interesting runtime semantics depend on the specific feature enabled by the future statement.

Note that there is nothing special about the statement:

```
import __future__ [as name]
```

That is not a future statement; it's an ordinary import statement with no special semantics or syntax restrictions.

Code compiled by calls to the built-in functions `exec()` and `compile()` that occur in a module `M` containing a future statement will, by default, use the new syntax or semantics associated with the future statement. This can be controlled by optional arguments to `compile()` — see the documentation of that function for details.

A future statement typed at an interactive interpreter prompt will take effect for the rest of the interpreter session. If an interpreter is started with the `-i` option, is passed a script name to execute, and the script includes a future statement, it will be in effect in the interactive session started after the script is executed.

See also:

PEP 236 - Back to the ___future___ The original proposal for the ___future___ mechanism.

7.12 The `global` statement

```
global_stmt  ::=  "global" identifier ("," identifier)*
```

The *global* statement is a declaration which holds for the entire current code block. It means that the listed identifiers are to be interpreted as globals. It would be impossible to assign to a global variable without *global*, although free variables may refer to globals without being declared global.

Names listed in a *global* statement must not be used in the same code block textually preceding that *global* statement.

Names listed in a *global* statement must not be defined as formal parameters or in a *for* loop control target, *class* definition, function definition, *import* statement, or variable annotation.

CPython implementation detail: The current implementation does not enforce some of these restrictions, but programs should not abuse this freedom, as future implementations may enforce them or silently change the meaning of the program.

Programmer's note: *global* is a directive to the parser. It applies only to code parsed at the same time as

the *global* statement. In particular, a *global* statement contained in a string or code object supplied to the built-in `exec()` function does not affect the code block *containing* the function call, and code contained in such a string is unaffected by *global* statements in the code containing the function call. The same applies to the `eval()` and `compile()` functions.

7.13 The `nonlocal` statement

```
nonlocal_stmt   ::=   "nonlocal" identifier ("," identifier)*
```

The *nonlocal* statement causes the listed identifiers to refer to previously bound variables in the nearest enclosing scope excluding globals. This is important because the default behavior for binding is to search the local namespace first. The statement allows encapsulated code to rebind variables outside of the local scope besides the global (module) scope.

Names listed in a *nonlocal* statement, unlike those listed in a *global* statement, must refer to pre-existing bindings in an enclosing scope (the scope in which a new binding should be created cannot be determined unambiguously).

Names listed in a *nonlocal* statement must not collide with pre-existing bindings in the local scope.

See also:

PEP 3104 - Access to Names in Outer Scopes The specification for the *nonlocal* statement.

CHAPTER

EIGHT

COMPOUND STATEMENTS

Compound statements contain (groups of) other statements; they affect or control the execution of those other statements in some way. In general, compound statements span multiple lines, although in simple incarnations a whole compound statement may be contained in one line.

The *if*, *while* and *for* statements implement traditional control flow constructs. *try* specifies exception handlers and/or cleanup code for a group of statements, while the *with* statement allows the execution of initialization and finalization code around a block of code. Function and class definitions are also syntactically compound statements.

A compound statement consists of one or more 'clauses.' A clause consists of a header and a 'suite.' The clause headers of a particular compound statement are all at the same indentation level. Each clause header begins with a uniquely identifying keyword and ends with a colon. A suite is a group of statements controlled by a clause. A suite can be one or more semicolon-separated simple statements on the same line as the header, following the header's colon, or it can be one or more indented statements on subsequent lines. Only the latter form of a suite can contain nested compound statements; the following is illegal, mostly because it wouldn't be clear to which *if* clause a following *else* clause would belong:

```
if test1: if test2: print(x)
```

Also note that the semicolon binds tighter than the colon in this context, so that in the following example, either all or none of the `print()` calls are executed:

```
if x < y < z: print(x); print(y); print(z)
```

Summarizing:

```
compound_stmt   ::=   if_stmt
                    | while_stmt
                    | for_stmt
                    | try_stmt
                    | with_stmt
                    | funcdef
                    | classdef
                    | async_with_stmt
                    | async_for_stmt
                    | async_funcdef
suite           ::=   stmt_list NEWLINE | NEWLINE INDENT statement+ DEDENT
statement       ::=   stmt_list NEWLINE | compound_stmt
stmt_list       ::=   simple_stmt (";" simple_stmt)* [";"]
```

Note that statements always end in a `NEWLINE` possibly followed by a `DEDENT`. Also note that optional continuation clauses always begin with a keyword that cannot start a statement, thus there are no ambiguities

(the 'dangling *else*' problem is solved in Python by requiring nested *if* statements to be indented).

The formatting of the grammar rules in the following sections places each clause on a separate line for clarity.

8.1 The `if` statement

The *if* statement is used for conditional execution:

```
if_stmt  ::=  "if" expression ":" suite
              ( "elif" expression ":" suite )*
              ["else" ":" suite]
```

It selects exactly one of the suites by evaluating the expressions one by one until one is found to be true (see section *Boolean operations* for the definition of true and false); then that suite is executed (and no other part of the *if* statement is executed or evaluated). If all expressions are false, the suite of the *else* clause, if present, is executed.

8.2 The `while` statement

The *while* statement is used for repeated execution as long as an expression is true:

```
while_stmt  ::=  "while" expression ":" suite
                 ["else" ":" suite]
```

This repeatedly tests the expression and, if it is true, executes the first suite; if the expression is false (which may be the first time it is tested) the suite of the *else* clause, if present, is executed and the loop terminates.

A *break* statement executed in the first suite terminates the loop without executing the *else* clause's suite. A *continue* statement executed in the first suite skips the rest of the suite and goes back to testing the expression.

8.3 The `for` statement

The *for* statement is used to iterate over the elements of a sequence (such as a string, tuple or list) or other iterable object:

```
for_stmt  ::=  "for" target_list "in" expression_list ":" suite
               ["else" ":" suite]
```

The expression list is evaluated once; it should yield an iterable object. An iterator is created for the result of the `expression_list`. The suite is then executed once for each item provided by the iterator, in the order returned by the iterator. Each item in turn is assigned to the target list using the standard rules for assignments (see *Assignment statements*), and then the suite is executed. When the items are exhausted (which is immediately when the sequence is empty or an iterator raises a `StopIteration` exception), the suite in the *else* clause, if present, is executed, and the loop terminates.

A *break* statement executed in the first suite terminates the loop without executing the *else* clause's suite. A *continue* statement executed in the first suite skips the rest of the suite and continues with the next item,

or with the *else* clause if there is no next item.

The for-loop makes assignments to the variables(s) in the target list. This overwrites all previous assignments to those variables including those made in the suite of the for-loop:

```
for i in range(10):
    print(i)
    i = 5             # this will not affect the for-loop
                      # because i will be overwritten with the next
                      # index in the range
```

Names in the target list are not deleted when the loop is finished, but if the sequence is empty, they will not have been assigned to at all by the loop. Hint: the built-in function `range()` returns an iterator of integers suitable to emulate the effect of Pascal's `for i := a to b do`; e.g., `list(range(3))` returns the list `[0, 1, 2]`.

Note: There is a subtlety when the sequence is being modified by the loop (this can only occur for mutable sequences, i.e. lists). An internal counter is used to keep track of which item is used next, and this is incremented on each iteration. When this counter has reached the length of the sequence the loop terminates. This means that if the suite deletes the current (or a previous) item from the sequence, the next item will be skipped (since it gets the index of the current item which has already been treated). Likewise, if the suite inserts an item in the sequence before the current item, the current item will be treated again the next time through the loop. This can lead to nasty bugs that can be avoided by making a temporary copy using a slice of the whole sequence, e.g.,

```
for x in a[:]:
    if x < 0: a.remove(x)
```

8.4 The `try` statement

The *try* statement specifies exception handlers and/or cleanup code for a group of statements:

```
try_stmt   ::=  try1_stmt | try2_stmt
try1_stmt  ::=  "try" ":" suite
                ("except" [expression ["as" identifier]] ":" suite)+
                ["else" ":" suite]
                ["finally" ":" suite]
try2_stmt  ::=  "try" ":" suite
                "finally" ":" suite
```

The *except* clause(s) specify one or more exception handlers. When no exception occurs in the *try* clause, no exception handler is executed. When an exception occurs in the *try* suite, a search for an exception handler is started. This search inspects the except clauses in turn until one is found that matches the exception. An expression-less except clause, if present, must be last; it matches any exception. For an except clause with an expression, that expression is evaluated, and the clause matches the exception if the resulting object is "compatible" with the exception. An object is compatible with an exception if it is the class or a base class of the exception object or a tuple containing an item compatible with the exception.

If no except clause matches the exception, the search for an exception handler continues in the surrounding code and on the invocation stack.[1]

[1] The exception is propagated to the invocation stack unless there is a *finally* clause which happens to raise another exception. That new exception causes the old one to be lost.

If the evaluation of an expression in the header of an except clause raises an exception, the original search for a handler is canceled and a search starts for the new exception in the surrounding code and on the call stack (it is treated as if the entire *try* statement raised the exception).

When a matching except clause is found, the exception is assigned to the target specified after the *as* keyword in that except clause, if present, and the except clause's suite is executed. All except clauses must have an executable block. When the end of this block is reached, execution continues normally after the entire try statement. (This means that if two nested handlers exist for the same exception, and the exception occurs in the try clause of the inner handler, the outer handler will not handle the exception.)

When an exception has been assigned using `as target`, it is cleared at the end of the except clause. This is as if

```
except E as N:
    foo
```

was translated to

```
except E as N:
    try:
        foo
    finally:
        del N
```

This means the exception must be assigned to a different name to be able to refer to it after the except clause. Exceptions are cleared because with the traceback attached to them, they form a reference cycle with the stack frame, keeping all locals in that frame alive until the next garbage collection occurs.

Before an except clause's suite is executed, details about the exception are stored in the `sys` module and can be accessed via `sys.exc_info()`. `sys.exc_info()` returns a 3-tuple consisting of the exception class, the exception instance and a traceback object (see section *The standard type hierarchy*) identifying the point in the program where the exception occurred. `sys.exc_info()` values are restored to their previous values (before the call) when returning from a function that handled an exception.

The optional *else* clause is executed if and when control flows off the end of the *try* clause.[2] Exceptions in the *else* clause are not handled by the preceding *except* clauses.

If *finally* is present, it specifies a 'cleanup' handler. The *try* clause is executed, including any *except* and *else* clauses. If an exception occurs in any of the clauses and is not handled, the exception is temporarily saved. The *finally* clause is executed. If there is a saved exception it is re-raised at the end of the *finally* clause. If the *finally* clause raises another exception, the saved exception is set as the context of the new exception. If the *finally* clause executes a *return* or *break* statement, the saved exception is discarded:

```
>>> def f():
...     try:
...         1/0
...     finally:
...         return 42
...
>>> f()
42
```

The exception information is not available to the program during execution of the *finally* clause.

When a *return*, *break* or *continue* statement is executed in the *try* suite of a *try*…*finally* statement, the *finally* clause is also executed 'on the way out.' A *continue* statement is illegal in the *finally* clause. (The reason is a problem with the current implementation — this restriction may be lifted in the future).

[2] Currently, control "flows off the end" except in the case of an exception or the execution of a *return*, *continue*, or *break* statement.

The return value of a function is determined by the last *return* statement executed. Since the *finally* clause always executes, a *return* statement executed in the *finally* clause will always be the last one executed:

```
>>> def foo():
...     try:
...         return 'try'
...     finally:
...         return 'finally'
...
>>> foo()
'finally'
```

Additional information on exceptions can be found in section *Exceptions*, and information on using the *raise* statement to generate exceptions may be found in section *The raise statement*.

8.5 The `with` statement

The *with* statement is used to wrap the execution of a block with methods defined by a context manager (see section *With Statement Context Managers*). This allows common *try*…*except*…*finally* usage patterns to be encapsulated for convenient reuse.

```
with_stmt   ::=   "with" with_item ("," with_item)* ":" suite
with_item   ::=   expression ["as" target]
```

The execution of the *with* statement with one "item" proceeds as follows:

1. The context expression (the expression given in the *with_item*) is evaluated to obtain a context manager.
2. The context manager's *__exit__()* is loaded for later use.
3. The context manager's *__enter__()* method is invoked.
4. If a target was included in the *with* statement, the return value from *__enter__()* is assigned to it.

   Note: The *with* statement guarantees that if the *__enter__()* method returns without an error, then *__exit__()* will always be called. Thus, if an error occurs during the assignment to the target list, it will be treated the same as an error occurring within the suite would be. See step 6 below.

5. The suite is executed.
6. The context manager's *__exit__()* method is invoked. If an exception caused the suite to be exited, its type, value, and traceback are passed as arguments to *__exit__()*. Otherwise, three `None` arguments are supplied.

   If the suite was exited due to an exception, and the return value from the *__exit__()* method was false, the exception is reraised. If the return value was true, the exception is suppressed, and execution continues with the statement following the *with* statement.

   If the suite was exited for any reason other than an exception, the return value from *__exit__()* is ignored, and execution proceeds at the normal location for the kind of exit that was taken.

With more than one item, the context managers are processed as if multiple *with* statements were nested:

```
with A() as a, B() as b:
    suite
```

is equivalent to

```
with A() as a:
    with B() as b:
        suite
```

Changed in version 3.1: Support for multiple context expressions.

See also:

PEP 343 - The "with" statement The specification, background, and examples for the Python *with* statement.

8.6 Function definitions

A function definition defines a user-defined function object (see section *The standard type hierarchy*):

```
funcdef                 ::=  [decorators] "def" funcname "(" [parameter_list] ")" ["->" expression]
decorators              ::=  decorator+
decorator               ::=  "@" dotted_name ["(" [argument_list [","]] ")"] NEWLINE
dotted_name             ::=  identifier ("." identifier)*
parameter_list          ::=  defparameter ("," defparameter)* ["," [parameter_list_starargs]]
                             | parameter_list_starargs
parameter_list_starargs ::=  "*" [parameter] ("," defparameter)* ["," ["**" parameter [","]]]
                             | "**" parameter [","]
parameter               ::=  identifier [":" expression]
defparameter            ::=  parameter ["=" expression]
funcname                ::=  identifier
```

A function definition is an executable statement. Its execution binds the function name in the current local namespace to a function object (a wrapper around the executable code for the function). This function object contains a reference to the current global namespace as the global namespace to be used when the function is called.

The function definition does not execute the function body; this gets executed only when the function is called.[3]

A function definition may be wrapped by one or more *decorator* expressions. Decorator expressions are evaluated when the function is defined, in the scope that contains the function definition. The result must be a callable, which is invoked with the function object as the only argument. The returned value is bound to the function name instead of the function object. Multiple decorators are applied in nested fashion. For example, the following code

```
@f1(arg)
@f2
def func(): pass
```

is roughly equivalent to

[3] A string literal appearing as the first statement in the function body is transformed into the function's `__doc__` attribute and therefore the function's *docstring*.

```
def func(): pass
func = f1(arg)(f2(func))
```

except that the original function is not temporarily bound to the name `func`.

When one or more *parameters* have the form *parameter* `=` *expression*, the function is said to have "default parameter values." For a parameter with a default value, the corresponding *argument* may be omitted from a call, in which case the parameter's default value is substituted. If a parameter has a default value, all following parameters up until the "`*`" must also have a default value — this is a syntactic restriction that is not expressed by the grammar.

Default parameter values are evaluated from left to right when the function definition is executed. This means that the expression is evaluated once, when the function is defined, and that the same "pre-computed" value is used for each call. This is especially important to understand when a default parameter is a mutable object, such as a list or a dictionary: if the function modifies the object (e.g. by appending an item to a list), the default value is in effect modified. This is generally not what was intended. A way around this is to use `None` as the default, and explicitly test for it in the body of the function, e.g.:

```
def whats_on_the_telly(penguin=None):
    if penguin is None:
        penguin = []
    penguin.append("property of the zoo")
    return penguin
```

Function call semantics are described in more detail in section *Calls*. A function call always assigns values to all parameters mentioned in the parameter list, either from position arguments, from keyword arguments, or from default values. If the form "`*identifier`" is present, it is initialized to a tuple receiving any excess positional parameters, defaulting to the empty tuple. If the form "`**identifier`" is present, it is initialized to a new ordered mapping receiving any excess keyword arguments, defaulting to a new empty mapping of the same type. Parameters after "`*`" or "`*identifier`" are keyword-only parameters and may only be passed used keyword arguments.

Parameters may have annotations of the form "`: expression`" following the parameter name. Any parameter may have an annotation even those of the form `*identifier` or `**identifier`. Functions may have "return" annotation of the form "`-> expression`" after the parameter list. These annotations can be any valid Python expression. The presence of annotations does not change the semantics of a function. The annotation values are available as values of a dictionary keyed by the parameters' names in the `__annotations__` attribute of the function object. If the `annotations` import from `__future__` is used, annotations are preserved as strings at runtime which enables postponed evaluation. Otherwise, they are evaluated when the function definition is executed. In this case annotations may be evaluated in a different order than they appear in the source code.

It is also possible to create anonymous functions (functions not bound to a name), for immediate use in expressions. This uses lambda expressions, described in section *Lambdas*. Note that the lambda expression is merely a shorthand for a simplified function definition; a function defined in a "*`def`*" statement can be passed around or assigned to another name just like a function defined by a lambda expression. The "*`def`*" form is actually more powerful since it allows the execution of multiple statements and annotations.

Programmer's note: Functions are first-class objects. A "`def`" statement executed inside a function definition defines a local function that can be returned or passed around. Free variables used in the nested function can access the local variables of the function containing the def. See section *Naming and binding* for details.

See also:

PEP 3107 - Function Annotations The original specification for function annotations.

PEP 484 - Type Hints Definition of a standard meaning for annotations: type hints.

PEP 526 - Syntax for Variable Annotations Ability to type hint variable declarations, including class variables and instance variables

PEP 563 - Postponed Evaluation of Annotations Support for forward references within annotations by preserving annotations in a string form at runtime instead of eager evaluation.

8.7 Class definitions

A class definition defines a class object (see section *The standard type hierarchy*):

```
classdef    ::=  [decorators] "class" classname [inheritance] ":" suite
inheritance ::=  "(" [argument_list] ")"
classname   ::=  identifier
```

A class definition is an executable statement. The inheritance list usually gives a list of base classes (see *Metaclasses* for more advanced uses), so each item in the list should evaluate to a class object which allows subclassing. Classes without an inheritance list inherit, by default, from the base class `object`; hence,

```
class Foo:
    pass
```

is equivalent to

```
class Foo(object):
    pass
```

The class's suite is then executed in a new execution frame (see *Naming and binding*), using a newly created local namespace and the original global namespace. (Usually, the suite contains mostly function definitions.) When the class's suite finishes execution, its execution frame is discarded but its local namespace is saved.[4] A class object is then created using the inheritance list for the base classes and the saved local namespace for the attribute dictionary. The class name is bound to this class object in the original local namespace.

The order in which attributes are defined in the class body is preserved in the new class's `__dict__`. Note that this is reliable only right after the class is created and only for classes that were defined using the definition syntax.

Class creation can be customized heavily using *metaclasses*.

Classes can also be decorated: just like when decorating functions,

```
@f1(arg)
@f2
class Foo: pass
```

is roughly equivalent to

```
class Foo: pass
Foo = f1(arg)(f2(Foo))
```

The evaluation rules for the decorator expressions are the same as for function decorators. The result is then bound to the class name.

Programmer's note: Variables defined in the class definition are class attributes; they are shared by instances. Instance attributes can be set in a method with `self.name = value`. Both class and instance

[4] A string literal appearing as the first statement in the class body is transformed into the namespace's `__doc__` item and therefore the class's *docstring*.

attributes are accessible through the notation "`self.name`", and an instance attribute hides a class attribute with the same name when accessed in this way. Class attributes can be used as defaults for instance attributes, but using mutable values there can lead to unexpected results. *Descriptors* can be used to create instance variables with different implementation details.

See also:

PEP 3115 - Metaclasses in Python 3 **PEP 3129** - Class Decorators

8.8 Coroutines

New in version 3.5.

8.8.1 Coroutine function definition

```
async_funcdef   ::=   [decorators] "async" "def" funcname "(" [parameter_list] ")" ["->" expression] ":
```

Execution of Python coroutines can be suspended and resumed at many points (see *coroutine*). In the body of a coroutine, any `await` and `async` identifiers become reserved keywords; *`await`* expressions, *`async for`* and *`async with`* can only be used in coroutine bodies.

Functions defined with `async def` syntax are always coroutine functions, even if they do not contain `await` or `async` keywords.

It is a `SyntaxError` to use `yield from` expressions in `async def` coroutines.

An example of a coroutine function:

```
async def func(param1, param2):
    do_stuff()
    await some_coroutine()
```

8.8.2 The `async for` statement

```
async_for_stmt   ::=   "async" for_stmt
```

An *asynchronous iterable* is able to call asynchronous code in its *iter* implementation, and *asynchronous iterator* can call asynchronous code in its *next* method.

The `async for` statement allows convenient iteration over asynchronous iterators.

The following code:

```
async for TARGET in ITER:
    BLOCK
else:
    BLOCK2
```

Is semantically equivalent to:

```
iter = (ITER)
iter = type(iter).__aiter__(iter)
running = True
while running:
    try:
```

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```
        TARGET = await type(iter).__anext__(iter)
    except StopAsyncIteration:
        running = False
    else:
        BLOCK
else:
    BLOCK2
```

See also *__aiter__()* and *__anext__()* for details.

It is a SyntaxError to use `async for` statement outside of an *async def* function.

8.8.3 The `async with` statement

```
async_with_stmt   ::=   "async" with_stmt
```

An *asynchronous context manager* is a *context manager* that is able to suspend execution in its *enter* and *exit* methods.

The following code:

```
async with EXPR as VAR:
    BLOCK
```

Is semantically equivalent to:

```
mgr = (EXPR)
aexit = type(mgr).__aexit__
aenter = type(mgr).__aenter__(mgr)

VAR = await aenter
try:
    BLOCK
except:
    if not await aexit(mgr, *sys.exc_info()):
        raise
else:
    await aexit(mgr, None, None, None)
```

See also *__aenter__()* and *__aexit__()* for details.

It is a SyntaxError to use `async with` statement outside of an *async def* function.

See also:

PEP 492 - Coroutines with async and await syntax

CHAPTER

NINE

TOP-LEVEL COMPONENTS

The Python interpreter can get its input from a number of sources: from a script passed to it as standard input or as program argument, typed in interactively, from a module source file, etc. This chapter gives the syntax used in these cases.

9.1 Complete Python programs

While a language specification need not prescribe how the language interpreter is invoked, it is useful to have a notion of a complete Python program. A complete Python program is executed in a minimally initialized environment: all built-in and standard modules are available, but none have been initialized, except for `sys` (various system services), `builtins` (built-in functions, exceptions and `None`) and `__main__`. The latter is used to provide the local and global namespace for execution of the complete program.

The syntax for a complete Python program is that for file input, described in the next section.

The interpreter may also be invoked in interactive mode; in this case, it does not read and execute a complete program but reads and executes one statement (possibly compound) at a time. The initial environment is identical to that of a complete program; each statement is executed in the namespace of `__main__`.

A complete program can be passed to the interpreter in three forms: with the `-c` *string* command line option, as a file passed as the first command line argument, or as standard input. If the file or standard input is a tty device, the interpreter enters interactive mode; otherwise, it executes the file as a complete program.

9.2 File input

All input read from non-interactive files has the same form:

```
file_input   ::=   (NEWLINE | statement)*
```

This syntax is used in the following situations:

- when parsing a complete Python program (from a file or from a string);
- when parsing a module;
- when parsing a string passed to the `exec()` function;

9.3 Interactive input

Input in interactive mode is parsed using the following grammar:

```
interactive_input   ::=    [stmt_list] NEWLINE | compound_stmt NEWLINE
```

Note that a (top-level) compound statement must be followed by a blank line in interactive mode; this is needed to help the parser detect the end of the input.

9.4 Expression input

`eval()` is used for expression input. It ignores leading whitespace. The string argument to `eval()` must have the following form:

```
eval_input   ::=    expression_list NEWLINE*
```

CHAPTER

TEN

FULL GRAMMAR SPECIFICATION

This is the full Python grammar, as it is read by the parser generator and used to parse Python source files:

```
# Grammar for Python

# NOTE WELL: You should also follow all the steps listed at
# https://devguide.python.org/grammar/

# Start symbols for the grammar:
#       single_input is a single interactive statement;
#       file_input is a module or sequence of commands read from an input file;
#       eval_input is the input for the eval() functions.
# NB: compound_stmt in single_input is followed by extra NEWLINE!
single_input: NEWLINE | simple_stmt | compound_stmt NEWLINE
file_input: (NEWLINE | stmt)* ENDMARKER
eval_input: testlist NEWLINE* ENDMARKER

decorator: '@' dotted_name [ '(' [arglist] ')' ] NEWLINE
decorators: decorator+
decorated: decorators (classdef | funcdef | async_funcdef)

async_funcdef: 'async' funcdef
funcdef: 'def' NAME parameters ['->' test] ':' suite

parameters: '(' [typedargslist] ')'
typedargslist: (tfpdef ['=' test] (',' tfpdef ['=' test])* [',' [
        '*' [tfpdef] (',' tfpdef ['=' test])* [',' ['**' tfpdef [',']]]
      | '**' tfpdef [',']]]
  | '*' [tfpdef] (',' tfpdef ['=' test])* [',' ['**' tfpdef [',']]]
  | '**' tfpdef [','])
tfpdef: NAME [':' test]
varargslist: (vfpdef ['=' test] (',' vfpdef ['=' test])* [',' [
        '*' [vfpdef] (',' vfpdef ['=' test])* [',' ['**' vfpdef [',']]]
      | '**' vfpdef [',']]]
  | '*' [vfpdef] (',' vfpdef ['=' test])* [',' ['**' vfpdef [',']]]
  | '**' vfpdef [',']
)
vfpdef: NAME

stmt: simple_stmt | compound_stmt
simple_stmt: small_stmt (';' small_stmt)* [';'] NEWLINE
small_stmt: (expr_stmt | del_stmt | pass_stmt | flow_stmt |
             import_stmt | global_stmt | nonlocal_stmt | assert_stmt)
expr_stmt: testlist_star_expr (annassign | augassign (yield_expr|testlist) |
                     ('=' (yield_expr|testlist_star_expr))*)
```

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```
annassign: ':' test ['=' test]
testlist_star_expr: (test|star_expr) (',' (test|star_expr))* [',']
augassign: ('+=' | '-=' | '*=' | '@=' | '/=' | '%=' | '&=' | '|=' | '^=' |
            '<<=' | '>>=' | '**=' | '//=')
# For normal and annotated assignments, additional restrictions enforced by the interpreter
del_stmt: 'del' exprlist
pass_stmt: 'pass'
flow_stmt: break_stmt | continue_stmt | return_stmt | raise_stmt | yield_stmt
break_stmt: 'break'
continue_stmt: 'continue'
return_stmt: 'return' [testlist]
yield_stmt: yield_expr
raise_stmt: 'raise' [test ['from' test]]
import_stmt: import_name | import_from
import_name: 'import' dotted_as_names
# note below: the ('.' | '...') is necessary because '...' is tokenized as ELLIPSIS
import_from: ('from' (('.' | '...')* dotted_name | ('.' | '...')+)
              'import' ('*' | '(' import_as_names ')' | import_as_names))
import_as_name: NAME ['as' NAME]
dotted_as_name: dotted_name ['as' NAME]
import_as_names: import_as_name (',' import_as_name)* [',']
dotted_as_names: dotted_as_name (',' dotted_as_name)*
dotted_name: NAME ('.' NAME)*
global_stmt: 'global' NAME (',' NAME)*
nonlocal_stmt: 'nonlocal' NAME (',' NAME)*
assert_stmt: 'assert' test [',' test]

compound_stmt: if_stmt | while_stmt | for_stmt | try_stmt | with_stmt | funcdef | classdef |␣
↪decorated | async_stmt
async_stmt: 'async' (funcdef | with_stmt | for_stmt)
if_stmt: 'if' test ':' suite ('elif' test ':' suite)* ['else' ':' suite]
while_stmt: 'while' test ':' suite ['else' ':' suite]
for_stmt: 'for' exprlist 'in' testlist ':' suite ['else' ':' suite]
try_stmt: ('try' ':' suite
           ((except_clause ':' suite)+
            ['else' ':' suite]
            ['finally' ':' suite] |
           'finally' ':' suite))
with_stmt: 'with' with_item (',' with_item)*  ':' suite
with_item: test ['as' expr]
# NB compile.c makes sure that the default except clause is last
except_clause: 'except' [test ['as' NAME]]
suite: simple_stmt | NEWLINE INDENT stmt+ DEDENT

test: or_test ['if' or_test 'else' test] | lambdef
test_nocond: or_test | lambdef_nocond
lambdef: 'lambda' [varargslist] ':' test
lambdef_nocond: 'lambda' [varargslist] ':' test_nocond
or_test: and_test ('or' and_test)*
and_test: not_test ('and' not_test)*
not_test: 'not' not_test | comparison
comparison: expr (comp_op expr)*
# <> isn't actually a valid comparison operator in Python. It's here for the
# sake of a __future__ import described in PEP 401 (which really works :-)
comp_op: '<'|'>'|'=='|'>='|'<='|'<>'|'!='|'in'|'not' 'in'|'is'|'is' 'not'
star_expr: '*' expr
```

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```
expr: xor_expr ('|' xor_expr)*
xor_expr: and_expr ('^' and_expr)*
and_expr: shift_expr ('&' shift_expr)*
shift_expr: arith_expr (('<<'|'>>') arith_expr)*
arith_expr: term (('+'|'-') term)*
term: factor (('*'|'@'|'/'|'%'|'//') factor)*
factor: ('+'|'-'|'~') factor | power
power: atom_expr ['**' factor]
atom_expr: ['await'] atom trailer*
atom: ('(' [yield_expr|testlist_comp] ')' |
       '[' [testlist_comp] ']' |
       '{' [dictorsetmaker] '}' |
       NAME | NUMBER | STRING+ | '...' | 'None' | 'True' | 'False')
testlist_comp: (test|star_expr) ( comp_for | (',' (test|star_expr))* [','] )
trailer: '(' [arglist] ')' | '[' subscriptlist ']' | '.' NAME
subscriptlist: subscript (',' subscript)* [',']
subscript: test | [test] ':' [test] [sliceop]
sliceop: ':' [test]
exprlist: (expr|star_expr) (',' (expr|star_expr))* [',']
testlist: test (',' test)* [',']
dictorsetmaker: ( ((test ':' test | '**' expr)
                   (comp_for | (',' (test ':' test | '**' expr))* [','])) |
                  ((test | star_expr)
                   (comp_for | (',' (test | star_expr))* [',']) )

classdef: 'class' NAME ['(' [arglist] ')'] ':' suite

arglist: argument (',' argument)*  [',']

# The reason that keywords are test nodes instead of NAME is that using NAME
# results in an ambiguity. ast.c makes sure it's a NAME.
# "test '=' test" is really "keyword '=' test", but we have no such token.
# These need to be in a single rule to avoid grammar that is ambiguous
# to our LL(1) parser. Even though 'test' includes '*expr' in star_expr,
# we explicitly match '*' here, too, to give it proper precedence.
# Illegal combinations and orderings are blocked in ast.c:
# multiple (test comp_for) arguments are blocked; keyword unpackings
# that precede iterable unpackings are blocked; etc.
argument: ( test [comp_for] |
            test '=' test |
            '**' test |
            '*' test )

comp_iter: comp_for | comp_if
sync_comp_for: 'for' exprlist 'in' or_test [comp_iter]
comp_for: ['async'] sync_comp_for
comp_if: 'if' test_nocond [comp_iter]

# not used in grammar, but may appear in "node" passed from Parser to Compiler
encoding_decl: NAME

yield_expr: 'yield' [yield_arg]
yield_arg: 'from' test | testlist
```

APPENDIX

A

GLOSSARY

`>>>` The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

`...` The default Python prompt of the interactive shell when entering code for an indented code block, when within a pair of matching left and right delimiters (parentheses, square brackets, curly braces or triple quotes), or after specifying a decorator.

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See 2to3-reference.

abstract base class Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with *magic methods*). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections.abc` module), numbers (in the `numbers` module), streams (in the `io` module), import finders and loaders (in the `importlib.abc` module). You can create your own ABCs with the `abc` module.

annotation A label associated with a variable, a class attribute or a function parameter or return value, used by convention as a *type hint*.

Annotations of local variables cannot be accessed at runtime, but annotations of global variables, class attributes, and functions are stored in the `__annotations__` special attribute of modules, classes, and functions, respectively.

See *variable annotation*, *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

argument A value passed to a *function* (or *method*) when calling the function. There are two kinds of argument:

- *keyword argument*: an argument preceded by an identifier (e.g. `name=`) in a function call or passed as a value in a dictionary preceded by `**`. For example, `3` and `5` are both keyword arguments in the following calls to `complex()`:

```
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- *positional argument*: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an *iterable* preceded by `*`. For example, `3` and `5` are both positional arguments in the following calls:

```
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the *Calls* section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the *parameter* glossary entry, the FAQ question on the difference between arguments and parameters, and **PEP 362**.

asynchronous context manager An object which controls the environment seen in an `async with` statement by defining `__aenter__()` and `__aexit__()` methods. Introduced by **PEP 492**.

asynchronous generator A function which returns an *asynchronous generator iterator*. It looks like a coroutine function defined with `async def` except that it contains `yield` expressions for producing a series of values usable in an `async for` loop.

Usually refers to a asynchronous generator function, but may refer to an *asynchronous generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

An asynchronous generator function may contain `await` expressions as well as `async for`, and `async with` statements.

asynchronous generator iterator An object created by a *asynchronous generator* function.

This is an *asynchronous iterator* which when called using the `__anext__()` method returns an awaitable object which will execute that the body of the asynchronous generator function until the next `yield` expression.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *asynchronous generator iterator* effectively resumes with another awaitable returned by `__anext__()`, it picks up where it left off. See **PEP 492** and **PEP 525**.

asynchronous iterable An object, that can be used in an `async for` statement. Must return an *asynchronous iterator* from its `__aiter__()` method. Introduced by **PEP 492**.

asynchronous iterator An object that implements `__aiter__()` and `__anext__()` methods. `__anext__` must return an *awaitable* object. `async for` resolves awaitable returned from asynchronous iterator's `__anext__()` method until it raises `StopAsyncIteration` exception. Introduced by **PEP 492**.

attribute A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

awaitable An object that can be used in an `await` expression. Can be a *coroutine* or an object with an `__await__()` method. See also **PEP 492**.

BDFL Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

binary file A *file object* able to read and write *bytes-like objects*. Examples of binary files are files opened in binary mode (`'rb'`, `'wb'` or `'rb+'`), `sys.stdin.buffer`, `sys.stdout.buffer`, and instances of `io.BytesIO` and `gzip.GzipFile`.

See also *text file* for a file object able to read and write `str` objects.

bytes-like object An object that supports the bufferobjects and can export a C-*contiguous* buffer. This includes all `bytes`, `bytearray`, and `array.array` objects, as well as many common `memoryview` objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as "read-write bytes-like objects". Example mutable buffer objects include `bytearray` and a `memoryview` of a `bytearray`. Other operations require the binary data to be stored in immutable objects ("read-only bytes-like objects"); examples of these include `bytes` and a `memoryview` of a `bytes` object.

bytecode Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for the dis module.

class A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

class variable A variable defined in a class and intended to be modified only at class level (i.e., not in an instance of the class).

coercion The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer `3`, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

complex number An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of `-1`), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

context manager An object which controls the environment seen in a *`with`* statement by defining *`__enter__()`* and *`__exit__()`* methods. See **PEP 343**.

contiguous A buffer is considered contiguous exactly if it is either *C-contiguous* or *Fortran contiguous*. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be laid out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

coroutine Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the *`async def`* statement. See also **PEP 492**.

coroutine function A function which returns a *coroutine* object. A coroutine function may be defined with the *`async def`* statement, and may contain *`await`*, *`async for`*, and *`async with`* keywords. These were introduced by **PEP 492**.

CPython The canonical implementation of the Python programming language, as distributed on python.org. The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

decorator A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)
```

(continues on next page)

(continued from previous page)

```
@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for *function definitions* and *class definitions* for more about decorators.

descriptor Any object which defines the methods *__get__()*, *__set__()*, or *__delete__()*. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using *a.b* to get, set or delete an attribute looks up the object named *b* in the class dictionary for *a*, but if *b* is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see *Implementing Descriptors*.

dictionary An associative array, where arbitrary keys are mapped to values. The keys can be any object with *__hash__()* and *__eq__()* methods. Called a hash in Perl.

dictionary view The objects returned from `dict.keys()`, `dict.values()`, and `dict.items()` are called dictionary views. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use `list(dictview)`. See dict-views.

docstring A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

duck-typing A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note, however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

EAFP Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many *try* and *except* statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

expression A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statement*s which cannot be used as expressions, such as *if*. Assignments are also statements, not expressions.

extension module A module written in C or C++, using Python's C API to interact with the core and with user code.

f-string String literals prefixed with `'f'` or `'F'` are commonly called "f-strings" which is short for *formatted string literals*. See also **PEP 498**.

file object An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw *binary files*, buffered *binary files* and *text files*. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the

`open()` function.

file-like object A synonym for *file object*.

finder An object that tries to find the *loader* for a module that is being imported.

Since Python 3.3, there are two types of finder: *meta path finders* for use with `sys.meta_path`, and *path entry finders* for use with `sys.path_hooks`.

See **PEP 302**, **PEP 420** and **PEP 451** for much more detail.

floor division Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See **PEP 238**.

function A series of statements which returns some value to a caller. It can also be passed zero or more *arguments* which may be used in the execution of the body. See also *parameter*, *method*, and the *Function definitions* section.

function annotation An *annotation* of a function parameter or return value.

Function annotations are usually used for *type hints*: for example this function is expected to take two `int` arguments and is also expected to have an `int` return value:

```
def sum_two_numbers(a: int, b: int) -> int:
   return a + b
```

Function annotation syntax is explained in section *Function definitions*.

See *variable annotation* and **PEP 484**, which describe this functionality.

___future___ A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

garbage collection The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles. The garbage collector can be controlled using the `gc` module.

generator A function which returns a *generator iterator*. It looks like a normal function except that it contains *`yield`* expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the `next()` function.

Usually refers to a generator function, but may refer to a *generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

generator iterator An object created by a *generator* function.

Each *`yield`* temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *generator iterator* resumes, it picks up where it left off (in contrast to functions which start fresh on every invocation).

generator expression An expression that returns an iterator. It looks like a normal expression followed by a *`for`* expression defining a loop variable, range, and an optional *`if`* expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))         # sum of squares 0, 1, 4, ... 81
285
```

generic function A function composed of multiple functions implementing the same operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the *single dispatch* glossary entry, the `functools.singledispatch()` decorator, and **PEP 443**.

GIL See *global interpreter lock*.

global interpreter lock The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a "free-threaded" interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

hash-based pyc A bytecode cache file that uses the hash rather than the last-modified time of the corresponding source file to determine its validity. See *Cached bytecode invalidation*.

hashable An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a *__hash__()* method), and can be compared to other objects (it needs an *__eq__()* method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python's immutable built-in objects are hashable; mutable containers (such as lists or dictionaries) are not. Objects which are instances of user-defined classes are hashable by default. They all compare unequal (except with themselves), and their hash value is derived from their `id()`.

IDLE An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

immutable An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

import path A list of locations (or *path entries*) that are searched by the *path based finder* for modules to import. During import, this list of locations usually comes from `sys.path`, but for subpackages it may also come from the parent package's `__path__` attribute.

importing The process by which Python code in one module is made available to Python code in another module.

importer An object that both finds and loads a module; both a *finder* and *loader* object.

interactive Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer's main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

interpreted Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically

have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the *garbage collector*. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the `__main__` module or the script being run has finished executing.

iterable An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict`, *file objects*, and objects of any classes you define with an *__iter__()* method or with a *__getitem__()* method that implements *Sequence* semantics.

Iterables can be used in a *for* loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

iterator An object representing a stream of data. Repeated calls to the iterator's `__next__()` method (or passing it to the built-in function `next()`) return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `__next__()` method just raise `StopIteration` again. Iterators are required to have an *__iter__()* method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a *for* loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in typeiter.

key function A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.merge()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example. the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a *lambda* expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the Sorting HOW TO for examples of how to create and use key functions.

keyword argument See *argument*.

lambda An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [parameters]: expression`

LBYL Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many *if* statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between "the looking" and "the leaping". For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

list A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements is O(1).

list comprehension A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ['{:#04x}'.format(x) for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The *if* clause is optional. If omitted, all elements in `range(256)` are processed.

loader An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details and `importlib.abc.Loader` for an *abstract base class*.

mapping A container object that supports arbitrary key lookups and implements the methods specified in the `Mapping` or `MutableMapping` abstract base classes. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

meta path finder A *finder* returned by a search of `sys.meta_path`. Meta path finders are related to, but different from *path entry finders*.

See `importlib.abc.MetaPathFinder` for the methods that meta path finders implement.

metaclass The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in *Metaclasses*.

method A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

method resolution order Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order for details of the algorithm used by the Python interpreter since the 2.3 release.

module An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects. Modules are loaded into Python by the process of *importing*.

See also *package*.

module spec A namespace containing the import-related information used to load a module. An instance of `importlib.machinery.ModuleSpec`.

MRO See *method resolution order*.

mutable Mutable objects can change their value but keep their `id()`. See also *immutable*.

named tuple Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

namespace The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `builtins.open` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.islice()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

namespace package A **PEP 420** *package* which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a *regular package* because they have no `__init__.py` file.

See also *module*.

nested scope The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The *`nonlocal`* allows writing to outer scopes.

new-style class Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python's newer, versatile features like *`__slots__`*, descriptors, properties, *`__getattribute__()`*, class methods, and static methods.

object Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

package A Python *module* which can contain submodules or recursively, subpackages. Technically, a package is a Python module with an `__path__` attribute.

See also *regular package* and *namespace package*.

parameter A named entity in a *function* (or method) definition that specifies an *argument* (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- *positional-or-keyword*: specifies an argument that can be passed either *positionally* or as a *keyword argument*. This is the default kind of parameter, for example *foo* and *bar* in the following:

```
def func(foo, bar=None): ...
```

- *positional-only*: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. `abs()`).
- *keyword-only*: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare `*` in the parameter list of the function definition before them, for example *kw_only1* and *kw_only2* in the following:

```
def func(arg, *, kw_only1, kw_only2): ...
```

- *var-positional*: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `*`, for example *args* in the following:

```
def func(*args, **kwargs): ...
```

- *var-keyword*: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `**`, for example *kwargs* in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the *argument* glossary entry, the FAQ question on the difference between arguments and parameters, the `inspect.Parameter` class, the *Function definitions* section, and **PEP 362**.

path entry A single location on the *import path* which the *path based finder* consults to find modules for importing.

path entry finder A *finder* returned by a callable on `sys.path_hooks` (i.e. a *path entry hook*) which knows how to locate modules given a *path entry*.

See `importlib.abc.PathEntryFinder` for the methods that path entry finders implement.

path entry hook A callable on the `sys.path_hook` list which returns a *path entry finder* if it knows how to find modules on a specific *path entry*.

path based finder One of the default *meta path finders* which searches an *import path* for modules.

path-like object An object representing a file system path. A path-like object is either a `str` or `bytes` object representing a path, or an object implementing the `os.PathLike` protocol. An object that supports the `os.PathLike` protocol can be converted to a `str` or `bytes` file system path by calling the `os.fspath()` function; `os.fsdecode()` and `os.fsencode()` can be used to guarantee a `str` or `bytes` result instead, respectively. Introduced by **PEP 519**.

PEP Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python or its processes or environment. PEPs should provide a concise technical specification and a rationale for proposed features.

PEPs are intended to be the primary mechanisms for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible for building consensus within the community and documenting dissenting opinions.

See **PEP 1**.

portion A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in **PEP 420**.

positional argument See *argument*.

provisional API A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a "solution of last resort" - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See **PEP 411** for more details.

provisional package See *provisional API*.

Python 3000 Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

Pythonic An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a *for* statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print(piece)
```

qualified name A dotted name showing the "path" from a module's global scope to a class, function or method defined in that module, as defined in **PEP 3155**. For top-level functions and classes, the qualified name is the same as the object's name:

```
>>> class C:
...     class D:
...         def meth(self):
...             pass
...
>>> C.__qualname__
'C'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```

When used to refer to modules, the *fully qualified name* means the entire dotted path to the module, including any parent packages, e.g. `email.mime.text`:

```
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

reference count The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

regular package A traditional *package*, such as a directory containing an `__init__.py` file.

See also *namespace package*.

___slots___ A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

sequence An *iterable* which supports efficient element access using integer indices via the *__getitem__()* special method and defines a *__len__()* method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `bytes`. Note that `dict` also supports *__getitem__()* and *__len__()*, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

The `collections.abc.Sequence` abstract base class defines a much richer interface that goes beyond just *__getitem__()* and *__len__()*, adding `count()`, `index()`, *__contains__()*, and *__reversed__()*. Types that implement this expanded interface can be registered explicitly using `register()`.

single dispatch A form of *generic function* dispatch where the implementation is chosen based on the type of a single argument.

slice An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally.

special method A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in *Special method names*.

statement A statement is part of a suite (a "block" of code). A statement is either an *expression* or one of several constructs with a keyword, such as *if*, *while* or *for*.

struct sequence A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

text encoding A codec which encodes Unicode strings to bytes.

text file A *file object* able to read and write `str` objects. Often, a text file actually accesses a byte-oriented datastream and handles the *text encoding* automatically. Examples of text files are files opened in text mode (`'r'` or `'w'`), `sys.stdin`, `sys.stdout`, and instances of `io.StringIO`.

See also *binary file* for a file object able to read and write *bytes-like objects*.

triple-quoted string A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

type The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

type alias A synonym for a type, created by assigning the type to an identifier.

Type aliases are useful for simplifying *type hints*. For example:

```
from typing import List, Tuple

def remove_gray_shades(
        colors: List[Tuple[int, int, int]]) -> List[Tuple[int, int, int]]:
    pass
```

could be made more readable like this:

```
from typing import List, Tuple

Color = Tuple[int, int, int]

def remove_gray_shades(colors: List[Color]) -> List[Color]:
    pass
```

See `typing` and **PEP 484**, which describe this functionality.

type hint An *annotation* that specifies the expected type for a variable, a class attribute, or a function parameter or return value.

Type hints are optional and are not enforced by Python but they are useful to static type analysis tools, and aid IDEs with code completion and refactoring.

Type hints of global variables, class attributes, and functions, but not local variables, can be accessed using `typing.get_type_hints()`.

See `typing` and **PEP 484**, which describe this functionality.

universal newlines A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old

Macintosh convention `'\r'`. See **PEP 278** and **PEP 3116**, as well as `bytes.splitlines()` for an additional use.

variable annotation An *annotation* of a variable or a class attribute.

When annotating a variable or a class attribute, assignment is optional:

```
class C:
    field: 'annotation'
```

Variable annotations are usually used for *type hints*: for example this variable is expected to take `int` values:

```
count: int = 0
```

Variable annotation syntax is explained in section *Annotated assignment statements*.

See *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

virtual environment A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also `venv`.

virtual machine A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

Zen of Python Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing "`import this`" at the interactive prompt.

APPENDIX

B

ABOUT THESE DOCUMENTS

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the reporting-bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the Docutils project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.

B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See Misc/ACKS in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!

APPENDIX

C

HISTORY AND LICENSE

C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see https://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see https://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

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2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2 and above	2.1.1	2001-now	PSF	yes

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C.3.1 Mersenne Twister

The `_random` module includes code based on a download from http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/MT2002/emt19937ar.html. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.

Before using, initialize the state by using init_genrand(seed)
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http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html
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```

C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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C.3.6 UUencode and UUdecode functions

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Modified by Jack Jansen, CWI, July 1995:
- Use binascii module to do the actual line-by-line conversion
  between ascii and binary. This results in a 1000-fold speedup. The C
  version is still 5 times faster, though.
- Arguments more compliant with Python standard
```

C.3.7 XML Remote Procedure Calls

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C.3.8 test_epoll

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C.3.9 Select kqueue

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C.3.10 SipHash24

The file `Python/pyhash.c` contains Marek Majkowski' implementation of Dan Bernstein's SipHash24 algorithm. The contains the following note:

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Original location:
   https://github.com/majek/csiphash/

Solution inspired by code from:
   Samuel Neves (supercop/crypto_auth/siphash24/little)
   djb (supercop/crypto_auth/siphash24/little2)
   Jean-Philippe Aumasson (https://131002.net/siphash/siphash24.c)
```

C.3.11 strtod and dtoa

The file `Python/dtoa.c`, which supplies C functions dtoa and strtod for conversion of C doubles to and from strings, is derived from the file of the same name by David M. Gay, currently available from http://www.netlib.org/fp/. The original file, as retrieved on March 16, 2009, contains the following copyright and licensing notice:

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C.3.12 OpenSSL

The modules `hashlib`, `posix`, `ssl`, `crypt` use the OpenSSL library for added performance if made available by the operating system. Additionally, the Windows and Mac OS X installers for Python may include a copy of the OpenSSL libraries, so we include a copy of the OpenSSL license here:

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C.3.13 expat

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C.3.14 libffi

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C.3.15 zlib

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C.3.16 cfuhash

The implementation of the hash table used by the `tracemalloc` is based on the cfuhash project:

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C.3.17 libmpdec

The `_decimal` module is built using an included copy of the libmpdec library unless the build is configured `--with-system-libmpdec`:

APPENDIX

D

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While reference-index describes the exact syntax and semantics of the Python language, this library reference manual describes the standard library that is distributed with Python. It also describes some of the optional components that are commonly included in Python distributions.

Python's standard library is very extensive, offering a wide range of facilities as indicated by the long table of contents listed below. The library contains built-in modules (written in C) that provide access to system functionality such as file I/O that would otherwise be inaccessible to Python programmers, as well as modules written in Python that provide standardized solutions for many problems that occur in everyday programming. Some of these modules are explicitly designed to encourage and enhance the portability of Python programs by abstracting away platform-specifics into platform-neutral APIs.

The Python installers for the Windows platform usually include the entire standard library and often also include many additional components. For Unix-like operating systems Python is normally provided as a collection of packages, so it may be necessary to use the packaging tools provided with the operating system to obtain some or all of the optional components.

In addition to the standard library, there is a growing collection of several thousand components (from individual programs and modules to packages and entire application development frameworks), available from the Python Package Index.

CHAPTER

ONE

INTRODUCTION

The "Python library" contains several different kinds of components.

It contains data types that would normally be considered part of the "core" of a language, such as numbers and lists. For these types, the Python language core defines the form of literals and places some constraints on their semantics, but does not fully define the semantics. (On the other hand, the language core does define syntactic properties like the spelling and priorities of operators.)

The library also contains built-in functions and exceptions — objects that can be used by all Python code without the need of an `import` statement. Some of these are defined by the core language, but many are not essential for the core semantics and are only described here.

The bulk of the library, however, consists of a collection of modules. There are many ways to dissect this collection. Some modules are written in C and built in to the Python interpreter; others are written in Python and imported in source form. Some modules provide interfaces that are highly specific to Python, like printing a stack trace; some provide interfaces that are specific to particular operating systems, such as access to specific hardware; others provide interfaces that are specific to a particular application domain, like the World Wide Web. Some modules are available in all versions and ports of Python; others are only available when the underlying system supports or requires them; yet others are available only when a particular configuration option was chosen at the time when Python was compiled and installed.

This manual is organized "from the inside out:" it first describes the built-in functions, data types and exceptions, and finally the modules, grouped in chapters of related modules.

This means that if you start reading this manual from the start, and skip to the next chapter when you get bored, you will get a reasonable overview of the available modules and application areas that are supported by the Python library. Of course, you don't *have* to read it like a novel — you can also browse the table of contents (in front of the manual), or look for a specific function, module or term in the index (in the back). And finally, if you enjoy learning about random subjects, you choose a random page number (see module *random*) and read a section or two. Regardless of the order in which you read the sections of this manual, it helps to start with chapter *Built-in Functions*, as the remainder of the manual assumes familiarity with this material.

Let the show begin!

CHAPTER

TWO

BUILT-IN FUNCTIONS

The Python interpreter has a number of functions and types built into it that are always available. They are listed here in alphabetical order.

		Built-in Functions		
abs()	*delattr()*	*hash()*	*memoryview()*	*set()*
all()	*dict()*	*help()*	*min()*	*setattr()*
any()	*dir()*	*hex()*	*next()*	*slice()*
ascii()	*divmod()*	*id()*	*object()*	*sorted()*
bin()	*enumerate()*	*input()*	*oct()*	*staticmethod()*
bool()	*eval()*	*int()*	*open()*	*str()*
breakpoint()	*exec()*	*isinstance()*	*ord()*	*sum()*
bytearray()	*filter()*	*issubclass()*	*pow()*	*super()*
bytes()	*float()*	*iter()*	*print()*	*tuple()*
callable()	*format()*	*len()*	*property()*	*type()*
chr()	*frozenset()*	*list()*	*range()*	*vars()*
classmethod()	*getattr()*	*locals()*	*repr()*	*zip()*
compile()	*globals()*	*map()*	*reversed()*	*__import__()*
complex()	*hasattr()*	*max()*	*round()*	

abs(*x*)

Return the absolute value of a number. The argument may be an integer or a floating point number. If the argument is a complex number, its magnitude is returned.

all(*iterable*)

Return `True` if all elements of the *iterable* are true (or if the iterable is empty). Equivalent to:

```
def all(iterable):
    for element in iterable:
        if not element:
            return False
    return True
```

any(*iterable*)

Return `True` if any element of the *iterable* is true. If the iterable is empty, return `False`. Equivalent to:

```
def any(iterable):
    for element in iterable:
        if element:
            return True
    return False
```

ascii(*object*)

As *repr()*, return a string containing a printable representation of an object, but escape the non-ASCII characters in the string returned by *repr()* using \x, \u or \U escapes. This generates a string similar to that returned by *repr()* in Python 2.

bin(*x*)

Convert an integer number to a binary string prefixed with "0b". The result is a valid Python expression. If *x* is not a Python *int* object, it has to define an `__index__()` method that returns an integer. Some examples:

```
>>> bin(3)
'0b11'
>>> bin(-10)
'-0b1010'
```

If prefix "0b" is desired or not, you can use either of the following ways.

```
>>> format(14, '#b'), format(14, 'b')
('0b1110', '1110')
>>> f'{14:#b}', f'{14:b}'
('0b1110', '1110')
```

See also *format()* for more information.

class bool([*x*])

Return a Boolean value, i.e. one of `True` or `False`. *x* is converted using the standard *truth testing procedure*. If *x* is false or omitted, this returns `False`; otherwise it returns `True`. The *bool* class is a subclass of *int* (see *Numeric Types — int, float, complex*). It cannot be subclassed further. Its only instances are `False` and `True` (see *Boolean Values*).

breakpoint(**args*, ***kws*)

This function drops you into the debugger at the call site. Specifically, it calls *sys.breakpointhook()*, passing `args` and `kws` straight through. By default, `sys.breakpointhook()` calls *pdb.set_trace()* expecting no arguments. In this case, it is purely a convenience function so you don't have to explicitly import *pdb* or type as much code to enter the debugger. However, *sys.breakpointhook()* can be set to some other function and *breakpoint()* will automatically call that, allowing you to drop into the debugger of choice.

New in version 3.7.

class bytearray([*source*[, *encoding*[, *errors*]]])

Return a new array of bytes. The *bytearray* class is a mutable sequence of integers in the range 0 <= x < 256. It has most of the usual methods of mutable sequences, described in *Mutable Sequence Types*, as well as most methods that the *bytes* type has, see *Bytes and Bytearray Operations*.

The optional *source* parameter can be used to initialize the array in a few different ways:

- If it is a *string*, you must also give the *encoding* (and optionally, *errors*) parameters; *bytearray()* then converts the string to bytes using *str.encode()*.
- If it is an *integer*, the array will have that size and will be initialized with null bytes.
- If it is an object conforming to the *buffer* interface, a read-only buffer of the object will be used to initialize the bytes array.
- If it is an *iterable*, it must be an iterable of integers in the range `0 <= x < 256`, which are used as the initial contents of the array.

Without an argument, an array of size 0 is created.

See also *Binary Sequence Types — bytes, bytearray, memoryview* and *Bytearray Objects*.

class bytes([*source*[, *encoding*[, *errors*]]])
Return a new "bytes" object, which is an immutable sequence of integers in the range `0 <= x < 256`. *bytes* is an immutable version of *bytearray* – it has the same non-mutating methods and the same indexing and slicing behavior.

Accordingly, constructor arguments are interpreted as for *bytearray()*.

Bytes objects can also be created with literals, see strings.

See also *Binary Sequence Types — bytes, bytearray, memoryview*, *Bytes Objects*, and *Bytes and Bytearray Operations*.

callable(*object*)
Return *True* if the *object* argument appears callable, *False* if not. If this returns true, it is still possible that a call fails, but if it is false, calling *object* will never succeed. Note that classes are callable (calling a class returns a new instance); instances are callable if their class has a `__call__()` method.

New in version 3.2: This function was first removed in Python 3.0 and then brought back in Python 3.2.

chr(*i*)
Return the string representing a character whose Unicode code point is the integer *i*. For example, `chr(97)` returns the string `'a'`, while `chr(8364)` returns the string `'€'`. This is the inverse of *ord()*.

The valid range for the argument is from 0 through 1,114,111 (0x10FFFF in base 16). *ValueError* will be raised if *i* is outside that range.

@classmethod
Transform a method into a class method.

A class method receives the class as implicit first argument, just like an instance method receives the instance. To declare a class method, use this idiom:

```
class C:
    @classmethod
    def f(cls, arg1, arg2, ...): ...
```

The `@classmethod` form is a function *decorator* – see the description of function definitions in function for details.

It can be called either on the class (such as `C.f()`) or on an instance (such as `C().f()`). The instance is ignored except for its class. If a class method is called for a derived class, the derived class object is passed as the implied first argument.

Class methods are different than C++ or Java static methods. If you want those, see *staticmethod()* in this section.

For more information on class methods, consult the documentation on the standard type hierarchy in types.

compile(*source*, *filename*, *mode*, *flags=0*, *dont_inherit=False*, *optimize=-1*)
Compile the *source* into a code or AST object. Code objects can be executed by *exec()* or *eval()*. *source* can either be a normal string, a byte string, or an AST object. Refer to the *ast* module documentation for information on how to work with AST objects.

The *filename* argument should give the file from which the code was read; pass some recognizable value if it wasn't read from a file (`'<string>'` is commonly used).

The *mode* argument specifies what kind of code must be compiled; it can be `'exec'` if *source* consists of a sequence of statements, `'eval'` if it consists of a single expression, or `'single'` if it consists of a single interactive statement (in the latter case, expression statements that evaluate to something other than `None` will be printed).

The optional arguments *flags* and *dont_inherit* control which future statements (see **PEP 236**) affect the compilation of *source*. If neither is present (or both are zero) the code is compiled with those future statements that are in effect in the code that is calling *compile()*. If the *flags* argument is given and *dont_inherit* is not (or is zero) then the future statements specified by the *flags* argument are used in addition to those that would be used anyway. If *dont_inherit* is a non-zero integer then the *flags* argument is it – the future statements in effect around the call to compile are ignored.

Future statements are specified by bits which can be bitwise ORed together to specify multiple statements. The bitfield required to specify a given feature can be found as the `compiler_flag` attribute on the `_Feature` instance in the *__future__* module.

The argument *optimize* specifies the optimization level of the compiler; the default value of `-1` selects the optimization level of the interpreter as given by `-O` options. Explicit levels are `0` (no optimization; `__debug__` is true), `1` (asserts are removed, `__debug__` is false) or `2` (docstrings are removed too).

This function raises *SyntaxError* if the compiled source is invalid, and *ValueError* if the source contains null bytes.

If you want to parse Python code into its AST representation, see *ast.parse()*.

Note: When compiling a string with multi-line code in `'single'` or `'eval'` mode, input must be terminated by at least one newline character. This is to facilitate detection of incomplete and complete statements in the *code* module.

Warning: It is possible to crash the Python interpreter with a sufficiently large/complex string when compiling to an AST object due to stack depth limitations in Python's AST compiler.

Changed in version 3.2: Allowed use of Windows and Mac newlines. Also input in `'exec'` mode does not have to end in a newline anymore. Added the *optimize* parameter.

Changed in version 3.5: Previously, *TypeError* was raised when null bytes were encountered in *source*.

`class complex(`[*real*[, *imag*]]`)`

Return a complex number with the value *real* + *imag**1j or convert a string or number to a complex number. If the first parameter is a string, it will be interpreted as a complex number and the function must be called without a second parameter. The second parameter can never be a string. Each argument may be any numeric type (including complex). If *imag* is omitted, it defaults to zero and the constructor serves as a numeric conversion like *int* and *float*. If both arguments are omitted, returns `0j`.

Note: When converting from a string, the string must not contain whitespace around the central `+` or `-` operator. For example, `complex('1+2j')` is fine, but `complex('1 + 2j')` raises *ValueError*.

The complex type is described in *Numeric Types — int, float, complex*.

Changed in version 3.6: Grouping digits with underscores as in code literals is allowed.

`delattr(`*object*, *name*`)`

This is a relative of *setattr()*. The arguments are an object and a string. The string must be the name of one of the object's attributes. The function deletes the named attribute, provided the object allows it. For example, `delattr(x, 'foobar')` is equivalent to `del x.foobar`.

`class dict(`***kwarg*`)`
`class dict(`*mapping*, ***kwarg*`)`

class dict(*iterable*, ***kwarg*)

Create a new dictionary. The *dict* object is the dictionary class. See *dict* and *Mapping Types — dict* for documentation about this class.

For other containers see the built-in *list*, *set*, and *tuple* classes, as well as the *collections* module.

dir([*object*])

Without arguments, return the list of names in the current local scope. With an argument, attempt to return a list of valid attributes for that object.

If the object has a method named `__dir__()`, this method will be called and must return the list of attributes. This allows objects that implement a custom `__getattr__()` or `__getattribute__()` function to customize the way *dir()* reports their attributes.

If the object does not provide `__dir__()`, the function tries its best to gather information from the object's *__dict__* attribute, if defined, and from its type object. The resulting list is not necessarily complete, and may be inaccurate when the object has a custom `__getattr__()`.

The default *dir()* mechanism behaves differently with different types of objects, as it attempts to produce the most relevant, rather than complete, information:

- If the object is a module object, the list contains the names of the module's attributes.
- If the object is a type or class object, the list contains the names of its attributes, and recursively of the attributes of its bases.
- Otherwise, the list contains the object's attributes' names, the names of its class's attributes, and recursively of the attributes of its class's base classes.

The resulting list is sorted alphabetically. For example:

```
>>> import struct
>>> dir()   # show the names in the module namespace
['__builtins__', '__name__', 'struct']
>>> dir(struct)   # show the names in the struct module
['Struct', '__all__', '__builtins__', '__cached__', '__doc__', '__file__',
 '__initializing__', '__loader__', '__name__', '__package__',
 '_clearcache', 'calcsize', 'error', 'pack', 'pack_into',
 'unpack', 'unpack_from']
>>> class Shape:
...     def __dir__(self):
...         return ['area', 'perimeter', 'location']
>>> s = Shape()
>>> dir(s)
['area', 'location', 'perimeter']
```

Note: Because *dir()* is supplied primarily as a convenience for use at an interactive prompt, it tries to supply an interesting set of names more than it tries to supply a rigorously or consistently defined set of names, and its detailed behavior may change across releases. For example, metaclass attributes are not in the result list when the argument is a class.

divmod(*a*, *b*)

Take two (non complex) numbers as arguments and return a pair of numbers consisting of their quotient and remainder when using integer division. With mixed operand types, the rules for binary arithmetic operators apply. For integers, the result is the same as `(a // b, a % b)`. For floating point numbers the result is `(q, a % b)`, where *q* is usually `math.floor(a / b)` but may be 1 less than that. In any case `q * b + a % b` is very close to *a*, if `a % b` is non-zero it has the same sign as *b*, and `0 <= abs(a % b) < abs(b)`.

enumerate(*iterable*, *start=0*)

Return an enumerate object. *iterable* must be a sequence, an *iterator*, or some other object which supports iteration. The *__next__()* method of the iterator returned by *enumerate()* returns a tuple containing a count (from *start* which defaults to 0) and the values obtained from iterating over *iterable*.

```
>>> seasons = ['Spring', 'Summer', 'Fall', 'Winter']
>>> list(enumerate(seasons))
[(0, 'Spring'), (1, 'Summer'), (2, 'Fall'), (3, 'Winter')]
>>> list(enumerate(seasons, start=1))
[(1, 'Spring'), (2, 'Summer'), (3, 'Fall'), (4, 'Winter')]
```

Equivalent to:

```
def enumerate(sequence, start=0):
    n = start
    for elem in sequence:
        yield n, elem
        n += 1
```

eval(*expression*, *globals=None*, *locals=None*)

The arguments are a string and optional globals and locals. If provided, *globals* must be a dictionary. If provided, *locals* can be any mapping object.

The *expression* argument is parsed and evaluated as a Python expression (technically speaking, a condition list) using the *globals* and *locals* dictionaries as global and local namespace. If the *globals* dictionary is present and lacks '__builtins__', the current globals are copied into *globals* before *expression* is parsed. This means that *expression* normally has full access to the standard *builtins* module and restricted environments are propagated. If the *locals* dictionary is omitted it defaults to the *globals* dictionary. If both dictionaries are omitted, the expression is executed in the environment where *eval()* is called. The return value is the result of the evaluated expression. Syntax errors are reported as exceptions. Example:

```
>>> x = 1
>>> eval('x+1')
2
```

This function can also be used to execute arbitrary code objects (such as those created by *compile()*). In this case pass a code object instead of a string. If the code object has been compiled with `'exec'` as the *mode* argument, *eval()*'s return value will be `None`.

Hints: dynamic execution of statements is supported by the *exec()* function. The *globals()* and *locals()* functions returns the current global and local dictionary, respectively, which may be useful to pass around for use by *eval()* or *exec()*.

See *ast.literal_eval()* for a function that can safely evaluate strings with expressions containing only literals.

exec(*object*[, *globals*[, *locals*]])

This function supports dynamic execution of Python code. *object* must be either a string or a code object. If it is a string, the string is parsed as a suite of Python statements which is then executed (unless a syntax error occurs).[1] If it is a code object, it is simply executed. In all cases, the code that's executed is expected to be valid as file input (see the section "File input" in the Reference Manual). Be aware that the `return` and `yield` statements may not be used outside of function definitions even within the context of code passed to the *exec()* function. The return value is `None`.

In all cases, if the optional parts are omitted, the code is executed in the current scope. If only *globals* is provided, it must be a dictionary, which will be used for both the global and the local variables. If

[1] Note that the parser only accepts the Unix-style end of line convention. If you are reading the code from a file, make sure to use newline conversion mode to convert Windows or Mac-style newlines.

globals and *locals* are given, they are used for the global and local variables, respectively. If provided, *locals* can be any mapping object. Remember that at module level, globals and locals are the same dictionary. If exec gets two separate objects as *globals* and *locals*, the code will be executed as if it were embedded in a class definition.

If the *globals* dictionary does not contain a value for the key `__builtins__`, a reference to the dictionary of the built-in module *builtins* is inserted under that key. That way you can control what builtins are available to the executed code by inserting your own `__builtins__` dictionary into *globals* before passing it to *exec()*.

Note: The built-in functions *globals()* and *locals()* return the current global and local dictionary, respectively, which may be useful to pass around for use as the second and third argument to *exec()*.

Note: The default *locals* act as described for function *locals()* below: modifications to the default *locals* dictionary should not be attempted. Pass an explicit *locals* dictionary if you need to see effects of the code on *locals* after function *exec()* returns.

`filter`(*function*, *iterable*)

Construct an iterator from those elements of *iterable* for which *function* returns true. *iterable* may be either a sequence, a container which supports iteration, or an iterator. If *function* is `None`, the identity function is assumed, that is, all elements of *iterable* that are false are removed.

Note that `filter(function, iterable)` is equivalent to the generator expression `(item for item in iterable if function(item))` if function is not `None` and `(item for item in iterable if item)` if function is `None`.

See *itertools.filterfalse()* for the complementary function that returns elements of *iterable* for which *function* returns false.

`class float`([*x*])

Return a floating point number constructed from a number or string *x*.

If the argument is a string, it should contain a decimal number, optionally preceded by a sign, and optionally embedded in whitespace. The optional sign may be `'+'` or `'-'`; a `'+'` sign has no effect on the value produced. The argument may also be a string representing a NaN (not-a-number), or a positive or negative infinity. More precisely, the input must conform to the following grammar after leading and trailing whitespace characters are removed:

```
sign            ::=   "+" | "-"
infinity        ::=   "Infinity" | "inf"
nan             ::=   "nan"
numeric_value   ::=   floatnumber | infinity | nan
numeric_string  ::=   [sign] numeric_value
```

Here `floatnumber` is the form of a Python floating-point literal, described in floating. Case is not significant, so, for example, “inf”, “Inf”, “INFINITY” and “iNfINity” are all acceptable spellings for positive infinity.

Otherwise, if the argument is an integer or a floating point number, a floating point number with the same value (within Python’s floating point precision) is returned. If the argument is outside the range of a Python float, an *OverflowError* will be raised.

For a general Python object `x`, `float(x)` delegates to `x.__float__()`.

If no argument is given, `0.0` is returned.

Examples:

```
>>> float('+1.23')
1.23
>>> float('   -12345\n')
-12345.0
>>> float('1e-003')
0.001
>>> float('+1E6')
1000000.0
>>> float('-Infinity')
-inf
```

The float type is described in *Numeric Types — int, float, complex*.

Changed in version 3.6: Grouping digits with underscores as in code literals is allowed.

format(*value*[, *format_spec*])

Convert a *value* to a "formatted" representation, as controlled by *format_spec*. The interpretation of *format_spec* will depend on the type of the *value* argument, however there is a standard formatting syntax that is used by most built-in types: *Format Specification Mini-Language*.

The default *format_spec* is an empty string which usually gives the same effect as calling *str(value)*.

A call to `format(value, format_spec)` is translated to `type(value).__format__(value, format_spec)` which bypasses the instance dictionary when searching for the value's `__format__()` method. A *TypeError* exception is raised if the method search reaches *object* and the *format_spec* is non-empty, or if either the *format_spec* or the return value are not strings.

Changed in version 3.4: `object().__format__(format_spec)` raises *TypeError* if *format_spec* is not an empty string.

class frozenset([*iterable*])

Return a new *frozenset* object, optionally with elements taken from *iterable*. `frozenset` is a built-in class. See *frozenset* and *Set Types — set, frozenset* for documentation about this class.

For other containers see the built-in *set*, *list*, *tuple*, and *dict* classes, as well as the *collections* module.

getattr(*object*, *name*[, *default*])

Return the value of the named attribute of *object*. *name* must be a string. If the string is the name of one of the object's attributes, the result is the value of that attribute. For example, `getattr(x, 'foobar')` is equivalent to `x.foobar`. If the named attribute does not exist, *default* is returned if provided, otherwise *AttributeError* is raised.

globals()

Return a dictionary representing the current global symbol table. This is always the dictionary of the current module (inside a function or method, this is the module where it is defined, not the module from which it is called).

hasattr(*object*, *name*)

The arguments are an object and a string. The result is `True` if the string is the name of one of the object's attributes, `False` if not. (This is implemented by calling `getattr(object, name)` and seeing whether it raises an *AttributeError* or not.)

hash(*object*)

Return the hash value of the object (if it has one). Hash values are integers. They are used to quickly compare dictionary keys during a dictionary lookup. Numeric values that compare equal have the same hash value (even if they are of different types, as is the case for 1 and 1.0).

Note: For objects with custom `__hash__()` methods, note that *hash()* truncates the return value based on the bit width of the host machine. See `__hash__()` for details.

help([*object*])
Invoke the built-in help system. (This function is intended for interactive use.) If no argument is given, the interactive help system starts on the interpreter console. If the argument is a string, then the string is looked up as the name of a module, function, class, method, keyword, or documentation topic, and a help page is printed on the console. If the argument is any other kind of object, a help page on the object is generated.

This function is added to the built-in namespace by the *site* module.

Changed in version 3.4: Changes to *pydoc* and *inspect* mean that the reported signatures for callables are now more comprehensive and consistent.

hex(*x*)
Convert an integer number to a lowercase hexadecimal string prefixed with "0x". If *x* is not a Python *int* object, it has to define an `__index__()` method that returns an integer. Some examples:

```
>>> hex(255)
'0xff'
>>> hex(-42)
'-0x2a'
```

If you want to convert an integer number to an uppercase or lower hexadecimal string with prefix or not, you can use either of the following ways:

```
>>> '%#x' % 255, '%x' % 255, '%X' % 255
('0xff', 'ff', 'FF')
>>> format(255, '#x'), format(255, 'x'), format(255, 'X')
('0xff', 'ff', 'FF')
>>> f'{255:#x}', f'{255:x}', f'{255:X}'
('0xff', 'ff', 'FF')
```

See also *format()* for more information.

See also *int()* for converting a hexadecimal string to an integer using a base of 16.

Note: To obtain a hexadecimal string representation for a float, use the *float.hex()* method.

id(*object*)
Return the "identity" of an object. This is an integer which is guaranteed to be unique and constant for this object during its lifetime. Two objects with non-overlapping lifetimes may have the same *id()* value.

CPython implementation detail: This is the address of the object in memory.

input([*prompt*])
If the *prompt* argument is present, it is written to standard output without a trailing newline. The function then reads a line from input, converts it to a string (stripping a trailing newline), and returns that. When EOF is read, *EOFError* is raised. Example:

```
>>> s = input('--> ')
--> Monty Python's Flying Circus
>>> s
"Monty Python's Flying Circus"
```

If the *readline* module was loaded, then *input()* will use it to provide elaborate line editing and history features.

class int(*x=0*)
class int(*x*, *base=10*)

Return an integer object constructed from a number or string *x*, or return `0` if no arguments are given. If *x* defines `__int__()`, `int(x)` returns `x.__int__()`. If *x* defines `__trunc__()`, it returns `x.__trunc__()`. For floating point numbers, this truncates towards zero.

If *x* is not a number or if *base* is given, then *x* must be a string, *bytes*, or *bytearray* instance representing an integer literal in radix *base*. Optionally, the literal can be preceded by `+` or `-` (with no space in between) and surrounded by whitespace. A base-n literal consists of the digits 0 to n-1, with `a` to `z` (or `A` to `Z`) having values 10 to 35. The default *base* is 10. The allowed values are 0 and 2–36. Base-2, -8, and -16 literals can be optionally prefixed with `0b`/`0B`, `0o`/`0O`, or `0x`/`0X`, as with integer literals in code. Base 0 means to interpret exactly as a code literal, so that the actual base is 2, 8, 10, or 16, and so that `int('010', 0)` is not legal, while `int('010')` is, as well as `int('010', 8)`.

The integer type is described in *Numeric Types — int, float, complex*.

Changed in version 3.4: If *base* is not an instance of *int* and the *base* object has a `base.__index__` method, that method is called to obtain an integer for the base. Previous versions used `base.__int__` instead of `base.__index__`.

Changed in version 3.6: Grouping digits with underscores as in code literals is allowed.

isinstance(*object*, *classinfo*)

Return true if the *object* argument is an instance of the *classinfo* argument, or of a (direct, indirect or *virtual*) subclass thereof. If *object* is not an object of the given type, the function always returns false. If *classinfo* is a tuple of type objects (or recursively, other such tuples), return true if *object* is an instance of any of the types. If *classinfo* is not a type or tuple of types and such tuples, a *TypeError* exception is raised.

issubclass(*class*, *classinfo*)

Return true if *class* is a subclass (direct, indirect or *virtual*) of *classinfo*. A class is considered a subclass of itself. *classinfo* may be a tuple of class objects, in which case every entry in *classinfo* will be checked. In any other case, a *TypeError* exception is raised.

iter(*object*[, *sentinel*])

Return an *iterator* object. The first argument is interpreted very differently depending on the presence of the second argument. Without a second argument, *object* must be a collection object which supports the iteration protocol (the `__iter__()` method), or it must support the sequence protocol (the `__getitem__()` method with integer arguments starting at `0`). If it does not support either of those protocols, *TypeError* is raised. If the second argument, *sentinel*, is given, then *object* must be a callable object. The iterator created in this case will call *object* with no arguments for each call to its *__next__()* method; if the value returned is equal to *sentinel*, *StopIteration* will be raised, otherwise the value will be returned.

See also *Iterator Types*.

One useful application of the second form of *iter()* is to read lines of a file until a certain line is reached. The following example reads a file until the *readline()* method returns an empty string:

```
with open('mydata.txt') as fp:
    for line in iter(fp.readline, ''):
        process_line(line)
```

len(*s*)

Return the length (the number of items) of an object. The argument may be a sequence (such as a string, bytes, tuple, list, or range) or a collection (such as a dictionary, set, or frozen set).

class list([*iterable*])
Rather than being a function, *list* is actually a mutable sequence type, as documented in *Lists* and *Sequence Types — list, tuple, range*.

locals()
Update and return a dictionary representing the current local symbol table. Free variables are returned by *locals()* when it is called in function blocks, but not in class blocks.

Note: The contents of this dictionary should not be modified; changes may not affect the values of local and free variables used by the interpreter.

---

map(*function*, *iterable*, ...)
Return an iterator that applies *function* to every item of *iterable*, yielding the results. If additional *iterable* arguments are passed, *function* must take that many arguments and is applied to the items from all iterables in parallel. With multiple iterables, the iterator stops when the shortest iterable is exhausted. For cases where the function inputs are already arranged into argument tuples, see *itertools.starmap()*.

max(*iterable*, *[, *key*, *default*])
max(*arg1*, *arg2*, **args*[, *key*])
Return the largest item in an iterable or the largest of two or more arguments.

If one positional argument is provided, it should be an *iterable*. The largest item in the iterable is returned. If two or more positional arguments are provided, the largest of the positional arguments is returned.

There are two optional keyword-only arguments. The *key* argument specifies a one-argument ordering function like that used for *list.sort()*. The *default* argument specifies an object to return if the provided iterable is empty. If the iterable is empty and *default* is not provided, a *ValueError* is raised.

If multiple items are maximal, the function returns the first one encountered. This is consistent with other sort-stability preserving tools such as `sorted(iterable, key=keyfunc, reverse=True)[0]` and `heapq.nlargest(1, iterable, key=keyfunc)`.

New in version 3.4: The *default* keyword-only argument.

memoryview(*obj*)
Return a "memory view" object created from the given argument. See *Memory Views* for more information.

min(*iterable*, *[, *key*, *default*])
min(*arg1*, *arg2*, **args*[, *key*])
Return the smallest item in an iterable or the smallest of two or more arguments.

If one positional argument is provided, it should be an *iterable*. The smallest item in the iterable is returned. If two or more positional arguments are provided, the smallest of the positional arguments is returned.

There are two optional keyword-only arguments. The *key* argument specifies a one-argument ordering function like that used for *list.sort()*. The *default* argument specifies an object to return if the provided iterable is empty. If the iterable is empty and *default* is not provided, a *ValueError* is raised.

If multiple items are minimal, the function returns the first one encountered. This is consistent with other sort-stability preserving tools such as `sorted(iterable, key=keyfunc)[0]` and `heapq.nsmallest(1, iterable, key=keyfunc)`.

New in version 3.4: The *default* keyword-only argument.

next(*iterator*[, *default*])
Retrieve the next item from the *iterator* by calling its *__next__()* method. If *default* is given, it is returned if the iterator is exhausted, otherwise *StopIteration* is raised.

class object
Return a new featureless object. *object* is a base for all classes. It has the methods that are common to all instances of Python classes. This function does not accept any arguments.

Note: *object* does *not* have a *__dict__*, so you can't assign arbitrary attributes to an instance of the *object* class.

---

oct(*x*)
Convert an integer number to an octal string prefixed with "0o". The result is a valid Python expression. If *x* is not a Python *int* object, it has to define an `__index__()` method that returns an integer. For example:

```
>>> oct(8)
'0o10'
>>> oct(-56)
'-0o70'
```

If you want to convert an integer number to octal string either with prefix "0o" or not, you can use either of the following ways.

```
>>> '%#o' % 10, '%o' % 10
('0o12', '12')
>>> format(10, '#o'), format(10, 'o')
('0o12', '12')
>>> f'{10:#o}', f'{10:o}'
('0o12', '12')
```

See also *format()* for more information.

open(*file*, *mode='r'*, *buffering=-1*, *encoding=None*, *errors=None*, *newline=None*, *closefd=True*, *opener=None*)
Open *file* and return a corresponding *file object*. If the file cannot be opened, an *OSError* is raised.

file is a *path-like object* giving the pathname (absolute or relative to the current working directory) of the file to be opened or an integer file descriptor of the file to be wrapped. (If a file descriptor is given, it is closed when the returned I/O object is closed, unless *closefd* is set to `False`.)

mode is an optional string that specifies the mode in which the file is opened. It defaults to `'r'` which means open for reading in text mode. Other common values are `'w'` for writing (truncating the file if it already exists), `'x'` for exclusive creation and `'a'` for appending (which on *some* Unix systems, means that *all* writes append to the end of the file regardless of the current seek position). In text mode, if *encoding* is not specified the encoding used is platform dependent: `locale.getpreferredencoding(False)` is called to get the current locale encoding. (For reading and writing raw bytes use binary mode and leave *encoding* unspecified.) The available modes are:

Character	Meaning
`'r'`	open for reading (default)
`'w'`	open for writing, truncating the file first
`'x'`	open for exclusive creation, failing if the file already exists
`'a'`	open for writing, appending to the end of the file if it exists
`'b'`	binary mode
`'t'`	text mode (default)
`'+'`	open a disk file for updating (reading and writing)
`'U'`	*universal newlines* mode (deprecated)

The default mode is `'r'` (open for reading text, synonym of `'rt'`). For binary read-write access, the mode `'w+b'` opens and truncates the file to 0 bytes. `'r+b'` opens the file without truncation.

As mentioned in the *Overview*, Python distinguishes between binary and text I/O. Files opened in binary mode (including `'b'` in the *mode* argument) return contents as *bytes* objects without any decoding. In text mode (the default, or when `'t'` is included in the *mode* argument), the contents of the file are returned as *str*, the bytes having been first decoded using a platform-dependent encoding or using the specified *encoding* if given.

Note: Python doesn't depend on the underlying operating system's notion of text files; all the processing is done by Python itself, and is therefore platform-independent.

---

buffering is an optional integer used to set the buffering policy. Pass 0 to switch buffering off (only allowed in binary mode), 1 to select line buffering (only usable in text mode), and an integer > 1 to indicate the size in bytes of a fixed-size chunk buffer. When no *buffering* argument is given, the default buffering policy works as follows:

- Binary files are buffered in fixed-size chunks; the size of the buffer is chosen using a heuristic trying to determine the underlying device's "block size" and falling back on *io.DEFAULT_BUFFER_SIZE*. On many systems, the buffer will typically be 4096 or 8192 bytes long.
- "Interactive" text files (files for which *isatty()* returns `True`) use line buffering. Other text files use the policy described above for binary files.

encoding is the name of the encoding used to decode or encode the file. This should only be used in text mode. The default encoding is platform dependent (whatever *locale.getpreferredencoding()* returns), but any *text encoding* supported by Python can be used. See the *codecs* module for the list of supported encodings.

errors is an optional string that specifies how encoding and decoding errors are to be handled—this cannot be used in binary mode. A variety of standard error handlers are available (listed under *Error Handlers*), though any error handling name that has been registered with *codecs.register_error()* is also valid. The standard names include:

- `'strict'` to raise a *ValueError* exception if there is an encoding error. The default value of `None` has the same effect.
- `'ignore'` ignores errors. Note that ignoring encoding errors can lead to data loss.
- `'replace'` causes a replacement marker (such as `'?'`) to be inserted where there is malformed data.
- `'surrogateescape'` will represent any incorrect bytes as code points in the Unicode Private Use Area ranging from U+DC80 to U+DCFF. These private code points will then be turned back into the same bytes when the `surrogateescape` error handler is used when writing data. This is useful for processing files in an unknown encoding.

- `'xmlcharrefreplace'` is only supported when writing to a file. Characters not supported by the encoding are replaced with the appropriate XML character reference `&#nnn;`.
- `'backslashreplace'` replaces malformed data by Python's backslashed escape sequences.
- `'namereplace'` (also only supported when writing) replaces unsupported characters with `\N{...}` escape sequences.

newline controls how *universal newlines* mode works (it only applies to text mode). It can be `None`, `''`, `'\n'`, `'\r'`, and `'\r\n'`. It works as follows:

- When reading input from the stream, if *newline* is `None`, universal newlines mode is enabled. Lines in the input can end in `'\n'`, `'\r'`, or `'\r\n'`, and these are translated into `'\n'` before being returned to the caller. If it is `''`, universal newlines mode is enabled, but line endings are returned to the caller untranslated. If it has any of the other legal values, input lines are only terminated by the given string, and the line ending is returned to the caller untranslated.
- When writing output to the stream, if *newline* is `None`, any `'\n'` characters written are translated to the system default line separator, *os.linesep*. If *newline* is `''` or `'\n'`, no translation takes place. If *newline* is any of the other legal values, any `'\n'` characters written are translated to the given string.

If *closefd* is `False` and a file descriptor rather than a filename was given, the underlying file descriptor will be kept open when the file is closed. If a filename is given *closefd* must be `True` (the default) otherwise an error will be raised.

A custom opener can be used by passing a callable as *opener*. The underlying file descriptor for the file object is then obtained by calling *opener* with (*file*, *flags*). *opener* must return an open file descriptor (passing *os.open* as *opener* results in functionality similar to passing `None`).

The newly created file is *non-inheritable*.

The following example uses the *dir_fd* parameter of the *os.open()* function to open a file relative to a given directory:

```
>>> import os
>>> dir_fd = os.open('somedir', os.O_RDONLY)
>>> def opener(path, flags):
...     return os.open(path, flags, dir_fd=dir_fd)
...
>>> with open('spamspam.txt', 'w', opener=opener) as f:
...     print('This will be written to somedir/spamspam.txt', file=f)
...
>>> os.close(dir_fd)  # don't leak a file descriptor
```

The type of *file object* returned by the *open()* function depends on the mode. When *open()* is used to open a file in a text mode (`'w'`, `'r'`, `'wt'`, `'rt'`, etc.), it returns a subclass of *io.TextIOBase* (specifically *io.TextIOWrapper*). When used to open a file in a binary mode with buffering, the returned class is a subclass of *io.BufferedIOBase*. The exact class varies: in read binary mode, it returns an *io.BufferedReader*; in write binary and append binary modes, it returns an *io.BufferedWriter*, and in read/write mode, it returns an *io.BufferedRandom*. When buffering is disabled, the raw stream, a subclass of *io.RawIOBase*, *io.FileIO*, is returned.

See also the file handling modules, such as, *fileinput*, *io* (where *open()* is declared), *os*, *os.path*, *tempfile*, and *shutil*.

Changed in version 3.3:

- The *opener* parameter was added.
- The `'x'` mode was added.
- *IOError* used to be raised, it is now an alias of *OSError*.

- *FileExistsError* is now raised if the file opened in exclusive creation mode (`'x'`) already exists.

Changed in version 3.4:

- The file is now non-inheritable.

Deprecated since version 3.4, will be removed in version 4.0: The `'U'` mode.

Changed in version 3.5:

- If the system call is interrupted and the signal handler does not raise an exception, the function now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).
- The `'namereplace'` error handler was added.

Changed in version 3.6:

- Support added to accept objects implementing *os.PathLike*.
- On Windows, opening a console buffer may return a subclass of *io.RawIOBase* other than *io.FileIO*.

`ord`(*c*)

Given a string representing one Unicode character, return an integer representing the Unicode code point of that character. For example, `ord('a')` returns the integer `97` and `ord('€')` (Euro sign) returns `8364`. This is the inverse of *chr()*.

`pow`(*x*, *y*[, *z*])

Return *x* to the power *y*; if *z* is present, return *x* to the power *y*, modulo *z* (computed more efficiently than `pow(x, y) % z`). The two-argument form `pow(x, y)` is equivalent to using the power operator: `x**y`.

The arguments must have numeric types. With mixed operand types, the coercion rules for binary arithmetic operators apply. For *int* operands, the result has the same type as the operands (after coercion) unless the second argument is negative; in that case, all arguments are converted to float and a float result is delivered. For example, `10**2` returns `100`, but `10**-2` returns `0.01`. If the second argument is negative, the third argument must be omitted. If *z* is present, *x* and *y* must be of integer types, and *y* must be non-negative.

`print`(**objects*, *sep=' '*, *end='\n'*, *file=sys.stdout*, *flush=False*)

Print *objects* to the text stream *file*, separated by *sep* and followed by *end*. *sep*, *end*, *file* and *flush*, if present, must be given as keyword arguments.

All non-keyword arguments are converted to strings like *str()* does and written to the stream, separated by *sep* and followed by *end*. Both *sep* and *end* must be strings; they can also be `None`, which means to use the default values. If no *objects* are given, *print()* will just write *end*.

The *file* argument must be an object with a `write(string)` method; if it is not present or `None`, *sys.stdout* will be used. Since printed arguments are converted to text strings, *print()* cannot be used with binary mode file objects. For these, use `file.write(...)` instead.

Whether output is buffered is usually determined by *file*, but if the *flush* keyword argument is true, the stream is forcibly flushed.

Changed in version 3.3: Added the *flush* keyword argument.

`class property`(*fget=None*, *fset=None*, *fdel=None*, *doc=None*)

Return a property attribute.

fget is a function for getting an attribute value. *fset* is a function for setting an attribute value. *fdel* is a function for deleting an attribute value. And *doc* creates a docstring for the attribute.

A typical use is to define a managed attribute `x`:

```
class C:
    def __init__(self):
        self._x = None

    def getx(self):
        return self._x

    def setx(self, value):
        self._x = value

    def delx(self):
        del self._x

    x = property(getx, setx, delx, "I'm the 'x' property.")
```

If *c* is an instance of *C*, `c.x` will invoke the getter, `c.x = value` will invoke the setter and `del c.x` the deleter.

If given, *doc* will be the docstring of the property attribute. Otherwise, the property will copy *fget*'s docstring (if it exists). This makes it possible to create read-only properties easily using *property()* as a *decorator*:

```
class Parrot:
    def __init__(self):
        self._voltage = 100000

    @property
    def voltage(self):
        """Get the current voltage."""
        return self._voltage
```

The `@property` decorator turns the `voltage()` method into a "getter" for a read-only attribute with the same name, and it sets the docstring for *voltage* to "Get the current voltage."

A property object has `getter`, `setter`, and `deleter` methods usable as decorators that create a copy of the property with the corresponding accessor function set to the decorated function. This is best explained with an example:

```
class C:
    def __init__(self):
        self._x = None

    @property
    def x(self):
        """I'm the 'x' property."""
        return self._x

    @x.setter
    def x(self, value):
        self._x = value

    @x.deleter
    def x(self):
        del self._x
```

This code is exactly equivalent to the first example. Be sure to give the additional functions the same name as the original property (`x` in this case.)

The returned property object also has the attributes `fget`, `fset`, and `fdel` corresponding to the constructor arguments.

Changed in version 3.5: The docstrings of property objects are now writeable.

range(*stop*)

range(*start*, *stop*[, *step*])

Rather than being a function, *range* is actually an immutable sequence type, as documented in *Ranges* and *Sequence Types — list, tuple, range*.

repr(*object*)

Return a string containing a printable representation of an object. For many types, this function makes an attempt to return a string that would yield an object with the same value when passed to *eval()*, otherwise the representation is a string enclosed in angle brackets that contains the name of the type of the object together with additional information often including the name and address of the object. A class can control what this function returns for its instances by defining a `__repr__()` method.

reversed(*seq*)

Return a reverse *iterator*. *seq* must be an object which has a `__reversed__()` method or supports the sequence protocol (the `__len__()` method and the `__getitem__()` method with integer arguments starting at `0`).

round(*number*[, *ndigits*])

Return *number* rounded to *ndigits* precision after the decimal point. If *ndigits* is omitted or is `None`, it returns the nearest integer to its input.

For the built-in types supporting *round()*, values are rounded to the closest multiple of 10 to the power minus *ndigits*; if two multiples are equally close, rounding is done toward the even choice (so, for example, both `round(0.5)` and `round(-0.5)` are `0`, and `round(1.5)` is `2`). Any integer value is valid for *ndigits* (positive, zero, or negative). The return value is an integer if *ndigits* is omitted or `None`. Otherwise the return value has the same type as *number*.

For a general Python object `number`, `round` delegates to `number.__round__`.

Note: The behavior of *round()* for floats can be surprising: for example, `round(2.675, 2)` gives `2.67` instead of the expected `2.68`. This is not a bug: it's a result of the fact that most decimal fractions can't be represented exactly as a float. See tut-fp-issues for more information.

---

class set([*iterable*])

Return a new *set* object, optionally with elements taken from *iterable*. `set` is a built-in class. See *set* and *Set Types — set, frozenset* for documentation about this class.

For other containers see the built-in *frozenset*, *list*, *tuple*, and *dict* classes, as well as the *collections* module.

setattr(*object*, *name*, *value*)

This is the counterpart of *getattr()*. The arguments are an object, a string and an arbitrary value. The string may name an existing attribute or a new attribute. The function assigns the value to the attribute, provided the object allows it. For example, `setattr(x, 'foobar', 123)` is equivalent to `x.foobar = 123`.

class slice(*stop*)

class slice(*start*, *stop*[, *step*])

Return a *slice* object representing the set of indices specified by `range(start, stop, step)`. The *start* and *step* arguments default to `None`. Slice objects have read-only data attributes `start`, `stop` and `step` which merely return the argument values (or their default). They have no other explicit functionality; however they are used by Numerical Python and other third party extensions. Slice

objects are also generated when extended indexing syntax is used. For example: `a[start:stop:step]` or `a[start:stop, i]`. See *itertools.islice()* for an alternate version that returns an iterator.

sorted(*iterable*, *, *key=None*, *reverse=False*)
Return a new sorted list from the items in *iterable*.

Has two optional arguments which must be specified as keyword arguments.

key specifies a function of one argument that is used to extract a comparison key from each list element: `key=str.lower`. The default value is `None` (compare the elements directly).

reverse is a boolean value. If set to `True`, then the list elements are sorted as if each comparison were reversed.

Use *functools.cmp_to_key()* to convert an old-style *cmp* function to a *key* function.

The built-in *sorted()* function is guaranteed to be stable. A sort is stable if it guarantees not to change the relative order of elements that compare equal — this is helpful for sorting in multiple passes (for example, sort by department, then by salary grade).

For sorting examples and a brief sorting tutorial, see sortinghowto.

@staticmethod
Transform a method into a static method.

A static method does not receive an implicit first argument. To declare a static method, use this idiom:

```
class C:
    @staticmethod
    def f(arg1, arg2, ...): ...
```

The `@staticmethod` form is a function *decorator* – see the description of function definitions in function for details.

It can be called either on the class (such as `C.f()`) or on an instance (such as `C().f()`). The instance is ignored except for its class.

Static methods in Python are similar to those found in Java or C++. Also see *classmethod()* for a variant that is useful for creating alternate class constructors.

Like all decorators, it is also possible to call `staticmethod` as a regular function and do something with its result. This is needed in some cases where you need a reference to a function from a class body and you want to avoid the automatic transformation to instance method. For these cases, use this idiom:

```
class C:
    builtin_open = staticmethod(open)
```

For more information on static methods, consult the documentation on the standard type hierarchy in types.

class str(*object=''*)
class str(*object=b''*, *encoding='utf-8'*, *errors='strict'*)
Return a *str* version of *object*. See *str()* for details.

`str` is the built-in string *class*. For general information about strings, see *Text Sequence Type — str*.

sum(*iterable*[, *start*])
Sums *start* and the items of an *iterable* from left to right and returns the total. *start* defaults to `0`. The *iterable*'s items are normally numbers, and the start value is not allowed to be a string.

For some use cases, there are good alternatives to *sum()*. The preferred, fast way to concatenate a sequence of strings is by calling `''.join(sequence)`. To add floating point values with extended precision, see *math.fsum()*. To concatenate a series of iterables, consider using *itertools.chain()*.

super([*type*[, *object-or-type*]])
Return a proxy object that delegates method calls to a parent or sibling class of *type*. This is useful for accessing inherited methods that have been overridden in a class. The search order is same as that used by *getattr()* except that the *type* itself is skipped.

The *__mro__* attribute of the *type* lists the method resolution search order used by both *getattr()* and *super()*. The attribute is dynamic and can change whenever the inheritance hierarchy is updated.

If the second argument is omitted, the super object returned is unbound. If the second argument is an object, `isinstance(obj, type)` must be true. If the second argument is a type, `issubclass(type2, type)` must be true (this is useful for classmethods).

There are two typical use cases for *super*. In a class hierarchy with single inheritance, *super* can be used to refer to parent classes without naming them explicitly, thus making the code more maintainable. This use closely parallels the use of *super* in other programming languages.

The second use case is to support cooperative multiple inheritance in a dynamic execution environment. This use case is unique to Python and is not found in statically compiled languages or languages that only support single inheritance. This makes it possible to implement "diamond diagrams" where multiple base classes implement the same method. Good design dictates that this method have the same calling signature in every case (because the order of calls is determined at runtime, because that order adapts to changes in the class hierarchy, and because that order can include sibling classes that are unknown prior to runtime).

For both use cases, a typical superclass call looks like this:

```
class C(B):
    def method(self, arg):
        super().method(arg)    # This does the same thing as:
                               # super(C, self).method(arg)
```

Note that *super()* is implemented as part of the binding process for explicit dotted attribute lookups such as `super().__getitem__(name)`. It does so by implementing its own `__getattribute__()` method for searching classes in a predictable order that supports cooperative multiple inheritance. Accordingly, *super()* is undefined for implicit lookups using statements or operators such as `super()[name]`.

Also note that, aside from the zero argument form, *super()* is not limited to use inside methods. The two argument form specifies the arguments exactly and makes the appropriate references. The zero argument form only works inside a class definition, as the compiler fills in the necessary details to correctly retrieve the class being defined, as well as accessing the current instance for ordinary methods.

For practical suggestions on how to design cooperative classes using *super()*, see guide to using super().

tuple([*iterable*])
Rather than being a function, *tuple* is actually an immutable sequence type, as documented in *Tuples* and *Sequence Types — list, tuple, range*.

class type(*object*)
class type(*name*, *bases*, *dict*)
With one argument, return the type of an *object*. The return value is a type object and generally the same object as returned by *object.__class__*.

The *isinstance()* built-in function is recommended for testing the type of an object, because it takes subclasses into account.

With three arguments, return a new type object. This is essentially a dynamic form of the `class` statement. The *name* string is the class name and becomes the *__name__* attribute; the *bases* tuple itemizes the base classes and becomes the *__bases__* attribute; and the *dict* dictionary is the namespace containing definitions for class body and is copied to a standard dictionary to become the *__dict__* attribute. For example, the following two statements create identical *type* objects:

```
>>> class X:
...     a = 1
...
>>> X = type('X', (object,), dict(a=1))
```

See also *Type Objects*.

Changed in version 3.6: Subclasses of *type* which don't override `type.__new__` may no longer use the one-argument form to get the type of an object.

vars([*object*])
Return the *__dict__* attribute for a module, class, instance, or any other object with a *__dict__* attribute.

Objects such as modules and instances have an updateable *__dict__* attribute; however, other objects may have write restrictions on their *__dict__* attributes (for example, classes use a *types.MappingProxyType* to prevent direct dictionary updates).

Without an argument, *vars()* acts like *locals()*. Note, the locals dictionary is only useful for reads since updates to the locals dictionary are ignored.

zip(**iterables*)
Make an iterator that aggregates elements from each of the iterables.

Returns an iterator of tuples, where the *i*-th tuple contains the *i*-th element from each of the argument sequences or iterables. The iterator stops when the shortest input iterable is exhausted. With a single iterable argument, it returns an iterator of 1-tuples. With no arguments, it returns an empty iterator. Equivalent to:

```
def zip(*iterables):
    # zip('ABCD', 'xy') --> Ax By
    sentinel = object()
    iterators = [iter(it) for it in iterables]
    while iterators:
        result = []
        for it in iterators:
            elem = next(it, sentinel)
            if elem is sentinel:
                return
            result.append(elem)
        yield tuple(result)
```

The left-to-right evaluation order of the iterables is guaranteed. This makes possible an idiom for clustering a data series into n-length groups using `zip(*[iter(s)]*n)`. This repeats the *same* iterator `n` times so that each output tuple has the result of `n` calls to the iterator. This has the effect of dividing the input into n-length chunks.

zip() should only be used with unequal length inputs when you don't care about trailing, unmatched values from the longer iterables. If those values are important, use *itertools.zip_longest()* instead.

zip() in conjunction with the `*` operator can be used to unzip a list:

```
>>> x = [1, 2, 3]
>>> y = [4, 5, 6]
>>> zipped = zip(x, y)
>>> list(zipped)
[(1, 4), (2, 5), (3, 6)]
>>> x2, y2 = zip(*zip(x, y))
>>> x == list(x2) and y == list(y2)
True
```

__import__(*name*, *globals=None*, *locals=None*, *fromlist=()*, *level=0*)

Note: This is an advanced function that is not needed in everyday Python programming, unlike *importlib.import_module()*.

This function is invoked by the `import` statement. It can be replaced (by importing the *builtins* module and assigning to `builtins.__import__`) in order to change semantics of the `import` statement, but doing so is **strongly** discouraged as it is usually simpler to use import hooks (see **PEP 302**) to attain the same goals and does not cause issues with code which assumes the default import implementation is in use. Direct use of *__import__()* is also discouraged in favor of *importlib.import_module()*.

The function imports the module *name*, potentially using the given *globals* and *locals* to determine how to interpret the name in a package context. The *fromlist* gives the names of objects or submodules that should be imported from the module given by *name*. The standard implementation does not use its *locals* argument at all, and uses its *globals* only to determine the package context of the `import` statement.

level specifies whether to use absolute or relative imports. `0` (the default) means only perform absolute imports. Positive values for *level* indicate the number of parent directories to search relative to the directory of the module calling *__import__()* (see **PEP 328** for the details).

When the *name* variable is of the form `package.module`, normally, the top-level package (the name up till the first dot) is returned, *not* the module named by *name*. However, when a non-empty *fromlist* argument is given, the module named by *name* is returned.

For example, the statement `import spam` results in bytecode resembling the following code:

```
spam = __import__('spam', globals(), locals(), [], 0)
```

The statement `import spam.ham` results in this call:

```
spam = __import__('spam.ham', globals(), locals(), [], 0)
```

Note how *__import__()* returns the toplevel module here because this is the object that is bound to a name by the `import` statement.

On the other hand, the statement `from spam.ham import eggs, sausage as saus` results in

```
_temp = __import__('spam.ham', globals(), locals(), ['eggs', 'sausage'], 0)
eggs = _temp.eggs
saus = _temp.sausage
```

Here, the `spam.ham` module is returned from *__import__()*. From this object, the names to import are retrieved and assigned to their respective names.

If you simply want to import a module (potentially within a package) by name, use *importlib.import_module()*.

Changed in version 3.3: Negative values for *level* are no longer supported (which also changes the default value to 0).

CHAPTER

THREE

BUILT-IN CONSTANTS

A small number of constants live in the built-in namespace. They are:

False
The false value of the *bool* type. Assignments to `False` are illegal and raise a *SyntaxError*.

True
The true value of the *bool* type. Assignments to `True` are illegal and raise a *SyntaxError*.

None
The sole value of the type `NoneType`. `None` is frequently used to represent the absence of a value, as when default arguments are not passed to a function. Assignments to `None` are illegal and raise a *SyntaxError*.

NotImplemented
Special value which should be returned by the binary special methods (e.g. `__eq__()`, `__lt__()`, `__add__()`, `__rsub__()`, etc.) to indicate that the operation is not implemented with respect to the other type; may be returned by the in-place binary special methods (e.g. `__imul__()`, `__iand__()`, etc.) for the same purpose. Its truth value is true.

Note: When a binary (or in-place) method returns `NotImplemented` the interpreter will try the reflected operation on the other type (or some other fallback, depending on the operator). If all attempts return `NotImplemented`, the interpreter will raise an appropriate exception. Incorrectly returning `NotImplemented` will result in a misleading error message or the `NotImplemented` value being returned to Python code.

See *Implementing the arithmetic operations* for examples.

Note: `NotImplementedError` and `NotImplemented` are not interchangeable, even though they have similar names and purposes. See *NotImplementedError* for details on when to use it.

Ellipsis
The same as `...`. Special value used mostly in conjunction with extended slicing syntax for user-defined container data types.

__debug__
This constant is true if Python was not started with an `-O` option. See also the `assert` statement.

Note: The names *None*, *False*, *True* and *__debug__* cannot be reassigned (assignments to them, even as an attribute name, raise *SyntaxError*), so they can be considered "true" constants.

3.1 Constants added by the site module

The *site* module (which is imported automatically during startup, except if the `-S` command-line option is given) adds several constants to the built-in namespace. They are useful for the interactive interpreter shell and should not be used in programs.

`quit`(*code=None*)
`exit`(*code=None*)
Objects that when printed, print a message like "Use quit() or Ctrl-D (i.e. EOF) to exit", and when called, raise *SystemExit* with the specified exit code.

`copyright`
`credits`
Objects that when printed or called, print the text of copyright or credits, respectively.

`license`
Object that when printed, prints the message "Type license() to see the full license text", and when called, displays the full license text in a pager-like fashion (one screen at a time).

CHAPTER

FOUR

BUILT-IN TYPES

The following sections describe the standard types that are built into the interpreter.

The principal built-in types are numerics, sequences, mappings, classes, instances and exceptions.

Some collection classes are mutable. The methods that add, subtract, or rearrange their members in place, and don't return a specific item, never return the collection instance itself but `None`.

Some operations are supported by several object types; in particular, practically all objects can be compared, tested for truth value, and converted to a string (with the *repr()* function or the slightly different *str()* function). The latter function is implicitly used when an object is written by the *print()* function.

4.1 Truth Value Testing

Any object can be tested for truth value, for use in an `if` or `while` condition or as operand of the Boolean operations below.

By default, an object is considered true unless its class defines either a `__bool__()` method that returns `False` or a `__len__()` method that returns zero, when called with the object.[1] Here are most of the built-in objects considered false:

- constants defined to be false: `None` and `False`.
- zero of any numeric type: `0`, `0.0`, `0j`, `Decimal(0)`, `Fraction(0, 1)`
- empty sequences and collections: `''`, `()`, `[]`, `{}`, `set()`, `range(0)`

Operations and built-in functions that have a Boolean result always return `0` or `False` for false and `1` or `True` for true, unless otherwise stated. (Important exception: the Boolean operations `or` and `and` always return one of their operands.)

4.2 Boolean Operations — `and`, `or`, `not`

These are the Boolean operations, ordered by ascending priority:

Operation	Result	Notes
`x or y`	if x is false, then y, else x	(1)
`x and y`	if x is false, then x, else y	(2)
`not x`	if x is false, then `True`, else `False`	(3)

Notes:

[1] Additional information on these special methods may be found in the Python Reference Manual (customization).

1. This is a short-circuit operator, so it only evaluates the second argument if the first one is false.
2. This is a short-circuit operator, so it only evaluates the second argument if the first one is true.
3. `not` has a lower priority than non-Boolean operators, so `not a == b` is interpreted as `not (a == b)`, and `a == not b` is a syntax error.

4.3 Comparisons

There are eight comparison operations in Python. They all have the same priority (which is higher than that of the Boolean operations). Comparisons can be chained arbitrarily; for example, `x < y <= z` is equivalent to `x < y and y <= z`, except that *y* is evaluated only once (but in both cases *z* is not evaluated at all when `x < y` is found to be false).

This table summarizes the comparison operations:

Operation	Meaning
`<`	strictly less than
`<=`	less than or equal
`>`	strictly greater than
`>=`	greater than or equal
`==`	equal
`!=`	not equal
`is`	object identity
`is not`	negated object identity

Objects of different types, except different numeric types, never compare equal. Furthermore, some types (for example, function objects) support only a degenerate notion of comparison where any two objects of that type are unequal. The `<`, `<=`, `>` and `>=` operators will raise a *TypeError* exception when comparing a complex number with another built-in numeric type, when the objects are of different types that cannot be compared, or in other cases where there is no defined ordering.

Non-identical instances of a class normally compare as non-equal unless the class defines the `__eq__()` method.

Instances of a class cannot be ordered with respect to other instances of the same class, or other types of object, unless the class defines enough of the methods `__lt__()`, `__le__()`, `__gt__()`, and `__ge__()` (in general, `__lt__()` and `__eq__()` are sufficient, if you want the conventional meanings of the comparison operators).

The behavior of the `is` and `is not` operators cannot be customized; also they can be applied to any two objects and never raise an exception.

Two more operations with the same syntactic priority, `in` and `not in`, are supported only by sequence types (below).

4.4 Numeric Types — `int`, `float`, `complex`

There are three distinct numeric types: *integers*, *floating point numbers*, and *complex numbers*. In addition, Booleans are a subtype of integers. Integers have unlimited precision. Floating point numbers are usually implemented using `double` in C; information about the precision and internal representation of floating point numbers for the machine on which your program is running is available in *sys.float_info*. Complex numbers have a real and imaginary part, which are each a floating point number. To extract these parts

from a complex number *z*, use `z.real` and `z.imag`. (The standard library includes additional numeric types, *fractions* that hold rationals, and *decimal* that hold floating-point numbers with user-definable precision.)

Numbers are created by numeric literals or as the result of built-in functions and operators. Unadorned integer literals (including hex, octal and binary numbers) yield integers. Numeric literals containing a decimal point or an exponent sign yield floating point numbers. Appending `'j'` or `'J'` to a numeric literal yields an imaginary number (a complex number with a zero real part) which you can add to an integer or float to get a complex number with real and imaginary parts.

Python fully supports mixed arithmetic: when a binary arithmetic operator has operands of different numeric types, the operand with the "narrower" type is widened to that of the other, where integer is narrower than floating point, which is narrower than complex. Comparisons between numbers of mixed type use the same rule.[2] The constructors *int()*, *float()*, and *complex()* can be used to produce numbers of a specific type.

All numeric types (except complex) support the following operations, sorted by ascending priority (all numeric operations have a higher priority than comparison operations):

Operation	Result	Notes	Full documentation
`x + y`	sum of x and y		
`x - y`	difference of x and y		
`x * y`	product of x and y		
`x / y`	quotient of x and y		
`x // y`	floored quotient of x and y	(1)	
`x % y`	remainder of `x / y`	(2)	
`-x`	x negated		
`+x`	x unchanged		
`abs(x)`	absolute value or magnitude of x		*abs()*
`int(x)`	x converted to integer	(3)(6)	*int()*
`float(x)`	x converted to floating point	(4)(6)	*float()*
`complex(re, im)`	a complex number with real part *re*, imaginary part *im*. *im* defaults to zero.	(6)	*complex()*
`c.conjugate()`	conjugate of the complex number c		
`divmod(x, y)`	the pair `(x // y, x % y)`	(2)	*divmod()*
`pow(x, y)`	x to the power y	(5)	*pow()*
`x ** y`	x to the power y	(5)	

Notes:

1. Also referred to as integer division. The resultant value is a whole integer, though the result's type is not necessarily int. The result is always rounded towards minus infinity: `1//2` is `0`, `(-1)//2` is `-1`, `1//(-2)` is `-1`, and `(-1)//(-2)` is `0`.
2. Not for complex numbers. Instead convert to floats using *abs()* if appropriate.
3. Conversion from floating point to integer may round or truncate as in C; see functions *math.floor()* and *math.ceil()* for well-defined conversions.
4. float also accepts the strings "nan" and "inf" with an optional prefix "+" or "-" for Not a Number (NaN) and positive or negative infinity.
5. Python defines `pow(0, 0)` and `0 ** 0` to be `1`, as is common for programming languages.
6. The numeric literals accepted include the digits `0` to `9` or any Unicode equivalent (code points with the `Nd` property).

[2] As a consequence, the list `[1, 2]` is considered equal to `[1.0, 2.0]`, and similarly for tuples.

See http://www.unicode.org/Public/10.0.0/ucd/extracted/DerivedNumericType.txt for a complete list of code points with the `Nd` property.

All *numbers.Real* types (*int* and *float*) also include the following operations:

Operation	Result
math.trunc(x)	x truncated to *Integral*
round(x[, n])	x rounded to n digits, rounding half to even. If n is omitted, it defaults to 0.
math.floor(x)	the greatest *Integral* $<= x$
math.ceil(x)	the least *Integral* $>= x$

For additional numeric operations see the *math* and *cmath* modules.

4.4.1 Bitwise Operations on Integer Types

Bitwise operations only make sense for integers. Negative numbers are treated as their 2's complement value (this assumes that there are enough bits so that no overflow occurs during the operation).

The priorities of the binary bitwise operations are all lower than the numeric operations and higher than the comparisons; the unary operation `~` has the same priority as the other unary numeric operations (`+` and `-`).

This table lists the bitwise operations sorted in ascending priority:

Operation	Result	Notes
`x | y`	bitwise *or* of x and y	
`x ^ y`	bitwise *exclusive or* of x and y	
`x & y`	bitwise *and* of x and y	
`x << n`	x shifted left by n bits	(1)(2)
`x >> n`	x shifted right by n bits	(1)(3)
`~x`	the bits of x inverted	

Notes:

1. Negative shift counts are illegal and cause a *ValueError* to be raised.
2. A left shift by n bits is equivalent to multiplication by `pow(2, n)` without overflow check.
3. A right shift by n bits is equivalent to division by `pow(2, n)` without overflow check.

4.4.2 Additional Methods on Integer Types

The int type implements the *numbers.Integral* *abstract base class*. In addition, it provides a few more methods:

`int.bit_length()`

Return the number of bits necessary to represent an integer in binary, excluding the sign and leading zeros:

```
>>> n = -37
>>> bin(n)
'-0b100101'
>>> n.bit_length()
6
```

More precisely, if `x` is nonzero, then `x.bit_length()` is the unique positive integer `k` such that `2**(k-1) <= abs(x) < 2**k`. Equivalently, when `abs(x)` is small enough to have a correctly rounded logarithm, then `k = 1 + int(log(abs(x), 2))`. If `x` is zero, then `x.bit_length()` returns `0`.

Equivalent to:

```
def bit_length(self):
    s = bin(self)       # binary representation:  bin(-37) --> '-0b100101'
    s = s.lstrip('-0b') # remove leading zeros and minus sign
    return len(s)       # len('100101') --> 6
```

New in version 3.1.

`int.to_bytes`(*length*, *byteorder*, ***, *signed=False*)

Return an array of bytes representing an integer.

```
>>> (1024).to_bytes(2, byteorder='big')
b'\x04\x00'
>>> (1024).to_bytes(10, byteorder='big')
b'\x00\x00\x00\x00\x00\x00\x00\x00\x04\x00'
>>> (-1024).to_bytes(10, byteorder='big', signed=True)
b'\xff\xff\xff\xff\xff\xff\xff\xff\xfc\x00'
>>> x = 1000
>>> x.to_bytes((x.bit_length() + 7) // 8, byteorder='little')
b'\xe8\x03'
```

The integer is represented using *length* bytes. An *OverflowError* is raised if the integer is not representable with the given number of bytes.

The *byteorder* argument determines the byte order used to represent the integer. If *byteorder* is `"big"`, the most significant byte is at the beginning of the byte array. If *byteorder* is `"little"`, the most significant byte is at the end of the byte array. To request the native byte order of the host system, use *sys.byteorder* as the byte order value.

The *signed* argument determines whether two's complement is used to represent the integer. If *signed* is `False` and a negative integer is given, an *OverflowError* is raised. The default value for *signed* is `False`.

New in version 3.2.

`classmethod int.from_bytes`(*bytes*, *byteorder*, ***, *signed=False*)

Return the integer represented by the given array of bytes.

```
>>> int.from_bytes(b'\x00\x10', byteorder='big')
16
>>> int.from_bytes(b'\x00\x10', byteorder='little')
4096
>>> int.from_bytes(b'\xfc\x00', byteorder='big', signed=True)
-1024
>>> int.from_bytes(b'\xfc\x00', byteorder='big', signed=False)
64512
>>> int.from_bytes([255, 0, 0], byteorder='big')
16711680
```

The argument *bytes* must either be a *bytes-like object* or an iterable producing bytes.

The *byteorder* argument determines the byte order used to represent the integer. If *byteorder* is `"big"`, the most significant byte is at the beginning of the byte array. If *byteorder* is `"little"`, the most significant byte is at the end of the byte array. To request the native byte order of the host system, use *sys.byteorder* as the byte order value.

The *signed* argument indicates whether two's complement is used to represent the integer.

New in version 3.2.

4.4.3 Additional Methods on Float

The float type implements the *numbers.Real abstract base class*. float also has the following additional methods.

`float.as_integer_ratio()`
Return a pair of integers whose ratio is exactly equal to the original float and with a positive denominator. Raises *OverflowError* on infinities and a *ValueError* on NaNs.

`float.is_integer()`
Return `True` if the float instance is finite with integral value, and `False` otherwise:

```
>>> (-2.0).is_integer()
True
>>> (3.2).is_integer()
False
```

Two methods support conversion to and from hexadecimal strings. Since Python's floats are stored internally as binary numbers, converting a float to or from a *decimal* string usually involves a small rounding error. In contrast, hexadecimal strings allow exact representation and specification of floating-point numbers. This can be useful when debugging, and in numerical work.

`float.hex()`
Return a representation of a floating-point number as a hexadecimal string. For finite floating-point numbers, this representation will always include a leading `0x` and a trailing `p` and exponent.

`classmethod float.fromhex(s)`
Class method to return the float represented by a hexadecimal string *s*. The string *s* may have leading and trailing whitespace.

Note that *float.hex()* is an instance method, while *float.fromhex()* is a class method.

A hexadecimal string takes the form:

```
[sign] ['0x'] integer ['.' fraction] ['p' exponent]
```

where the optional `sign` may by either `+` or `-`, `integer` and `fraction` are strings of hexadecimal digits, and `exponent` is a decimal integer with an optional leading sign. Case is not significant, and there must be at least one hexadecimal digit in either the integer or the fraction. This syntax is similar to the syntax specified in section 6.4.4.2 of the C99 standard, and also to the syntax used in Java 1.5 onwards. In particular, the output of *float.hex()* is usable as a hexadecimal floating-point literal in C or Java code, and hexadecimal strings produced by C's `%a` format character or Java's `Double.toHexString` are accepted by *float.fromhex()*.

Note that the exponent is written in decimal rather than hexadecimal, and that it gives the power of 2 by which to multiply the coefficient. For example, the hexadecimal string `0x3.a7p10` represents the floating-point number `(3 + 10./16 + 7./16**2) * 2.0**10`, or `3740.0`:

```
>>> float.fromhex('0x3.a7p10')
3740.0
```

Applying the reverse conversion to `3740.0` gives a different hexadecimal string representing the same number:

```
>>> float.hex(3740.0)
'0x1.d380000000000p+11'
```

4.4.4 Hashing of numeric types

For numbers `x` and `y`, possibly of different types, it's a requirement that `hash(x) == hash(y)` whenever `x == y` (see the `__hash__()` method documentation for more details). For ease of implementation and efficiency across a variety of numeric types (including *int*, *float*, *decimal.Decimal* and *fractions.Fraction*) Python's hash for numeric types is based on a single mathematical function that's defined for any rational number, and hence applies to all instances of *int* and *fractions.Fraction*, and all finite instances of *float* and *decimal.Decimal*. Essentially, this function is given by reduction modulo `P` for a fixed prime `P`. The value of `P` is made available to Python as the `modulus` attribute of *sys.hash_info*.

CPython implementation detail: Currently, the prime used is `P = 2**31 - 1` on machines with 32-bit C longs and `P = 2**61 - 1` on machines with 64-bit C longs.

Here are the rules in detail:

- If `x = m / n` is a nonnegative rational number and `n` is not divisible by `P`, define `hash(x)` as `m * invmod(n, P) % P`, where `invmod(n, P)` gives the inverse of `n` modulo `P`.
- If `x = m / n` is a nonnegative rational number and `n` is divisible by `P` (but `m` is not) then `n` has no inverse modulo `P` and the rule above doesn't apply; in this case define `hash(x)` to be the constant value `sys.hash_info.inf`.
- If `x = m / n` is a negative rational number define `hash(x)` as `-hash(-x)`. If the resulting hash is `-1`, replace it with `-2`.
- The particular values `sys.hash_info.inf`, `-sys.hash_info.inf` and `sys.hash_info.nan` are used as hash values for positive infinity, negative infinity, or nans (respectively). (All hashable nans have the same hash value.)
- For a *complex* number `z`, the hash values of the real and imaginary parts are combined by computing `hash(z.real) + sys.hash_info.imag * hash(z.imag)`, reduced modulo `2**sys.hash_info.width` so that it lies in `range(-2**(sys.hash_info.width - 1), 2**(sys.hash_info.width - 1))`. Again, if the result is `-1`, it's replaced with `-2`.

To clarify the above rules, here's some example Python code, equivalent to the built-in hash, for computing the hash of a rational number, *float*, or *complex*:

```
import sys, math

def hash_fraction(m, n):
    """Compute the hash of a rational number m / n.

    Assumes m and n are integers, with n positive.
    Equivalent to hash(fractions.Fraction(m, n)).

    """
    P = sys.hash_info.modulus
    # Remove common factors of P.  (Unnecessary if m and n already coprime.)
    while m % P == n % P == 0:
        m, n = m // P, n // P

    if n % P == 0:
        hash_value = sys.hash_info.inf
    else:
        # Fermat's Little Theorem: pow(n, P-1, P) is 1, so
        # pow(n, P-2, P) gives the inverse of n modulo P.
        hash_value = (abs(m) % P) * pow(n, P - 2, P) % P
    if m < 0:
        hash_value = -hash_value
    if hash_value == -1:
```

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```
        hash_value = -2
    return hash_value

def hash_float(x):
    """Compute the hash of a float x."""

    if math.isnan(x):
        return sys.hash_info.nan
    elif math.isinf(x):
        return sys.hash_info.inf if x > 0 else -sys.hash_info.inf
    else:
        return hash_fraction(*x.as_integer_ratio())

def hash_complex(z):
    """Compute the hash of a complex number z."""

    hash_value = hash_float(z.real) + sys.hash_info.imag * hash_float(z.imag)
    # do a signed reduction modulo 2**sys.hash_info.width
    M = 2**(sys.hash_info.width - 1)
    hash_value = (hash_value & (M - 1)) - (hash_value & M)
    if hash_value == -1:
        hash_value = -2
    return hash_value
```

4.5 Iterator Types

Python supports a concept of iteration over containers. This is implemented using two distinct methods; these are used to allow user-defined classes to support iteration. Sequences, described below in more detail, always support the iteration methods.

One method needs to be defined for container objects to provide iteration support:

`container.__iter__()`
: Return an iterator object. The object is required to support the iterator protocol described below. If a container supports different types of iteration, additional methods can be provided to specifically request iterators for those iteration types. (An example of an object supporting multiple forms of iteration would be a tree structure which supports both breadth-first and depth-first traversal.) This method corresponds to the `tp_iter` slot of the type structure for Python objects in the Python/C API.

The iterator objects themselves are required to support the following two methods, which together form the *iterator protocol*:

`iterator.__iter__()`
: Return the iterator object itself. This is required to allow both containers and iterators to be used with the `for` and `in` statements. This method corresponds to the `tp_iter` slot of the type structure for Python objects in the Python/C API.

`iterator.__next__()`
: Return the next item from the container. If there are no further items, raise the *StopIteration* exception. This method corresponds to the `tp_iternext` slot of the type structure for Python objects in the Python/C API.

Python defines several iterator objects to support iteration over general and specific sequence types, dictionaries, and other more specialized forms. The specific types are not important beyond their implementation of the iterator protocol.

Once an iterator's *__next__()* method raises *StopIteration*, it must continue to do so on subsequent calls. Implementations that do not obey this property are deemed broken.

4.5.1 Generator Types

Python's *generator*s provide a convenient way to implement the iterator protocol. If a container object's `__iter__()` method is implemented as a generator, it will automatically return an iterator object (technically, a generator object) supplying the `__iter__()` and `__next__()` methods. More information about generators can be found in the documentation for the yield expression.

4.6 Sequence Types — `list`, `tuple`, `range`

There are three basic sequence types: lists, tuples, and range objects. Additional sequence types tailored for processing of *binary data* and *text strings* are described in dedicated sections.

4.6.1 Common Sequence Operations

The operations in the following table are supported by most sequence types, both mutable and immutable. The *collections.abc.Sequence* ABC is provided to make it easier to correctly implement these operations on custom sequence types.

This table lists the sequence operations sorted in ascending priority. In the table, s and t are sequences of the same type, n, i, j and k are integers and x is an arbitrary object that meets any type and value restrictions imposed by s.

The `in` and `not in` operations have the same priorities as the comparison operations. The `+` (concatenation) and `*` (repetition) operations have the same priority as the corresponding numeric operations.[3]

Operation	Result	Notes
`x in s`	`True` if an item of s is equal to x, else `False`	(1)
`x not in s`	`False` if an item of s is equal to x, else `True`	(1)
`s + t`	the concatenation of s and t	(6)(7)
`s * n` or `n * s`	equivalent to adding s to itself n times	(2)(7)
`s[i]`	ith item of s, origin 0	(3)
`s[i:j]`	slice of s from i to j	(3)(4)
`s[i:j:k]`	slice of s from i to j with step k	(3)(5)
`len(s)`	length of s	
`min(s)`	smallest item of s	
`max(s)`	largest item of s	
`s.index(x[, i[, j]])`	index of the first occurrence of x in s (at or after index i and before index j)	(8)
`s.count(x)`	total number of occurrences of x in s	

Sequences of the same type also support comparisons. In particular, tuples and lists are compared lexicographically by comparing corresponding elements. This means that to compare equal, every element must compare equal and the two sequences must be of the same type and have the same length. (For full details see comparisons in the language reference.)

Notes:

[3] They must have since the parser can't tell the type of the operands.

1. While the `in` and `not in` operations are used only for simple containment testing in the general case, some specialised sequences (such as *str*, *bytes* and *bytearray*) also use them for subsequence testing:

```
>>> "gg" in "eggs"
True
```

2. Values of n less than `0` are treated as `0` (which yields an empty sequence of the same type as s). Note that items in the sequence s are not copied; they are referenced multiple times. This often haunts new Python programmers; consider:

```
>>> lists = [[]] * 3
>>> lists
[[], [], []]
>>> lists[0].append(3)
>>> lists
[[3], [3], [3]]
```

What has happened is that `[[]]` is a one-element list containing an empty list, so all three elements of `[[]] * 3` are references to this single empty list. Modifying any of the elements of `lists` modifies this single list. You can create a list of different lists this way:

```
>>> lists = [[] for i in range(3)]
>>> lists[0].append(3)
>>> lists[1].append(5)
>>> lists[2].append(7)
>>> lists
[[3], [5], [7]]
```

Further explanation is available in the FAQ entry faq-multidimensional-list.

3. If i or j is negative, the index is relative to the end of sequence s: `len(s) + i` or `len(s) + j` is substituted. But note that `-0` is still `0`.

4. The slice of s from i to j is defined as the sequence of items with index k such that `i <= k < j`. If i or j is greater than `len(s)`, use `len(s)`. If i is omitted or `None`, use `0`. If j is omitted or `None`, use `len(s)`. If i is greater than or equal to j, the slice is empty.

5. The slice of s from i to j with step k is defined as the sequence of items with index `x = i + n*k` such that `0 <= n < (j-i)/k`. In other words, the indices are `i`, `i+k`, `i+2*k`, `i+3*k` and so on, stopping when j is reached (but never including j). When k is positive, i and j are reduced to `len(s)` if they are greater. When k is negative, i and j are reduced to `len(s) - 1` if they are greater. If i or j are omitted or `None`, they become "end" values (which end depends on the sign of k). Note, k cannot be zero. If k is `None`, it is treated like `1`.

6. Concatenating immutable sequences always results in a new object. This means that building up a sequence by repeated concatenation will have a quadratic runtime cost in the total sequence length. To get a linear runtime cost, you must switch to one of the alternatives below:

   - if concatenating *str* objects, you can build a list and use *str.join()* at the end or else write to an *io.StringIO* instance and retrieve its value when complete
   - if concatenating *bytes* objects, you can similarly use *bytes.join()* or *io.BytesIO*, or you can do in-place concatenation with a *bytearray* object. *bytearray* objects are mutable and have an efficient overallocation mechanism
   - if concatenating *tuple* objects, extend a *list* instead
   - for other types, investigate the relevant class documentation

7. Some sequence types (such as *range*) only support item sequences that follow specific patterns, and hence don't support sequence concatenation or repetition.

8. `index` raises *ValueError* when x is not found in s. Not all implementations support passing the additional arguments i and j. These arguments allow efficient searching of subsections of the sequence. Passing the extra arguments is roughly equivalent to using `s[i:j].index(x)`, only without copying any data and with the returned index being relative to the start of the sequence rather than the start of the slice.

4.6.2 Immutable Sequence Types

The only operation that immutable sequence types generally implement that is not also implemented by mutable sequence types is support for the *hash()* built-in.

This support allows immutable sequences, such as *tuple* instances, to be used as *dict* keys and stored in *set* and *frozenset* instances.

Attempting to hash an immutable sequence that contains unhashable values will result in *TypeError*.

4.6.3 Mutable Sequence Types

The operations in the following table are defined on mutable sequence types. The *collections.abc.MutableSequence* ABC is provided to make it easier to correctly implement these operations on custom sequence types.

In the table s is an instance of a mutable sequence type, t is any iterable object and x is an arbitrary object that meets any type and value restrictions imposed by s (for example, *bytearray* only accepts integers that meet the value restriction `0 <= x <= 255`).

Operation	Result	Notes
`s[i] = x`	item i of s is replaced by x	
`s[i:j] = t`	slice of s from i to j is replaced by the contents of the iterable t	
`del s[i:j]`	same as `s[i:j] = []`	
`s[i:j:k] = t`	the elements of `s[i:j:k]` are replaced by those of t	(1)
`del s[i:j:k]`	removes the elements of `s[i:j:k]` from the list	
`s.append(x)`	appends x to the end of the sequence (same as `s[len(s):len(s)] = [x]`)	
`s.clear()`	removes all items from `s` (same as `del s[:]`)	(5)
`s.copy()`	creates a shallow copy of `s` (same as `s[:]`)	(5)
`s.extend(t)` or `s += t`	extends s with the contents of t (for the most part the same as `s[len(s):len(s)] = t`)	
`s *= n`	updates s with its contents repeated n times	(6)
`s.insert(i, x)`	inserts x into s at the index given by i (same as `s[i:i] = [x]`)	
`s.pop([i])`	retrieves the item at i and also removes it from s	(2)
`s.remove(x)`	remove the first item from s where `s[i]` is equal to x	(3)
`s.reverse()`	reverses the items of s in place	(4)

Notes:

1. t must have the same length as the slice it is replacing.
2. The optional argument i defaults to `-1`, so that by default the last item is removed and returned.
3. `remove` raises *ValueError* when x is not found in s.
4. The `reverse()` method modifies the sequence in place for economy of space when reversing a large sequence. To remind users that it operates by side effect, it does not return the reversed sequence.
5. `clear()` and `copy()` are included for consistency with the interfaces of mutable containers that don't support slicing operations (such as *dict* and *set*)

New in version 3.3: `clear()` and `copy()` methods.

6. The value *n* is an integer, or an object implementing `__index__()`. Zero and negative values of *n* clear the sequence. Items in the sequence are not copied; they are referenced multiple times, as explained for `s * n` under *Common Sequence Operations*.

4.6.4 Lists

Lists are mutable sequences, typically used to store collections of homogeneous items (where the precise degree of similarity will vary by application).

`class list([iterable])`

Lists may be constructed in several ways:

- Using a pair of square brackets to denote the empty list: `[]`
- Using square brackets, separating items with commas: `[a]`, `[a, b, c]`
- Using a list comprehension: `[x for x in iterable]`
- Using the type constructor: `list()` or `list(iterable)`

The constructor builds a list whose items are the same and in the same order as *iterable*'s items. *iterable* may be either a sequence, a container that supports iteration, or an iterator object. If *iterable* is already a list, a copy is made and returned, similar to `iterable[:]`. For example, `list('abc')` returns `['a', 'b', 'c']` and `list( (1, 2, 3) )` returns `[1, 2, 3]`. If no argument is given, the constructor creates a new empty list, `[]`.

Many other operations also produce lists, including the *sorted()* built-in.

Lists implement all of the *common* and *mutable* sequence operations. Lists also provide the following additional method:

`sort(*, key=None, reverse=False)`

This method sorts the list in place, using only `<` comparisons between items. Exceptions are not suppressed - if any comparison operations fail, the entire sort operation will fail (and the list will likely be left in a partially modified state).

sort() accepts two arguments that can only be passed by keyword (*keyword-only arguments*):

key specifies a function of one argument that is used to extract a comparison key from each list element (for example, `key=str.lower`). The key corresponding to each item in the list is calculated once and then used for the entire sorting process. The default value of `None` means that list items are sorted directly without calculating a separate key value.

The *functools.cmp_to_key()* utility is available to convert a 2.x style *cmp* function to a *key* function.

reverse is a boolean value. If set to `True`, then the list elements are sorted as if each comparison were reversed.

This method modifies the sequence in place for economy of space when sorting a large sequence. To remind users that it operates by side effect, it does not return the sorted sequence (use *sorted()* to explicitly request a new sorted list instance).

The *sort()* method is guaranteed to be stable. A sort is stable if it guarantees not to change the relative order of elements that compare equal — this is helpful for sorting in multiple passes (for example, sort by department, then by salary grade).

CPython implementation detail: While a list is being sorted, the effect of attempting to mutate, or even inspect, the list is undefined. The C implementation of Python makes the list appear empty for the duration, and raises *ValueError* if it can detect that the list has been mutated during a sort.

4.6.5 Tuples

Tuples are immutable sequences, typically used to store collections of heterogeneous data (such as the 2-tuples produced by the *enumerate()* built-in). Tuples are also used for cases where an immutable sequence of homogeneous data is needed (such as allowing storage in a *set* or *dict* instance).

class tuple([*iterable*])

Tuples may be constructed in a number of ways:

- Using a pair of parentheses to denote the empty tuple: `()`
- Using a trailing comma for a singleton tuple: `a,` or `(a,)`
- Separating items with commas: `a, b, c` or `(a, b, c)`
- Using the *tuple()* built-in: `tuple()` or `tuple(iterable)`

The constructor builds a tuple whose items are the same and in the same order as *iterable*'s items. *iterable* may be either a sequence, a container that supports iteration, or an iterator object. If *iterable* is already a tuple, it is returned unchanged. For example, `tuple('abc')` returns `('a', 'b', 'c')` and `tuple( [1, 2, 3] )` returns `(1, 2, 3)`. If no argument is given, the constructor creates a new empty tuple, `()`.

Note that it is actually the comma which makes a tuple, not the parentheses. The parentheses are optional, except in the empty tuple case, or when they are needed to avoid syntactic ambiguity. For example, `f(a, b, c)` is a function call with three arguments, while `f((a, b, c))` is a function call with a 3-tuple as the sole argument.

Tuples implement all of the *common* sequence operations.

For heterogeneous collections of data where access by name is clearer than access by index, *collections.namedtuple()* may be a more appropriate choice than a simple tuple object.

4.6.6 Ranges

The *range* type represents an immutable sequence of numbers and is commonly used for looping a specific number of times in `for` loops.

class range(*stop*)

class range(*start*, *stop*[, *step*])

The arguments to the range constructor must be integers (either built-in *int* or any object that implements the `__index__` special method). If the *step* argument is omitted, it defaults to `1`. If the *start* argument is omitted, it defaults to `0`. If *step* is zero, *ValueError* is raised.

For a positive *step*, the contents of a range `r` are determined by the formula `r[i] = start + step*i` where `i >= 0` and `r[i] < stop`.

For a negative *step*, the contents of the range are still determined by the formula `r[i] = start + step*i`, but the constraints are `i >= 0` and `r[i] > stop`.

A range object will be empty if `r[0]` does not meet the value constraint. Ranges do support negative indices, but these are interpreted as indexing from the end of the sequence determined by the positive indices.

Ranges containing absolute values larger than *sys.maxsize* are permitted but some features (such as *len()*) may raise *OverflowError*.

Range examples:

```
>>> list(range(10))
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
>>> list(range(1, 11))
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
>>> list(range(0, 30, 5))
[0, 5, 10, 15, 20, 25]
>>> list(range(0, 10, 3))
[0, 3, 6, 9]
>>> list(range(0, -10, -1))
[0, -1, -2, -3, -4, -5, -6, -7, -8, -9]
>>> list(range(0))
[]
>>> list(range(1, 0))
[]
```

Ranges implement all of the *common* sequence operations except concatenation and repetition (due to the fact that range objects can only represent sequences that follow a strict pattern and repetition and concatenation will usually violate that pattern).

start
: The value of the *start* parameter (or `0` if the parameter was not supplied)

stop
: The value of the *stop* parameter

step
: The value of the *step* parameter (or `1` if the parameter was not supplied)

The advantage of the *range* type over a regular *list* or *tuple* is that a *range* object will always take the same (small) amount of memory, no matter the size of the range it represents (as it only stores the **start**, **stop** and **step** values, calculating individual items and subranges as needed).

Range objects implement the *collections.abc.Sequence* ABC, and provide features such as containment tests, element index lookup, slicing and support for negative indices (see *Sequence Types — list, tuple, range*):

```
>>> r = range(0, 20, 2)
>>> r
range(0, 20, 2)
>>> 11 in r
False
>>> 10 in r
True
>>> r.index(10)
5
>>> r[5]
10
>>> r[:5]
range(0, 10, 2)
>>> r[-1]
18
```

Testing range objects for equality with `==` and `!=` compares them as sequences. That is, two range objects are considered equal if they represent the same sequence of values. (Note that two range objects that compare equal might have different *start*, *stop* and *step* attributes, for example `range(0) == range(2, 1, 3)` or `range(0, 3, 2) == range(0, 4, 2)`.)

Changed in version 3.2: Implement the Sequence ABC. Support slicing and negative indices. Test *int* objects for membership in constant time instead of iterating through all items.

Changed in version 3.3: Define '==' and '!=' to compare range objects based on the sequence of values they define (instead of comparing based on object identity).

New in version 3.3: The *start*, *stop* and *step* attributes.

See also:

- The linspace recipe shows how to implement a lazy version of range that suitable for floating point applications.

4.7 Text Sequence Type — str

Textual data in Python is handled with *str* objects, or *strings*. Strings are immutable *sequences* of Unicode code points. String literals are written in a variety of ways:

- Single quotes: `'allows embedded "double" quotes'`
- Double quotes: `"allows embedded 'single' quotes"`.
- Triple quoted: `'''Three single quotes'''`, `"""Three double quotes"""`

Triple quoted strings may span multiple lines - all associated whitespace will be included in the string literal.

String literals that are part of a single expression and have only whitespace between them will be implicitly converted to a single string literal. That is, `("spam " "eggs") == "spam eggs"`.

See strings for more about the various forms of string literal, including supported escape sequences, and the `r` ("raw") prefix that disables most escape sequence processing.

Strings may also be created from other objects using the *str* constructor.

Since there is no separate "character" type, indexing a string produces strings of length 1. That is, for a non-empty string *s*, `s[0] == s[0:1]`.

There is also no mutable string type, but *str.join()* or *io.StringIO* can be used to efficiently construct strings from multiple fragments.

Changed in version 3.3: For backwards compatibility with the Python 2 series, the `u` prefix is once again permitted on string literals. It has no effect on the meaning of string literals and cannot be combined with the `r` prefix.

class str(*object=''*)
class str(*object=b''*, *encoding='utf-8'*, *errors='strict'*)

Return a *string* version of *object*. If *object* is not provided, returns the empty string. Otherwise, the behavior of `str()` depends on whether *encoding* or *errors* is given, as follows.

If neither *encoding* nor *errors* is given, `str(object)` returns `object.__str__()`, which is the "informal" or nicely printable string representation of *object*. For string objects, this is the string itself. If *object* does not have a `__str__()` method, then *str()* falls back to returning *repr(object)*.

If at least one of *encoding* or *errors* is given, *object* should be a *bytes-like object* (e.g. *bytes* or *bytearray*). In this case, if *object* is a *bytes* (or *bytearray*) object, then `str(bytes, encoding, errors)` is equivalent to *bytes.decode(encoding, errors)*. Otherwise, the bytes object underlying the buffer object is obtained before calling *bytes.decode()*. See *Binary Sequence Types — bytes, bytearray, memoryview* and bufferobjects for information on buffer objects.

Passing a *bytes* object to *str()* without the *encoding* or *errors* arguments falls under the first case of returning the informal string representation (see also the `-b` command-line option to Python). For example:

```
>>> str(b'Zoot!')
"b'Zoot!'"
```

For more information on the `str` class and its methods, see *Text Sequence Type — str* and the *String Methods* section below. To output formatted strings, see the f-strings and *Format String Syntax* sections. In addition, see the *Text Processing Services* section.

4.7.1 String Methods

Strings implement all of the *common* sequence operations, along with the additional methods described below.

Strings also support two styles of string formatting, one providing a large degree of flexibility and customization (see *str.format()*, *Format String Syntax* and *Custom String Formatting*) and the other based on C `printf` style formatting that handles a narrower range of types and is slightly harder to use correctly, but is often faster for the cases it can handle (*printf-style String Formatting*).

The *Text Processing Services* section of the standard library covers a number of other modules that provide various text related utilities (including regular expression support in the *re* module).

`str.capitalize()`
Return a copy of the string with its first character capitalized and the rest lowercased.

`str.casefold()`
Return a casefolded copy of the string. Casefolded strings may be used for caseless matching.

Casefolding is similar to lowercasing but more aggressive because it is intended to remove all case distinctions in a string. For example, the German lowercase letter `'ß'` is equivalent to `"ss"`. Since it is already lowercase, *lower()* would do nothing to `'ß'`; *casefold()* converts it to `"ss"`.

The casefolding algorithm is described in section 3.13 of the Unicode Standard.

New in version 3.3.

`str.center(`*width*[, *fillchar*]`)`
Return centered in a string of length *width*. Padding is done using the specified *fillchar* (default is an ASCII space). The original string is returned if *width* is less than or equal to `len(s)`.

`str.count(`*sub*[, *start*[, *end*]]`)`
Return the number of non-overlapping occurrences of substring *sub* in the range [*start*, *end*]. Optional arguments *start* and *end* are interpreted as in slice notation.

`str.encode(`*encoding="utf-8"*, *errors="strict"*`)`
Return an encoded version of the string as a bytes object. Default encoding is `'utf-8'`. *errors* may be given to set a different error handling scheme. The default for *errors* is `'strict'`, meaning that encoding errors raise a *UnicodeError*. Other possible values are `'ignore'`, `'replace'`, `'xmlcharrefreplace'`, `'backslashreplace'` and any other name registered via *codecs.register_error()*, see section *Error Handlers*. For a list of possible encodings, see section *Standard Encodings*.

Changed in version 3.1: Support for keyword arguments added.

`str.endswith(`*suffix*[, *start*[, *end*]]`)`
Return `True` if the string ends with the specified *suffix*, otherwise return `False`. *suffix* can also be a tuple of suffixes to look for. With optional *start*, test beginning at that position. With optional *end*, stop comparing at that position.

`str.expandtabs(`*tabsize=8*`)`
Return a copy of the string where all tab characters are replaced by one or more spaces, depending on the current column and the given tab size. Tab positions occur every *tabsize* characters (default is 8, giving tab positions at columns 0, 8, 16 and so on). To expand the string, the current column is set to zero and the string is examined character by character. If the character is a tab (`\t`), one or more space characters are inserted in the result until the current column is equal to the next tab

position. (The tab character itself is not copied.) If the character is a newline (\n) or return (\r), it is copied and the current column is reset to zero. Any other character is copied unchanged and the current column is incremented by one regardless of how the character is represented when printed.

```
>>> '01\t012\t0123\t01234'.expandtabs()
'01      012     0123    01234'
>>> '01\t012\t0123\t01234'.expandtabs(4)
'01  012 0123    01234'
```

str.find(*sub*[, *start*[, *end*]])

Return the lowest index in the string where substring *sub* is found within the slice `s[start:end]`. Optional arguments *start* and *end* are interpreted as in slice notation. Return `-1` if *sub* is not found.

Note: The *find()* method should be used only if you need to know the position of *sub*. To check if *sub* is a substring or not, use the `in` operator:

```
>>> 'Py' in 'Python'
True
```

---

str.format(**args*, ***kwargs*)

Perform a string formatting operation. The string on which this method is called can contain literal text or replacement fields delimited by braces `{}`. Each replacement field contains either the numeric index of a positional argument, or the name of a keyword argument. Returns a copy of the string where each replacement field is replaced with the string value of the corresponding argument.

```
>>> "The sum of 1 + 2 is {0}".format(1+2)
'The sum of 1 + 2 is 3'
```

See *Format String Syntax* for a description of the various formatting options that can be specified in format strings.

Note: When formatting a number (*int*, *float*, *float* and subclasses) with the `n` type (ex: `'{:n}'.format(1234)`), the function sets temporarily the `LC_CTYPE` locale to the `LC_NUMERIC` locale to decode `decimal_point` and `thousands_sep` fields of `localeconv()` if they are non-ASCII or longer than 1 byte, and the `LC_NUMERIC` locale is different than the `LC_CTYPE` locale. This temporary change affects other threads.

Changed in version 3.7: When formatting a number with the `n` type, the function sets temporarily the `LC_CTYPE` locale to the `LC_NUMERIC` locale in some cases.

str.format_map(*mapping*)

Similar to `str.format(**mapping)`, except that `mapping` is used directly and not copied to a *dict*. This is useful if for example `mapping` is a dict subclass:

```
>>> class Default(dict):
...     def __missing__(self, key):
...         return key
...
>>> '{name} was born in {country}'.format_map(Default(name='Guido'))
'Guido was born in country'
```

New in version 3.2.

str.index(*sub*[, *start*[, *end*]])

Like *find()*, but raise *ValueError* when the substring is not found.

`str.isalnum()`
Return true if all characters in the string are alphanumeric and there is at least one character, false otherwise. A character `c` is alphanumeric if one of the following returns `True`: `c.isalpha()`, `c.isdecimal()`, `c.isdigit()`, or `c.isnumeric()`.

`str.isalpha()`
Return true if all characters in the string are alphabetic and there is at least one character, false otherwise. Alphabetic characters are those characters defined in the Unicode character database as "Letter", i.e., those with general category property being one of "Lm", "Lt", "Lu", "Ll", or "Lo". Note that this is different from the "Alphabetic" property defined in the Unicode Standard.

`str.isascii()`
Return true if the string is empty or all characters in the string are ASCII, false otherwise. ASCII characters have code points in the range U+0000-U+007F.

New in version 3.7.

`str.isdecimal()`
Return true if all characters in the string are decimal characters and there is at least one character, false otherwise. Decimal characters are those that can be used to form numbers in base 10, e.g. U+0660, ARABIC-INDIC DIGIT ZERO. Formally a decimal character is a character in the Unicode General Category "Nd".

`str.isdigit()`
Return true if all characters in the string are digits and there is at least one character, false otherwise. Digits include decimal characters and digits that need special handling, such as the compatibility superscript digits. This covers digits which cannot be used to form numbers in base 10, like the Kharosthi numbers. Formally, a digit is a character that has the property value Numeric_Type=Digit or Numeric_Type=Decimal.

`str.isidentifier()`
Return true if the string is a valid identifier according to the language definition, section identifiers.

Use *`keyword.iskeyword()`* to test for reserved identifiers such as `def` and `class`.

`str.islower()`
Return true if all cased characters[4] in the string are lowercase and there is at least one cased character, false otherwise.

`str.isnumeric()`
Return true if all characters in the string are numeric characters, and there is at least one character, false otherwise. Numeric characters include digit characters, and all characters that have the Unicode numeric value property, e.g. U+2155, VULGAR FRACTION ONE FIFTH. Formally, numeric characters are those with the property value Numeric_Type=Digit, Numeric_Type=Decimal or Numeric_Type=Numeric.

`str.isprintable()`
Return true if all characters in the string are printable or the string is empty, false otherwise. Nonprintable characters are those characters defined in the Unicode character database as "Other" or "Separator", excepting the ASCII space (0x20) which is considered printable. (Note that printable characters in this context are those which should not be escaped when *`repr()`* is invoked on a string. It has no bearing on the handling of strings written to *`sys.stdout`* or *`sys.stderr`*.)

`str.isspace()`
Return true if there are only whitespace characters in the string and there is at least one character, false otherwise. Whitespace characters are those characters defined in the Unicode character database as "Other" or "Separator" and those with bidirectional property being one of "WS", "B", or "S".

[4] Cased characters are those with general category property being one of "Lu" (Letter, uppercase), "Ll" (Letter, lowercase), or "Lt" (Letter, titlecase).

str.istitle()
Return true if the string is a titlecased string and there is at least one character, for example uppercase characters may only follow uncased characters and lowercase characters only cased ones. Return false otherwise.

str.isupper()
Return true if all cased characters[4] in the string are uppercase and there is at least one cased character, false otherwise.

str.join(*iterable*)
Return a string which is the concatenation of the strings in *iterable*. A *TypeError* will be raised if there are any non-string values in *iterable*, including *bytes* objects. The separator between elements is the string providing this method.

str.ljust(*width*[, *fillchar*])
Return the string left justified in a string of length *width*. Padding is done using the specified *fillchar* (default is an ASCII space). The original string is returned if *width* is less than or equal to `len(s)`.

str.lower()
Return a copy of the string with all the cased characters[4] converted to lowercase.

The lowercasing algorithm used is described in section 3.13 of the Unicode Standard.

str.lstrip([*chars*])
Return a copy of the string with leading characters removed. The *chars* argument is a string specifying the set of characters to be removed. If omitted or `None`, the *chars* argument defaults to removing whitespace. The *chars* argument is not a prefix; rather, all combinations of its values are stripped:

```
>>> '   spacious   '.lstrip()
'spacious   '
>>> 'www.example.com'.lstrip('cmowz.')
'example.com'
```

static str.maketrans(*x*[, *y*[, *z*]])
This static method returns a translation table usable for *str.translate()*.

If there is only one argument, it must be a dictionary mapping Unicode ordinals (integers) or characters (strings of length 1) to Unicode ordinals, strings (of arbitrary lengths) or `None`. Character keys will then be converted to ordinals.

If there are two arguments, they must be strings of equal length, and in the resulting dictionary, each character in x will be mapped to the character at the same position in y. If there is a third argument, it must be a string, whose characters will be mapped to `None` in the result.

str.partition(*sep*)
Split the string at the first occurrence of *sep*, and return a 3-tuple containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, return a 3-tuple containing the string itself, followed by two empty strings.

str.replace(*old*, *new*[, *count*])
Return a copy of the string with all occurrences of substring *old* replaced by *new*. If the optional argument *count* is given, only the first *count* occurrences are replaced.

str.rfind(*sub*[, *start*[, *end*]])
Return the highest index in the string where substring *sub* is found, such that *sub* is contained within `s[start:end]`. Optional arguments *start* and *end* are interpreted as in slice notation. Return `-1` on failure.

str.rindex(*sub*[, *start*[, *end*]])
Like *rfind()* but raises *ValueError* when the substring *sub* is not found.

str.rjust(*width*[, *fillchar*])
Return the string right justified in a string of length *width*. Padding is done using the specified *fillchar* (default is an ASCII space). The original string is returned if *width* is less than or equal to `len(s)`.

str.rpartition(*sep*)
Split the string at the last occurrence of *sep*, and return a 3-tuple containing the part before the separator, the separator itself, and the part after the separator. If the separator is not found, return a 3-tuple containing two empty strings, followed by the string itself.

str.rsplit(*sep=None*, *maxsplit=-1*)
Return a list of the words in the string, using *sep* as the delimiter string. If *maxsplit* is given, at most *maxsplit* splits are done, the *rightmost* ones. If *sep* is not specified or `None`, any whitespace string is a separator. Except for splitting from the right, *rsplit()* behaves like *split()* which is described in detail below.

str.rstrip([*chars*])
Return a copy of the string with trailing characters removed. The *chars* argument is a string specifying the set of characters to be removed. If omitted or `None`, the *chars* argument defaults to removing whitespace. The *chars* argument is not a suffix; rather, all combinations of its values are stripped:

```
>>> '   spacious   '.rstrip()
'   spacious'
>>> 'mississippi'.rstrip('ipz')
'mississ'
```

str.split(*sep=None*, *maxsplit=-1*)
Return a list of the words in the string, using *sep* as the delimiter string. If *maxsplit* is given, at most *maxsplit* splits are done (thus, the list will have at most `maxsplit+1` elements). If *maxsplit* is not specified or `-1`, then there is no limit on the number of splits (all possible splits are made).

If *sep* is given, consecutive delimiters are not grouped together and are deemed to delimit empty strings (for example, `'1,,2'.split(',')` returns `['1', '', '2']`). The *sep* argument may consist of multiple characters (for example, `'1<>2<>3'.split('<>')` returns `['1', '2', '3']`). Splitting an empty string with a specified separator returns `['']`.

For example:

```
>>> '1,2,3'.split(',')
['1', '2', '3']
>>> '1,2,3'.split(',', maxsplit=1)
['1', '2,3']
>>> '1,2,,3,'.split(',')
['1', '2', '', '3', '']
```

If *sep* is not specified or is `None`, a different splitting algorithm is applied: runs of consecutive whitespace are regarded as a single separator, and the result will contain no empty strings at the start or end if the string has leading or trailing whitespace. Consequently, splitting an empty string or a string consisting of just whitespace with a `None` separator returns `[]`.

For example:

```
>>> '1 2 3'.split()
['1', '2', '3']
>>> '1 2 3'.split(maxsplit=1)
['1', '2 3']
>>> '   1   2   3   '.split()
['1', '2', '3']
```

str.splitlines([*keepends*])
Return a list of the lines in the string, breaking at line boundaries. Line breaks are not included in the

resulting list unless *keepends* is given and true.

This method splits on the following line boundaries. In particular, the boundaries are a superset of *universal newlines*.

Representation	Description
\n	Line Feed
\r	Carriage Return
\r\n	Carriage Return + Line Feed
\v or \x0b	Line Tabulation
\f or \x0c	Form Feed
\x1c	File Separator
\x1d	Group Separator
\x1e	Record Separator
\x85	Next Line (C1 Control Code)
\u2028	Line Separator
\u2029	Paragraph Separator

Changed in version 3.2: \v and \f added to list of line boundaries.

For example:

```
>>> 'ab c\n\nde fg\rkl\r\n'.splitlines()
['ab c', '', 'de fg', 'kl']
>>> 'ab c\n\nde fg\rkl\r\n'.splitlines(keepends=True)
['ab c\n', '\n', 'de fg\r', 'kl\r\n']
```

Unlike *split()* when a delimiter string *sep* is given, this method returns an empty list for the empty string, and a terminal line break does not result in an extra line:

```
>>> "".splitlines()
[]
>>> "One line\n".splitlines()
['One line']
```

For comparison, split('\n') gives:

```
>>> ''.split('\n')
['']
>>> 'Two lines\n'.split('\n')
['Two lines', '']
```

str.startswith(*prefix*[, *start*[, *end*]])

Return True if string starts with the *prefix*, otherwise return False. *prefix* can also be a tuple of prefixes to look for. With optional *start*, test string beginning at that position. With optional *end*, stop comparing string at that position.

str.strip([*chars*])

Return a copy of the string with the leading and trailing characters removed. The *chars* argument is a string specifying the set of characters to be removed. If omitted or None, the *chars* argument defaults to removing whitespace. The *chars* argument is not a prefix or suffix; rather, all combinations of its values are stripped:

```
>>> '   spacious   '.strip()
'spacious'
>>> 'www.example.com'.strip('cmowz.')
'example'
```

The outermost leading and trailing *chars* argument values are stripped from the string. Characters are removed from the leading end until reaching a string character that is not contained in the set of characters in *chars*. A similar action takes place on the trailing end. For example:

```
>>> comment_string = '#....... Section 3.2.1 Issue #32 .......'
>>> comment_string.strip('.#! ')
'Section 3.2.1 Issue #32'
```

`str.swapcase()`
Return a copy of the string with uppercase characters converted to lowercase and vice versa. Note that it is not necessarily true that `s.swapcase().swapcase() == s`.

`str.title()`
Return a titlecased version of the string where words start with an uppercase character and the remaining characters are lowercase.

For example:

```
>>> 'Hello world'.title()
'Hello World'
```

The algorithm uses a simple language-independent definition of a word as groups of consecutive letters. The definition works in many contexts but it means that apostrophes in contractions and possessives form word boundaries, which may not be the desired result:

```
>>> "they're bill's friends from the UK".title()
"They'Re Bill'S Friends From The Uk"
```

A workaround for apostrophes can be constructed using regular expressions:

```
>>> import re
>>> def titlecase(s):
...     return re.sub(r"[A-Za-z]+('[A-Za-z]+)?",
...                   lambda mo: mo.group(0)[0].upper() +
...                              mo.group(0)[1:].lower(),
...                   s)
...
>>> titlecase("they're bill's friends.")
"They're Bill's Friends."
```

`str.translate(`*table*`)`
Return a copy of the string in which each character has been mapped through the given translation table. The table must be an object that implements indexing via `__getitem__()`, typically a *mapping* or *sequence*. When indexed by a Unicode ordinal (an integer), the table object can do any of the following: return a Unicode ordinal or a string, to map the character to one or more other characters; return `None`, to delete the character from the return string; or raise a *LookupError* exception, to map the character to itself.

You can use *str.maketrans()* to create a translation map from character-to-character mappings in different formats.

See also the *codecs* module for a more flexible approach to custom character mappings.

`str.upper()`
Return a copy of the string with all the cased characters[4] converted to uppercase. Note that `s.upper().isupper()` might be `False` if `s` contains uncased characters or if the Unicode category of the resulting character(s) is not "Lu" (Letter, uppercase), but e.g. "Lt" (Letter, titlecase).

The uppercasing algorithm used is described in section 3.13 of the Unicode Standard.

`str.zfill(width)`

Return a copy of the string left filled with ASCII `'0'` digits to make a string of length *width*. A leading sign prefix (`'+'`/`'-'`) is handled by inserting the padding *after* the sign character rather than before. The original string is returned if *width* is less than or equal to `len(s)`.

For example:

```
>>> "42".zfill(5)
'00042'
>>> "-42".zfill(5)
'-0042'
```

4.7.2 `printf`-style String Formatting

Note: The formatting operations described here exhibit a variety of quirks that lead to a number of common errors (such as failing to display tuples and dictionaries correctly). Using the newer formatted string literals, the *`str.format()`* interface, or *template strings* may help avoid these errors. Each of these alternatives provides their own trade-offs and benefits of simplicity, flexibility, and/or extensibility.

String objects have one unique built-in operation: the `%` operator (modulo). This is also known as the string *formatting* or *interpolation* operator. Given `format % values` (where *format* is a string), `%` conversion specifications in *format* are replaced with zero or more elements of *values*. The effect is similar to using the `sprintf()` in the C language.

If *format* requires a single argument, *values* may be a single non-tuple object.[5] Otherwise, *values* must be a tuple with exactly the number of items specified by the format string, or a single mapping object (for example, a dictionary).

A conversion specifier contains two or more characters and has the following components, which must occur in this order:

1. The `'%'` character, which marks the start of the specifier.
2. Mapping key (optional), consisting of a parenthesised sequence of characters (for example, `(somename)`).
3. Conversion flags (optional), which affect the result of some conversion types.
4. Minimum field width (optional). If specified as an `'*'` (asterisk), the actual width is read from the next element of the tuple in *values*, and the object to convert comes after the minimum field width and optional precision.
5. Precision (optional), given as a `'.'` (dot) followed by the precision. If specified as `'*'` (an asterisk), the actual precision is read from the next element of the tuple in *values*, and the value to convert comes after the precision.
6. Length modifier (optional).
7. Conversion type.

When the right argument is a dictionary (or other mapping type), then the formats in the string *must* include a parenthesised mapping key into that dictionary inserted immediately after the `'%'` character. The mapping key selects the value to be formatted from the mapping. For example:

```
>>> print('%(language)s has %(number)03d quote types.' %
...       {'language': "Python", "number": 2})
Python has 002 quote types.
```

[5] To format only a tuple you should therefore provide a singleton tuple whose only element is the tuple to be formatted.

In this case no * specifiers may occur in a format (since they require a sequential parameter list).

The conversion flag characters are:

Flag	Meaning
'#'	The value conversion will use the "alternate form" (where defined below).
'0'	The conversion will be zero padded for numeric values.
'-'	The converted value is left adjusted (overrides the '0' conversion if both are given).
' '	(a space) A blank should be left before a positive number (or empty string) produced by a signed conversion.
'+'	A sign character ('+' or '-') will precede the conversion (overrides a "space" flag).

A length modifier (h, l, or L) may be present, but is ignored as it is not necessary for Python – so e.g. %ld is identical to %d.

The conversion types are:

Conversion	Meaning	Notes
'd'	Signed integer decimal.	
'i'	Signed integer decimal.	
'o'	Signed octal value.	(1)
'u'	Obsolete type – it is identical to 'd'.	(6)
'x'	Signed hexadecimal (lowercase).	(2)
'X'	Signed hexadecimal (uppercase).	(2)
'e'	Floating point exponential format (lowercase).	(3)
'E'	Floating point exponential format (uppercase).	(3)
'f'	Floating point decimal format.	(3)
'F'	Floating point decimal format.	(3)
'g'	Floating point format. Uses lowercase exponential format if exponent is less than -4 or not less than precision, decimal format otherwise.	(4)
'G'	Floating point format. Uses uppercase exponential format if exponent is less than -4 or not less than precision, decimal format otherwise.	(4)
'c'	Single character (accepts integer or single character string).	
'r'	String (converts any Python object using *repr()*).	(5)
's'	String (converts any Python object using *str()*).	(5)
'a'	String (converts any Python object using *ascii()*).	(5)
'%'	No argument is converted, results in a '%' character in the result.	

Notes:

1. The alternate form causes a leading octal specifier ('0o') to be inserted before the first digit.
2. The alternate form causes a leading '0x' or '0X' (depending on whether the 'x' or 'X' format was used) to be inserted before the first digit.
3. The alternate form causes the result to always contain a decimal point, even if no digits follow it.

   The precision determines the number of digits after the decimal point and defaults to 6.
4. The alternate form causes the result to always contain a decimal point, and trailing zeroes are not removed as they would otherwise be.

   The precision determines the number of significant digits before and after the decimal point and defaults to 6.
5. If precision is N, the output is truncated to N characters.

6. See **PEP 237**.

Since Python strings have an explicit length, `%s` conversions do not assume that `'\0'` is the end of the string.

Changed in version 3.1: `%f` conversions for numbers whose absolute value is over 1e50 are no longer replaced by `%g` conversions.

4.8 Binary Sequence Types — `bytes`, `bytearray`, `memoryview`

The core built-in types for manipulating binary data are *bytes* and *bytearray*. They are supported by *memoryview* which uses the buffer protocol to access the memory of other binary objects without needing to make a copy.

The *array* module supports efficient storage of basic data types like 32-bit integers and IEEE754 double-precision floating values.

4.8.1 Bytes Objects

Bytes objects are immutable sequences of single bytes. Since many major binary protocols are based on the ASCII text encoding, bytes objects offer several methods that are only valid when working with ASCII compatible data and are closely related to string objects in a variety of other ways.

class bytes([*source*[, *encoding*[, *errors*]]])

Firstly, the syntax for bytes literals is largely the same as that for string literals, except that a `b` prefix is added:

- Single quotes: `b'still allows embedded "double" quotes'`
- Double quotes: `b"still allows embedded 'single' quotes"`.
- Triple quoted: `b'''3 single quotes'''`, `b"""3 double quotes"""`

Only ASCII characters are permitted in bytes literals (regardless of the declared source code encoding). Any binary values over 127 must be entered into bytes literals using the appropriate escape sequence.

As with string literals, bytes literals may also use a `r` prefix to disable processing of escape sequences. See strings for more about the various forms of bytes literal, including supported escape sequences.

While bytes literals and representations are based on ASCII text, bytes objects actually behave like immutable sequences of integers, with each value in the sequence restricted such that `0 <= x < 256` (attempts to violate this restriction will trigger *ValueError*. This is done deliberately to emphasise that while many binary formats include ASCII based elements and can be usefully manipulated with some text-oriented algorithms, this is not generally the case for arbitrary binary data (blindly applying text processing algorithms to binary data formats that are not ASCII compatible will usually lead to data corruption).

In addition to the literal forms, bytes objects can be created in a number of other ways:

- A zero-filled bytes object of a specified length: `bytes(10)`
- From an iterable of integers: `bytes(range(20))`
- Copying existing binary data via the buffer protocol: `bytes(obj)`

Also see the *bytes* built-in.

Since 2 hexadecimal digits correspond precisely to a single byte, hexadecimal numbers are a commonly used format for describing binary data. Accordingly, the bytes type has an additional class method to read data in that format:

classmethod fromhex(*string*)

This *bytes* class method returns a bytes object, decoding the given string object. The string must contain two hexadecimal digits per byte, with ASCII whitespace being ignored.

```
>>> bytes.fromhex('2Ef0 F1f2  ')
b'.\xf0\xf1\xf2'
```

Changed in version 3.7: *bytes.fromhex()* now skips all ASCII whitespace in the string, not just spaces.

A reverse conversion function exists to transform a bytes object into its hexadecimal representation.

hex()

Return a string object containing two hexadecimal digits for each byte in the instance.

```
>>> b'\xf0\xf1\xf2'.hex()
'f0f1f2'
```

New in version 3.5.

Since bytes objects are sequences of integers (akin to a tuple), for a bytes object *b*, `b[0]` will be an integer, while `b[0:1]` will be a bytes object of length 1. (This contrasts with text strings, where both indexing and slicing will produce a string of length 1)

The representation of bytes objects uses the literal format (`b'...'`) since it is often more useful than e.g. `bytes([46, 46, 46])`. You can always convert a bytes object into a list of integers using `list(b)`.

Note: For Python 2.x users: In the Python 2.x series, a variety of implicit conversions between 8-bit strings (the closest thing 2.x offers to a built-in binary data type) and Unicode strings were permitted. This was a backwards compatibility workaround to account for the fact that Python originally only supported 8-bit text, and Unicode text was a later addition. In Python 3.x, those implicit conversions are gone - conversions between 8-bit binary data and Unicode text must be explicit, and bytes and string objects will always compare unequal.

4.8.2 Bytearray Objects

bytearray objects are a mutable counterpart to *bytes* objects.

class bytearray([*source*[, *encoding*[, *errors*]]])

There is no dedicated literal syntax for bytearray objects, instead they are always created by calling the constructor:

- Creating an empty instance: `bytearray()`
- Creating a zero-filled instance with a given length: `bytearray(10)`
- From an iterable of integers: `bytearray(range(20))`
- Copying existing binary data via the buffer protocol: `bytearray(b'Hi!')`

As bytearray objects are mutable, they support the *mutable* sequence operations in addition to the common bytes and bytearray operations described in *Bytes and Bytearray Operations*.

Also see the *bytearray* built-in.

Since 2 hexadecimal digits correspond precisely to a single byte, hexadecimal numbers are a commonly used format for describing binary data. Accordingly, the bytearray type has an additional class method to read data in that format:

classmethod fromhex(*string*)

This *bytearray* class method returns bytearray object, decoding the given string object. The string must contain two hexadecimal digits per byte, with ASCII whitespace being ignored.

```
>>> bytearray.fromhex('2Ef0 F1f2  ')
bytearray(b'.\xf0\xf1\xf2')
```

Changed in version 3.7: *bytearray.fromhex()* now skips all ASCII whitespace in the string, not just spaces.

A reverse conversion function exists to transform a bytearray object into its hexadecimal representation.

hex()

Return a string object containing two hexadecimal digits for each byte in the instance.

```
>>> bytearray(b'\xf0\xf1\xf2').hex()
'f0f1f2'
```

New in version 3.5.

Since bytearray objects are sequences of integers (akin to a list), for a bytearray object *b*, `b[0]` will be an integer, while `b[0:1]` will be a bytearray object of length 1. (This contrasts with text strings, where both indexing and slicing will produce a string of length 1)

The representation of bytearray objects uses the bytes literal format (`bytearray(b'...')`) since it is often more useful than e.g. `bytearray([46, 46, 46])`. You can always convert a bytearray object into a list of integers using `list(b)`.

4.8.3 Bytes and Bytearray Operations

Both bytes and bytearray objects support the *common* sequence operations. They interoperate not just with operands of the same type, but with any *bytes-like object*. Due to this flexibility, they can be freely mixed in operations without causing errors. However, the return type of the result may depend on the order of operands.

Note: The methods on bytes and bytearray objects don't accept strings as their arguments, just as the methods on strings don't accept bytes as their arguments. For example, you have to write:

```
a = "abc"
b = a.replace("a", "f")
```

and:

```
a = b"abc"
b = a.replace(b"a", b"f")
```

Some bytes and bytearray operations assume the use of ASCII compatible binary formats, and hence should be avoided when working with arbitrary binary data. These restrictions are covered below.

Note: Using these ASCII based operations to manipulate binary data that is not stored in an ASCII based format may lead to data corruption.

The following methods on bytes and bytearray objects can be used with arbitrary binary data.

bytes.count(*sub*[, *start*[, *end*]])

bytearray.count(*sub*[, *start*[, *end*]])
: Return the number of non-overlapping occurrences of subsequence *sub* in the range [*start*, *end*]. Optional arguments *start* and *end* are interpreted as in slice notation.

  The subsequence to search for may be any *bytes-like object* or an integer in the range 0 to 255.

  Changed in version 3.3: Also accept an integer in the range 0 to 255 as the subsequence.

bytes.decode(*encoding="utf-8"*, *errors="strict"*)
bytearray.decode(*encoding="utf-8"*, *errors="strict"*)
: Return a string decoded from the given bytes. Default encoding is `'utf-8'`. *errors* may be given to set a different error handling scheme. The default for *errors* is `'strict'`, meaning that encoding errors raise a *UnicodeError*. Other possible values are `'ignore'`, `'replace'` and any other name registered via *codecs.register_error()*, see section *Error Handlers*. For a list of possible encodings, see section *Standard Encodings*.

  Note: Passing the *encoding* argument to *str* allows decoding any *bytes-like object* directly, without needing to make a temporary bytes or bytearray object.

  Changed in version 3.1: Added support for keyword arguments.

bytes.endswith(*suffix*[, *start*[, *end*]])
bytearray.endswith(*suffix*[, *start*[, *end*]])
: Return `True` if the binary data ends with the specified *suffix*, otherwise return `False`. *suffix* can also be a tuple of suffixes to look for. With optional *start*, test beginning at that position. With optional *end*, stop comparing at that position.

  The suffix(es) to search for may be any *bytes-like object*.

bytes.find(*sub*[, *start*[, *end*]])
bytearray.find(*sub*[, *start*[, *end*]])
: Return the lowest index in the data where the subsequence *sub* is found, such that *sub* is contained in the slice `s[start:end]`. Optional arguments *start* and *end* are interpreted as in slice notation. Return `-1` if *sub* is not found.

  The subsequence to search for may be any *bytes-like object* or an integer in the range 0 to 255.

  Note: The *find()* method should be used only if you need to know the position of *sub*. To check if *sub* is a substring or not, use the `in` operator:

```
>>> b'Py' in b'Python'
True
```

  Changed in version 3.3: Also accept an integer in the range 0 to 255 as the subsequence.

bytes.index(*sub*[, *start*[, *end*]])
bytearray.index(*sub*[, *start*[, *end*]])
: Like *find()*, but raise *ValueError* when the subsequence is not found.

  The subsequence to search for may be any *bytes-like object* or an integer in the range 0 to 255.

  Changed in version 3.3: Also accept an integer in the range 0 to 255 as the subsequence.

bytes.join(*iterable*)
bytearray.join(*iterable*)
: Return a bytes or bytearray object which is the concatenation of the binary data sequences in *iterable*. A *TypeError* will be raised if there are any values in *iterable* that are not *bytes-like objects*, including

str objects. The separator between elements is the contents of the bytes or bytearray object providing this method.

static bytes.maketrans(*from*, *to*)
static bytearray.maketrans(*from*, *to*)
This static method returns a translation table usable for *bytes.translate()* that will map each character in *from* into the character at the same position in *to*; *from* and *to* must both be *bytes-like objects* and have the same length.

New in version 3.1.

bytes.partition(*sep*)
bytearray.partition(*sep*)
Split the sequence at the first occurrence of *sep*, and return a 3-tuple containing the part before the separator, the separator itself or its bytearray copy, and the part after the separator. If the separator is not found, return a 3-tuple containing a copy of the original sequence, followed by two empty bytes or bytearray objects.

The separator to search for may be any *bytes-like object*.

bytes.replace(*old*, *new*[, *count*])
bytearray.replace(*old*, *new*[, *count*])
Return a copy of the sequence with all occurrences of subsequence *old* replaced by *new*. If the optional argument *count* is given, only the first *count* occurrences are replaced.

The subsequence to search for and its replacement may be any *bytes-like object*.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

---

bytes.rfind(*sub*[, *start*[, *end*]])
bytearray.rfind(*sub*[, *start*[, *end*]])
Return the highest index in the sequence where the subsequence *sub* is found, such that *sub* is contained within `s[start:end]`. Optional arguments *start* and *end* are interpreted as in slice notation. Return `-1` on failure.

The subsequence to search for may be any *bytes-like object* or an integer in the range 0 to 255.

Changed in version 3.3: Also accept an integer in the range 0 to 255 as the subsequence.

bytes.rindex(*sub*[, *start*[, *end*]])
bytearray.rindex(*sub*[, *start*[, *end*]])
Like *rfind()* but raises *ValueError* when the subsequence *sub* is not found.

The subsequence to search for may be any *bytes-like object* or an integer in the range 0 to 255.

Changed in version 3.3: Also accept an integer in the range 0 to 255 as the subsequence.

bytes.rpartition(*sep*)
bytearray.rpartition(*sep*)
Split the sequence at the last occurrence of *sep*, and return a 3-tuple containing the part before the separator, the separator itself or its bytearray copy, and the part after the separator. If the separator is not found, return a 3-tuple containing a copy of the original sequence, followed by two empty bytes or bytearray objects.

The separator to search for may be any *bytes-like object*.

bytes.startswith(*prefix*[, *start*[, *end*]])
bytearray.startswith(*prefix*[, *start*[, *end*]])
Return `True` if the binary data starts with the specified *prefix*, otherwise return `False`. *prefix* can also

be a tuple of prefixes to look for. With optional *start*, test beginning at that position. With optional *end*, stop comparing at that position.

The prefix(es) to search for may be any *bytes-like object*.

`bytes.translate(`*table*, *delete=b''*`)`
`bytearray.translate(`*table*, *delete=b''*`)`

Return a copy of the bytes or bytearray object where all bytes occurring in the optional argument *delete* are removed, and the remaining bytes have been mapped through the given translation table, which must be a bytes object of length 256.

You can use the *bytes.maketrans()* method to create a translation table.

Set the *table* argument to `None` for translations that only delete characters:

```
>>> b'read this short text'.translate(None, b'aeiou')
b'rd ths shrt txt'
```

Changed in version 3.6: *delete* is now supported as a keyword argument.

The following methods on bytes and bytearray objects have default behaviours that assume the use of ASCII compatible binary formats, but can still be used with arbitrary binary data by passing appropriate arguments. Note that all of the bytearray methods in this section do *not* operate in place, and instead produce new objects.

`bytes.center(`*width*[, *fillbyte*]`)`
`bytearray.center(`*width*[, *fillbyte*]`)`

Return a copy of the object centered in a sequence of length *width*. Padding is done using the specified *fillbyte* (default is an ASCII space). For *bytes* objects, the original sequence is returned if *width* is less than or equal to `len(s)`.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

`bytes.ljust(`*width*[, *fillbyte*]`)`
`bytearray.ljust(`*width*[, *fillbyte*]`)`

Return a copy of the object left justified in a sequence of length *width*. Padding is done using the specified *fillbyte* (default is an ASCII space). For *bytes* objects, the original sequence is returned if *width* is less than or equal to `len(s)`.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

`bytes.lstrip(`[*chars*]`)`
`bytearray.lstrip(`[*chars*]`)`

Return a copy of the sequence with specified leading bytes removed. The *chars* argument is a binary sequence specifying the set of byte values to be removed - the name refers to the fact this method is usually used with ASCII characters. If omitted or `None`, the *chars* argument defaults to removing ASCII whitespace. The *chars* argument is not a prefix; rather, all combinations of its values are stripped:

```
>>> b'   spacious   '.lstrip()
b'spacious   '
>>> b'www.example.com'.lstrip(b'cmowz.')
b'example.com'
```

The binary sequence of byte values to remove may be any *bytes-like object*.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

`bytes.rjust(`*width*[, *fillbyte*]`)`
`bytearray.rjust(`*width*[, *fillbyte*]`)`

Return a copy of the object right justified in a sequence of length *width*. Padding is done using the specified *fillbyte* (default is an ASCII space). For `bytes` objects, the original sequence is returned if *width* is less than or equal to `len(s)`.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

`bytes.rsplit(`*sep=None*, *maxsplit=-1*`)`
`bytearray.rsplit(`*sep=None*, *maxsplit=-1*`)`

Split the binary sequence into subsequences of the same type, using *sep* as the delimiter string. If *maxsplit* is given, at most *maxsplit* splits are done, the *rightmost* ones. If *sep* is not specified or `None`, any subsequence consisting solely of ASCII whitespace is a separator. Except for splitting from the right, `rsplit()` behaves like `split()` which is described in detail below.

`bytes.rstrip(`[*chars*]`)`
`bytearray.rstrip(`[*chars*]`)`

Return a copy of the sequence with specified trailing bytes removed. The *chars* argument is a binary sequence specifying the set of byte values to be removed - the name refers to the fact this method is usually used with ASCII characters. If omitted or `None`, the *chars* argument defaults to removing ASCII whitespace. The *chars* argument is not a suffix; rather, all combinations of its values are stripped:

```
>>> b'   spacious   '.rstrip()
b'   spacious'
>>> b'mississippi'.rstrip(b'ipz')
b'mississ'
```

The binary sequence of byte values to remove may be any *bytes-like object*.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

`bytes.split(`*sep=None*, *maxsplit=-1*`)`
`bytearray.split(`*sep=None*, *maxsplit=-1*`)`

Split the binary sequence into subsequences of the same type, using *sep* as the delimiter string. If *maxsplit* is given and non-negative, at most *maxsplit* splits are done (thus, the list will have at most `maxsplit+1` elements). If *maxsplit* is not specified or is `-1`, then there is no limit on the number of splits (all possible splits are made).

If *sep* is given, consecutive delimiters are not grouped together and are deemed to delimit empty subsequences (for example, `b'1,,2'.split(b',')` returns `[b'1', b'', b'2']`). The *sep* argument may consist of a multibyte sequence (for example, `b'1<>2<>3'.split(b'<>')` returns `[b'1', b'2', b'3']`). Splitting an empty sequence with a specified separator returns `[b'']` or `[bytearray(b'')]` depending on the type of object being split. The *sep* argument may be any *bytes-like object*.

For example:

```
>>> b'1,2,3'.split(b',')
[b'1', b'2', b'3']
>>> b'1,2,3'.split(b',', maxsplit=1)
[b'1', b'2,3']
>>> b'1,2,,3,'.split(b',')
[b'1', b'2', b'', b'3', b'']
```

If *sep* is not specified or is `None`, a different splitting algorithm is applied: runs of consecutive ASCII whitespace are regarded as a single separator, and the result will contain no empty strings at the start or end if the sequence has leading or trailing whitespace. Consequently, splitting an empty sequence or a sequence consisting solely of ASCII whitespace without a specified separator returns `[]`.

For example:

```
>>> b'1 2 3'.split()
[b'1', b'2', b'3']
>>> b'1 2 3'.split(maxsplit=1)
[b'1', b'2 3']
>>> b'   1   2   3   '.split()
[b'1', b'2', b'3']
```

bytes.strip([*chars*])

bytearray.strip([*chars*])

Return a copy of the sequence with specified leading and trailing bytes removed. The *chars* argument is a binary sequence specifying the set of byte values to be removed - the name refers to the fact this method is usually used with ASCII characters. If omitted or `None`, the *chars* argument defaults to removing ASCII whitespace. The *chars* argument is not a prefix or suffix; rather, all combinations of its values are stripped:

```
>>> b'   spacious   '.strip()
b'spacious'
>>> b'www.example.com'.strip(b'cmowz.')
b'example'
```

The binary sequence of byte values to remove may be any *bytes-like object*.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

The following methods on bytes and bytearray objects assume the use of ASCII compatible binary formats and should not be applied to arbitrary binary data. Note that all of the bytearray methods in this section do *not* operate in place, and instead produce new objects.

bytes.capitalize()

bytearray.capitalize()

Return a copy of the sequence with each byte interpreted as an ASCII character, and the first byte capitalized and the rest lowercased. Non-ASCII byte values are passed through unchanged.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

bytes.expandtabs(*tabsize=8*)

bytearray.expandtabs(*tabsize=8*)

Return a copy of the sequence where all ASCII tab characters are replaced by one or more ASCII spaces, depending on the current column and the given tab size. Tab positions occur every *tabsize*

bytes (default is 8, giving tab positions at columns 0, 8, 16 and so on). To expand the sequence, the current column is set to zero and the sequence is examined byte by byte. If the byte is an ASCII tab character (`b'\t'`), one or more space characters are inserted in the result until the current column is equal to the next tab position. (The tab character itself is not copied.) If the current byte is an ASCII newline (`b'\n'`) or carriage return (`b'\r'`), it is copied and the current column is reset to zero. Any other byte value is copied unchanged and the current column is incremented by one regardless of how the byte value is represented when printed:

```
>>> b'01\t012\t0123\t01234'.expandtabs()
b'01      012     0123    01234'
>>> b'01\t012\t0123\t01234'.expandtabs(4)
b'01  012 0123    01234'
```

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

bytes.isalnum()
bytearray.isalnum()

Return true if all bytes in the sequence are alphabetical ASCII characters or ASCII decimal digits and the sequence is not empty, false otherwise. Alphabetic ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ'`. ASCII decimal digits are those byte values in the sequence `b'0123456789'`.

For example:

```
>>> b'ABCabc1'.isalnum()
True
>>> b'ABC abc1'.isalnum()
False
```

bytes.isalpha()
bytearray.isalpha()

Return true if all bytes in the sequence are alphabetic ASCII characters and the sequence is not empty, false otherwise. Alphabetic ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ'`.

For example:

```
>>> b'ABCabc'.isalpha()
True
>>> b'ABCabc1'.isalpha()
False
```

bytes.isascii()
bytearray.isascii()

Return true if the sequence is empty or all bytes in the sequence are ASCII, false otherwise. ASCII bytes are in the range 0-0x7F.

New in version 3.7.

bytes.isdigit()
bytearray.isdigit()

Return true if all bytes in the sequence are ASCII decimal digits and the sequence is not empty, false otherwise. ASCII decimal digits are those byte values in the sequence `b'0123456789'`.

For example:

```
>>> b'1234'.isdigit()
True
>>> b'1.23'.isdigit()
False
```

bytes.islower()
bytearray.islower()
Return true if there is at least one lowercase ASCII character in the sequence and no uppercase ASCII characters, false otherwise.

For example:

```
>>> b'hello world'.islower()
True
>>> b'Hello world'.islower()
False
```

Lowercase ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyz'`. Uppercase ASCII characters are those byte values in the sequence `b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`.

bytes.isspace()
bytearray.isspace()
Return true if all bytes in the sequence are ASCII whitespace and the sequence is not empty, false otherwise. ASCII whitespace characters are those byte values in the sequence `b' \t\n\r\x0b\f'` (space, tab, newline, carriage return, vertical tab, form feed).

bytes.istitle()
bytearray.istitle()
Return true if the sequence is ASCII titlecase and the sequence is not empty, false otherwise. See *bytes.title()* for more details on the definition of "titlecase".

For example:

```
>>> b'Hello World'.istitle()
True
>>> b'Hello world'.istitle()
False
```

bytes.isupper()
bytearray.isupper()
Return true if there is at least one uppercase alphabetic ASCII character in the sequence and no lowercase ASCII characters, false otherwise.

For example:

```
>>> b'HELLO WORLD'.isupper()
True
>>> b'Hello world'.isupper()
False
```

Lowercase ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyz'`. Uppercase ASCII characters are those byte values in the sequence `b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`.

bytes.lower()
bytearray.lower()
Return a copy of the sequence with all the uppercase ASCII characters converted to their corresponding lowercase counterpart.

For example:

```
>>> b'Hello World'.lower()
b'hello world'
```

Lowercase ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyz'`. Uppercase ASCII characters are those byte values in the sequence `b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

---

bytes.splitlines(*keepends=False*)
bytearray.splitlines(*keepends=False*)

Return a list of the lines in the binary sequence, breaking at ASCII line boundaries. This method uses the *universal newlines* approach to splitting lines. Line breaks are not included in the resulting list unless *keepends* is given and true.

For example:

```
>>> b'ab c\n\nde fg\rkl\r\n'.splitlines()
[b'ab c', b'', b'de fg', b'kl']
>>> b'ab c\n\nde fg\rkl\r\n'.splitlines(keepends=True)
[b'ab c\n', b'\n', b'de fg\r', b'kl\r\n']
```

Unlike *split()* when a delimiter string *sep* is given, this method returns an empty list for the empty string, and a terminal line break does not result in an extra line:

```
>>> b"".split(b'\n'), b"Two lines\n".split(b'\n')
([b''], [b'Two lines', b''])
>>> b"".splitlines(), b"One line\n".splitlines()
([], [b'One line'])
```

bytes.swapcase()
bytearray.swapcase()

Return a copy of the sequence with all the lowercase ASCII characters converted to their corresponding uppercase counterpart and vice-versa.

For example:

```
>>> b'Hello World'.swapcase()
b'hELLO wORLD'
```

Lowercase ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyz'`. Uppercase ASCII characters are those byte values in the sequence `b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`.

Unlike *str.swapcase()*, it is always the case that `bin.swapcase().swapcase() == bin` for the binary versions. Case conversions are symmetrical in ASCII, even though that is not generally true for arbitrary Unicode code points.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

---

bytes.title()
bytearray.title()

Return a titlecased version of the binary sequence where words start with an uppercase ASCII character and the remaining characters are lowercase. Uncased byte values are left unmodified.

For example:

```
>>> b'Hello world'.title()
b'Hello World'
```

Lowercase ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyz'`. Uppercase ASCII characters are those byte values in the sequence `b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`. All other byte values are uncased.

The algorithm uses a simple language-independent definition of a word as groups of consecutive letters. The definition works in many contexts but it means that apostrophes in contractions and possessives form word boundaries, which may not be the desired result:

```
>>> b"they're bill's friends from the UK".title()
b"They're Bill's Friends From The Uk"
```

A workaround for apostrophes can be constructed using regular expressions:

```
>>> import re
>>> def titlecase(s):
...     return re.sub(rb"[A-Za-z]+('[A-Za-z]+)?",
...                   lambda mo: mo.group(0)[0:1].upper() +
...                              mo.group(0)[1:].lower(),
...                   s)
...
>>> titlecase(b"they're bill's friends.")
b"They're Bill's Friends."
```

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

`bytes.upper()`
`bytearray.upper()`

Return a copy of the sequence with all the lowercase ASCII characters converted to their corresponding uppercase counterpart.

For example:

```
>>> b'Hello World'.upper()
b'HELLO WORLD'
```

Lowercase ASCII characters are those byte values in the sequence `b'abcdefghijklmnopqrstuvwxyz'`. Uppercase ASCII characters are those byte values in the sequence `b'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

`bytes.zfill(`*width*`)`
`bytearray.zfill(`*width*`)`

Return a copy of the sequence left filled with ASCII `b'0'` digits to make a sequence of length *width*. A leading sign prefix (`b'+'`/ `b'-'` is handled by inserting the padding *after* the sign character rather than before. For *bytes* objects, the original sequence is returned if *width* is less than or equal to `len(seq)`.

For example:

```
>>> b"42".zfill(5)
b'00042'
```

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```
>>> b"-42".zfill(5)
b'-0042'
```

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

4.8.4 `printf`-style Bytes Formatting

Note: The formatting operations described here exhibit a variety of quirks that lead to a number of common errors (such as failing to display tuples and dictionaries correctly). If the value being printed may be a tuple or dictionary, wrap it in a tuple.

Bytes objects (`bytes`/`bytearray`) have one unique built-in operation: the `%` operator (modulo). This is also known as the bytes *formatting* or *interpolation* operator. Given `format % values` (where *format* is a bytes object), `%` conversion specifications in *format* are replaced with zero or more elements of *values*. The effect is similar to using the `sprintf()` in the C language.

If *format* requires a single argument, *values* may be a single non-tuple object.[5] Otherwise, *values* must be a tuple with exactly the number of items specified by the format bytes object, or a single mapping object (for example, a dictionary).

A conversion specifier contains two or more characters and has the following components, which must occur in this order:

1. The `'%'` character, which marks the start of the specifier.
2. Mapping key (optional), consisting of a parenthesised sequence of characters (for example, `(somename)`).
3. Conversion flags (optional), which affect the result of some conversion types.
4. Minimum field width (optional). If specified as an `'*'` (asterisk), the actual width is read from the next element of the tuple in *values*, and the object to convert comes after the minimum field width and optional precision.
5. Precision (optional), given as a `'.'` (dot) followed by the precision. If specified as `'*'` (an asterisk), the actual precision is read from the next element of the tuple in *values*, and the value to convert comes after the precision.
6. Length modifier (optional).
7. Conversion type.

When the right argument is a dictionary (or other mapping type), then the formats in the bytes object *must* include a parenthesised mapping key into that dictionary inserted immediately after the `'%'` character. The mapping key selects the value to be formatted from the mapping. For example:

```
>>> print(b'%(language)s has %(number)03d quote types.' %
...       {b'language': b"Python", b"number": 2})
b'Python has 002 quote types.'
```

In this case no `*` specifiers may occur in a format (since they require a sequential parameter list).

The conversion flag characters are:

Flag	Meaning
'#'	The value conversion will use the "alternate form" (where defined below).
'0'	The conversion will be zero padded for numeric values.
'-'	The converted value is left adjusted (overrides the '0' conversion if both are given).
' '	(a space) A blank should be left before a positive number (or empty string) produced by a signed conversion.
'+'	A sign character ('+' or '-') will precede the conversion (overrides a "space" flag).

A length modifier (h, l, or L) may be present, but is ignored as it is not necessary for Python – so e.g. %ld is identical to %d.

The conversion types are:

Conversion	Meaning	Notes
'd'	Signed integer decimal.	
'i'	Signed integer decimal.	
'o'	Signed octal value.	(1)
'u'	Obsolete type – it is identical to 'd'.	(8)
'x'	Signed hexadecimal (lowercase).	(2)
'X'	Signed hexadecimal (uppercase).	(2)
'e'	Floating point exponential format (lowercase).	(3)
'E'	Floating point exponential format (uppercase).	(3)
'f'	Floating point decimal format.	(3)
'F'	Floating point decimal format.	(3)
'g'	Floating point format. Uses lowercase exponential format if exponent is less than -4 or not less than precision, decimal format otherwise.	(4)
'G'	Floating point format. Uses uppercase exponential format if exponent is less than -4 or not less than precision, decimal format otherwise.	(4)
'c'	Single byte (accepts integer or single byte objects).	
'b'	Bytes (any object that follows the buffer protocol or has __bytes__()).	(5)
's'	's' is an alias for 'b' and should only be used for Python2/3 code bases.	(6)
'a'	Bytes (converts any Python object using repr(obj).encode('ascii', 'backslashreplace)).	(5)
'r'	'r' is an alias for 'a' and should only be used for Python2/3 code bases.	(7)
'%'	No argument is converted, results in a '%' character in the result.	

Notes:

1. The alternate form causes a leading octal specifier ('0o') to be inserted before the first digit.
2. The alternate form causes a leading '0x' or '0X' (depending on whether the 'x' or 'X' format was used) to be inserted before the first digit.
3. The alternate form causes the result to always contain a decimal point, even if no digits follow it.

   The precision determines the number of digits after the decimal point and defaults to 6.
4. The alternate form causes the result to always contain a decimal point, and trailing zeroes are not removed as they would otherwise be.

   The precision determines the number of significant digits before and after the decimal point and defaults to 6.
5. If precision is N, the output is truncated to N characters.
6. b'%s' is deprecated, but will not be removed during the 3.x series.

7. `b'%r'` is deprecated, but will not be removed during the 3.x series.
8. See **PEP 237**.

Note: The bytearray version of this method does *not* operate in place - it always produces a new object, even if no changes were made.

See also:

PEP 461 - Adding % formatting to bytes and bytearray

New in version 3.5.

4.8.5 Memory Views

memoryview objects allow Python code to access the internal data of an object that supports the buffer protocol without copying.

class memoryview(*obj*)

Create a *memoryview* that references *obj*. *obj* must support the buffer protocol. Built-in objects that support the buffer protocol include *bytes* and *bytearray*.

A *memoryview* has the notion of an *element*, which is the atomic memory unit handled by the originating object *obj*. For many simple types such as *bytes* and *bytearray*, an element is a single byte, but other types such as *array.array* may have bigger elements.

`len(view)` is equal to the length of *tolist*. If `view.ndim = 0`, the length is 1. If `view.ndim = 1`, the length is equal to the number of elements in the view. For higher dimensions, the length is equal to the length of the nested list representation of the view. The *itemsize* attribute will give you the number of bytes in a single element.

A *memoryview* supports slicing and indexing to expose its data. One-dimensional slicing will result in a subview:

```
>>> v = memoryview(b'abcefg')
>>> v[1]
98
>>> v[-1]
103
>>> v[1:4]
<memory at 0x7f3ddc9f4350>
>>> bytes(v[1:4])
b'bce'
```

If *format* is one of the native format specifiers from the *struct* module, indexing with an integer or a tuple of integers is also supported and returns a single *element* with the correct type. One-dimensional memoryviews can be indexed with an integer or a one-integer tuple. Multi-dimensional memoryviews can be indexed with tuples of exactly *ndim* integers where *ndim* is the number of dimensions. Zero-dimensional memoryviews can be indexed with the empty tuple.

Here is an example with a non-byte format:

```
>>> import array
>>> a = array.array('l', [-11111111, 22222222, -33333333, 44444444])
>>> m = memoryview(a)
>>> m[0]
-11111111
>>> m[-1]
```

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```
44444444
>>> m[::2].tolist()
[-11111111, -33333333]
```

If the underlying object is writable, the memoryview supports one-dimensional slice assignment. Resizing is not allowed:

```
>>> data = bytearray(b'abcefg')
>>> v = memoryview(data)
>>> v.readonly
False
>>> v[0] = ord(b'z')
>>> data
bytearray(b'zbcefg')
>>> v[1:4] = b'123'
>>> data
bytearray(b'z123fg')
>>> v[2:3] = b'spam'
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: memoryview assignment: lvalue and rvalue have different structures
>>> v[2:6] = b'spam'
>>> data
bytearray(b'z1spam')
```

One-dimensional memoryviews of hashable (read-only) types with formats 'B', 'b' or 'c' are also hashable. The hash is defined as `hash(m) == hash(m.tobytes())`:

```
>>> v = memoryview(b'abcefg')
>>> hash(v) == hash(b'abcefg')
True
>>> hash(v[2:4]) == hash(b'ce')
True
>>> hash(v[::-2]) == hash(b'abcefg'[::-2])
True
```

Changed in version 3.3: One-dimensional memoryviews can now be sliced. One-dimensional memoryviews with formats 'B', 'b' or 'c' are now hashable.

Changed in version 3.4: memoryview is now registered automatically with *collections.abc.Sequence*

Changed in version 3.5: memoryviews can now be indexed with tuple of integers.

memoryview has several methods:

`__eq__`(*exporter*)
: A memoryview and a **PEP 3118** exporter are equal if their shapes are equivalent and if all corresponding values are equal when the operands' respective format codes are interpreted using *struct* syntax.

  For the subset of *struct* format strings currently supported by *tolist()*, `v` and `w` are equal if `v.tolist() == w.tolist()`:

  ```
  >>> import array
  >>> a = array.array('I', [1, 2, 3, 4, 5])
  >>> b = array.array('d', [1.0, 2.0, 3.0, 4.0, 5.0])
  >>> c = array.array('b', [5, 3, 1])
  >>> x = memoryview(a)
  ```

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```
>>> y = memoryview(b)
>>> x == a == y == b
True
>>> x.tolist() == a.tolist() == y.tolist() == b.tolist()
True
>>> z = y[::-2]
>>> z == c
True
>>> z.tolist() == c.tolist()
True
```

If either format string is not supported by the *struct* module, then the objects will always compare as unequal (even if the format strings and buffer contents are identical):

```
>>> from ctypes import BigEndianStructure, c_long
>>> class BEPoint(BigEndianStructure):
...     _fields_ = [("x", c_long), ("y", c_long)]
...
>>> point = BEPoint(100, 200)
>>> a = memoryview(point)
>>> b = memoryview(point)
>>> a == point
False
>>> a == b
False
```

Note that, as with floating point numbers, `v is w` does *not* imply `v == w` for memoryview objects.

Changed in version 3.3: Previous versions compared the raw memory disregarding the item format and the logical array structure.

tobytes()

Return the data in the buffer as a bytestring. This is equivalent to calling the *bytes* constructor on the memoryview.

```
>>> m = memoryview(b"abc")
>>> m.tobytes()
b'abc'
>>> bytes(m)
b'abc'
```

For non-contiguous arrays the result is equal to the flattened list representation with all elements converted to bytes. *tobytes()* supports all format strings, including those that are not in *struct* module syntax.

hex()

Return a string object containing two hexadecimal digits for each byte in the buffer.

```
>>> m = memoryview(b"abc")
>>> m.hex()
'616263'
```

New in version 3.5.

tolist()

Return the data in the buffer as a list of elements.

```
>>> memoryview(b'abc').tolist()
[97, 98, 99]
>>> import array
>>> a = array.array('d', [1.1, 2.2, 3.3])
>>> m = memoryview(a)
>>> m.tolist()
[1.1, 2.2, 3.3]
```

Changed in version 3.3: *tolist()* now supports all single character native formats in *struct* module syntax as well as multi-dimensional representations.

release()

Release the underlying buffer exposed by the memoryview object. Many objects take special actions when a view is held on them (for example, a *bytearray* would temporarily forbid resizing); therefore, calling release() is handy to remove these restrictions (and free any dangling resources) as soon as possible.

After this method has been called, any further operation on the view raises a *ValueError* (except *release()* itself which can be called multiple times):

```
>>> m = memoryview(b'abc')
>>> m.release()
>>> m[0]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operation forbidden on released memoryview object
```

The context management protocol can be used for a similar effect, using the `with` statement:

```
>>> with memoryview(b'abc') as m:
...     m[0]
...
97
>>> m[0]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operation forbidden on released memoryview object
```

New in version 3.2.

cast(*format*[, *shape*])

Cast a memoryview to a new format or shape. *shape* defaults to `[byte_length//new_itemsize]`, which means that the result view will be one-dimensional. The return value is a new memoryview, but the buffer itself is not copied. Supported casts are 1D -> C-*contiguous* and C-contiguous -> 1D.

The destination format is restricted to a single element native format in *struct* syntax. One of the formats must be a byte format ('B', 'b' or 'c'). The byte length of the result must be the same as the original length.

Cast 1D/long to 1D/unsigned bytes:

```
>>> import array
>>> a = array.array('l', [1,2,3])
>>> x = memoryview(a)
>>> x.format
'l'
>>> x.itemsize
8
```

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```
>>> len(x)
3
>>> x.nbytes
24
>>> y = x.cast('B')
>>> y.format
'B'
>>> y.itemsize
1
>>> len(y)
24
>>> y.nbytes
24
```

Cast 1D/unsigned bytes to 1D/char:

```
>>> b = bytearray(b'zyz')
>>> x = memoryview(b)
>>> x[0] = b'a'
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: memoryview: invalid value for format "B"
>>> y = x.cast('c')
>>> y[0] = b'a'
>>> b
bytearray(b'ayz')
```

Cast 1D/bytes to 3D/ints to 1D/signed char:

```
>>> import struct
>>> buf = struct.pack("i"*12, *list(range(12)))
>>> x = memoryview(buf)
>>> y = x.cast('i', shape=[2,2,3])
>>> y.tolist()
[[[0, 1, 2], [3, 4, 5]], [[6, 7, 8], [9, 10, 11]]]
>>> y.format
'i'
>>> y.itemsize
4
>>> len(y)
2
>>> y.nbytes
48
>>> z = y.cast('b')
>>> z.format
'b'
>>> z.itemsize
1
>>> len(z)
48
>>> z.nbytes
48
```

Cast 1D/unsigned char to 2D/unsigned long:

```
>>> buf = struct.pack("L"*6, *list(range(6)))
>>> x = memoryview(buf)
```

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```
>>> y = x.cast('L', shape=[2,3])
>>> len(y)
2
>>> y.nbytes
48
>>> y.tolist()
[[0, 1, 2], [3, 4, 5]]
```

New in version 3.3.

Changed in version 3.5: The source format is no longer restricted when casting to a byte view.

There are also several readonly attributes available:

obj

The underlying object of the memoryview:

```
>>> b  = bytearray(b'xyz')
>>> m = memoryview(b)
>>> m.obj is b
True
```

New in version 3.3.

nbytes

`nbytes == product(shape) * itemsize == len(m.tobytes())`. This is the amount of space in bytes that the array would use in a contiguous representation. It is not necessarily equal to len(m):

```
>>> import array
>>> a = array.array('i', [1,2,3,4,5])
>>> m = memoryview(a)
>>> len(m)
5
>>> m.nbytes
20
>>> y = m[::2]
>>> len(y)
3
>>> y.nbytes
12
>>> len(y.tobytes())
12
```

Multi-dimensional arrays:

```
>>> import struct
>>> buf = struct.pack("d"*12, *[1.5*x for x in range(12)])
>>> x = memoryview(buf)
>>> y = x.cast('d', shape=[3,4])
>>> y.tolist()
[[0.0, 1.5, 3.0, 4.5], [6.0, 7.5, 9.0, 10.5], [12.0, 13.5, 15.0, 16.5]]
>>> len(y)
3
>>> y.nbytes
96
```

New in version 3.3.

readonly
A bool indicating whether the memory is read only.

format
A string containing the format (in *struct* module style) for each element in the view. A memoryview can be created from exporters with arbitrary format strings, but some methods (e.g. *tolist()*) are restricted to native single element formats.

Changed in version 3.3: format `'B'` is now handled according to the struct module syntax. This means that `memoryview(b'abc')[0] == b'abc'[0] == 97`.

itemsize
The size in bytes of each element of the memoryview:

```
>>> import array, struct
>>> m = memoryview(array.array('H', [32000, 32001, 32002]))
>>> m.itemsize
2
>>> m[0]
32000
>>> struct.calcsize('H') == m.itemsize
True
```

ndim
An integer indicating how many dimensions of a multi-dimensional array the memory represents.

shape
A tuple of integers the length of *ndim* giving the shape of the memory as an N-dimensional array.

Changed in version 3.3: An empty tuple instead of `None` when ndim = 0.

strides
A tuple of integers the length of *ndim* giving the size in bytes to access each element for each dimension of the array.

Changed in version 3.3: An empty tuple instead of `None` when ndim = 0.

suboffsets
Used internally for PIL-style arrays. The value is informational only.

c_contiguous
A bool indicating whether the memory is C-*contiguous*.

New in version 3.3.

f_contiguous
A bool indicating whether the memory is Fortran *contiguous*.

New in version 3.3.

contiguous
A bool indicating whether the memory is *contiguous*.

New in version 3.3.

4.9 Set Types — `set`, `frozenset`

A *set* object is an unordered collection of distinct *hashable* objects. Common uses include membership testing, removing duplicates from a sequence, and computing mathematical operations such as intersection, union, difference, and symmetric difference. (For other containers see the built-in *dict*, *list*, and *tuple* classes, and the *collections* module.)

Like other collections, sets support `x in set`, `len(set)`, and `for x in set`. Being an unordered collection, sets do not record element position or order of insertion. Accordingly, sets do not support indexing, slicing, or other sequence-like behavior.

There are currently two built-in set types, *set* and *frozenset*. The *set* type is mutable — the contents can be changed using methods like `add()` and `remove()`. Since it is mutable, it has no hash value and cannot be used as either a dictionary key or as an element of another set. The *frozenset* type is immutable and *hashable* — its contents cannot be altered after it is created; it can therefore be used as a dictionary key or as an element of another set.

Non-empty sets (not frozensets) can be created by placing a comma-separated list of elements within braces, for example: `{'jack', 'sjoerd'}`, in addition to the *set* constructor.

The constructors for both classes work the same:

class set([*iterable*])

class frozenset([*iterable*])

Return a new set or frozenset object whose elements are taken from *iterable*. The elements of a set must be *hashable*. To represent sets of sets, the inner sets must be *frozenset* objects. If *iterable* is not specified, a new empty set is returned.

Instances of *set* and *frozenset* provide the following operations:

len(s)
Return the number of elements in set *s* (cardinality of *s*).

x in s
Test *x* for membership in *s*.

x not in s
Test *x* for non-membership in *s*.

isdisjoint(*other*)
Return `True` if the set has no elements in common with *other*. Sets are disjoint if and only if their intersection is the empty set.

issubset(*other*)
set <= other
Test whether every element in the set is in *other*.

set < other
Test whether the set is a proper subset of *other*, that is, `set <= other and set != other`.

issuperset(*other*)
set >= other
Test whether every element in *other* is in the set.

set > other
Test whether the set is a proper superset of *other*, that is, `set >= other and set != other`.

union(**others*)
set | other | ...
Return a new set with elements from the set and all others.

intersection(**others*)
set & other & ...
Return a new set with elements common to the set and all others.

difference(**others*)
set - other - ...
Return a new set with elements in the set that are not in the others.

symmetric_difference(*other*)

set ^ other
Return a new set with elements in either the set or *other* but not both.

copy()
Return a new set with a shallow copy of *s*.

Note, the non-operator versions of *union()*, *intersection()*, *difference()*, and *symmetric_difference()*, *issubset()*, and *issuperset()* methods will accept any iterable as an argument. In contrast, their operator based counterparts require their arguments to be sets. This precludes error-prone constructions like `set('abc') & 'cbs'` in favor of the more readable `set('abc').intersection('cbs')`.

Both *set* and *frozenset* support set to set comparisons. Two sets are equal if and only if every element of each set is contained in the other (each is a subset of the other). A set is less than another set if and only if the first set is a proper subset of the second set (is a subset, but is not equal). A set is greater than another set if and only if the first set is a proper superset of the second set (is a superset, but is not equal).

Instances of *set* are compared to instances of *frozenset* based on their members. For example, `set('abc') == frozenset('abc')` returns `True` and so does `set('abc') in set([frozenset('abc')])`.

The subset and equality comparisons do not generalize to a total ordering function. For example, any two nonempty disjoint sets are not equal and are not subsets of each other, so *all* of the following return `False`: `a<b`, `a==b`, or `a>b`.

Since sets only define partial ordering (subset relationships), the output of the *list.sort()* method is undefined for lists of sets.

Set elements, like dictionary keys, must be *hashable*.

Binary operations that mix *set* instances with *frozenset* return the type of the first operand. For example: `frozenset('ab') | set('bc')` returns an instance of *frozenset*.

The following table lists operations available for *set* that do not apply to immutable instances of *frozenset*:

update(*others***)**
set |= other | ...
Update the set, adding elements from all others.

intersection_update(*others***)**
set &= other & ...
Update the set, keeping only elements found in it and all others.

difference_update(*others***)**
set -= other | ...
Update the set, removing elements found in others.

symmetric_difference_update(*other***)**
set ^= other
Update the set, keeping only elements found in either set, but not in both.

add(*elem***)**
Add element *elem* to the set.

remove(*elem***)**
Remove element *elem* from the set. Raises *KeyError* if *elem* is not contained in the set.

discard(*elem***)**
Remove element *elem* from the set if it is present.

pop()
Remove and return an arbitrary element from the set. Raises *KeyError* if the set is empty.

clear()
Remove all elements from the set.

Note, the non-operator versions of the *update()*, *intersection_update()*, *difference_update()*, and *symmetric_difference_update()* methods will accept any iterable as an argument.

Note, the *elem* argument to the **__contains__()**, *remove()*, and *discard()* methods may be a set. To support searching for an equivalent frozenset, a temporary one is created from *elem*.

4.10 Mapping Types — dict

A *mapping* object maps *hashable* values to arbitrary objects. Mappings are mutable objects. There is currently only one standard mapping type, the *dictionary*. (For other containers see the built-in *list*, *set*, and *tuple* classes, and the *collections* module.)

A dictionary's keys are *almost* arbitrary values. Values that are not *hashable*, that is, values containing lists, dictionaries or other mutable types (that are compared by value rather than by object identity) may not be used as keys. Numeric types used for keys obey the normal rules for numeric comparison: if two numbers compare equal (such as `1` and `1.0`) then they can be used interchangeably to index the same dictionary entry. (Note however, that since computers store floating-point numbers as approximations it is usually unwise to use them as dictionary keys.)

Dictionaries can be created by placing a comma-separated list of `key: value` pairs within braces, for example: `{'jack': 4098, 'sjoerd': 4127}` or `{4098: 'jack', 4127: 'sjoerd'}`, or by the *dict* constructor.

class dict(***kwarg***)**
class dict(*mapping***, ***kwarg***)**
class dict(*iterable***, ***kwarg***)**
Return a new dictionary initialized from an optional positional argument and a possibly empty set of keyword arguments.

If no positional argument is given, an empty dictionary is created. If a positional argument is given and it is a mapping object, a dictionary is created with the same key-value pairs as the mapping object. Otherwise, the positional argument must be an *iterable* object. Each item in the iterable must itself be an iterable with exactly two objects. The first object of each item becomes a key in the new dictionary, and the second object the corresponding value. If a key occurs more than once, the last value for that key becomes the corresponding value in the new dictionary.

If keyword arguments are given, the keyword arguments and their values are added to the dictionary created from the positional argument. If a key being added is already present, the value from the keyword argument replaces the value from the positional argument.

To illustrate, the following examples all return a dictionary equal to `{"one": 1, "two": 2, "three": 3}`:

```
>>> a = dict(one=1, two=2, three=3)
>>> b = {'one': 1, 'two': 2, 'three': 3}
>>> c = dict(zip(['one', 'two', 'three'], [1, 2, 3]))
>>> d = dict([('two', 2), ('one', 1), ('three', 3)])
>>> e = dict({'three': 3, 'one': 1, 'two': 2})
>>> a == b == c == d == e
True
```

Providing keyword arguments as in the first example only works for keys that are valid Python identifiers. Otherwise, any valid keys can be used.

These are the operations that dictionaries support (and therefore, custom mapping types should support too):

len(d)
Return the number of items in the dictionary *d*.

d[key]
Return the item of *d* with key *key*. Raises a *KeyError* if *key* is not in the map.

If a subclass of dict defines a method `__missing__()` and *key* is not present, the `d[key]` operation calls that method with the key *key* as argument. The `d[key]` operation then returns or raises whatever is returned or raised by the `__missing__(key)` call. No other operations or methods invoke `__missing__()`. If `__missing__()` is not defined, *KeyError* is raised. `__missing__()` must be a method; it cannot be an instance variable:

```
>>> class Counter(dict):
...     def __missing__(self, key):
...         return 0
>>> c = Counter()
>>> c['red']
0
>>> c['red'] += 1
>>> c['red']
1
```

The example above shows part of the implementation of *collections.Counter*. A different `__missing__` method is used by *collections.defaultdict*.

d[key] = value
Set `d[key]` to *value*.

del d[key]
Remove `d[key]` from *d*. Raises a *KeyError* if *key* is not in the map.

key in d
Return `True` if *d* has a key *key*, else `False`.

key not in d
Equivalent to `not key in d`.

iter(d)
Return an iterator over the keys of the dictionary. This is a shortcut for `iter(d.keys())`.

clear()
Remove all items from the dictionary.

copy()
Return a shallow copy of the dictionary.

classmethod fromkeys(*seq*[, *value*]**)**
Create a new dictionary with keys from *seq* and values set to *value*.

fromkeys() is a class method that returns a new dictionary. *value* defaults to `None`.

get(*key*[, *default*]**)**
Return the value for *key* if *key* is in the dictionary, else *default*. If *default* is not given, it defaults to `None`, so that this method never raises a *KeyError*.

items()
Return a new view of the dictionary's items (`(key, value)` pairs). See the *documentation of view objects*.

keys()
Return a new view of the dictionary's keys. See the *documentation of view objects*.

`pop`(*key*[, *default*])
: If *key* is in the dictionary, remove it and return its value, else return *default*. If *default* is not given and *key* is not in the dictionary, a *KeyError* is raised.

`popitem`()
: Remove and return an arbitrary `(key, value)` pair from the dictionary.

  popitem() is useful to destructively iterate over a dictionary, as often used in set algorithms. If the dictionary is empty, calling *popitem()* raises a *KeyError*.

`setdefault`(*key*[, *default*])
: If *key* is in the dictionary, return its value. If not, insert *key* with a value of *default* and return *default*. *default* defaults to `None`.

`update`([*other*])
: Update the dictionary with the key/value pairs from *other*, overwriting existing keys. Return `None`.

  update() accepts either another dictionary object or an iterable of key/value pairs (as tuples or other iterables of length two). If keyword arguments are specified, the dictionary is then updated with those key/value pairs: `d.update(red=1, blue=2)`.

`values`()
: Return a new view of the dictionary's values. See the *documentation of view objects*.

Dictionaries compare equal if and only if they have the same `(key, value)` pairs. Order comparisons ('<', '<=', '>=', '>') raise *TypeError*.

Dictionaries preserve insertion order. Note that updating a key does not affect the order. Keys added after deletion are inserted at the end.

```
>>> d = {"one": 1, "two": 2, "three": 3, "four": 4}
>>> d
{'one': 1, 'two': 2, 'three': 3, 'four': 4}
>>> list(d)
['one', 'two', 'three', 'four']
>>> list(d.values())
[1, 2, 3, 4]
>>> d["one"] = 42
>>> d
{'one': 42, 'two': 2, 'three': 3, 'four': 4}
>>> del d["two"]
>>> d["two"] = None
>>> d
{'one': 42, 'three': 3, 'four': 4, 'two': None}
```

Changed in version 3.7: Dictionary order is guaranteed to be insertion order. This behavior was implementation detail of CPython from 3.6.

See also:

types.MappingProxyType can be used to create a read-only view of a *dict*.

4.10.1 Dictionary view objects

The objects returned by *dict.keys()*, *dict.values()* and *dict.items()* are *view objects*. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes.

Dictionary views can be iterated over to yield their respective data, and support membership tests:

`len(dictview)`
: Return the number of entries in the dictionary.

`iter(dictview)`
: Return an iterator over the keys, values or items (represented as tuples of `(key, value)`) in the dictionary.

  Keys and values are iterated over in insertion order. This allows the creation of `(value, key)` pairs using *zip()*: `pairs = zip(d.values(), d.keys())`. Another way to create the same list is `pairs = [(v, k) for (k, v) in d.items()]`.

  Iterating views while adding or deleting entries in the dictionary may raise a *RuntimeError* or fail to iterate over all entries.

  Changed in version 3.7: Dictionary order is guaranteed to be insertion order.

`x in dictview`
: Return `True` if *x* is in the underlying dictionary's keys, values or items (in the latter case, *x* should be a `(key, value)` tuple).

Keys views are set-like since their entries are unique and hashable. If all values are hashable, so that `(key, value)` pairs are unique and hashable, then the items view is also set-like. (Values views are not treated as set-like since the entries are generally not unique.) For set-like views, all of the operations defined for the abstract base class *collections.abc.Set* are available (for example, `==`, `<`, or `^`).

An example of dictionary view usage:

```
>>> dishes = {'eggs': 2, 'sausage': 1, 'bacon': 1, 'spam': 500}
>>> keys = dishes.keys()
>>> values = dishes.values()

>>> # iteration
>>> n = 0
>>> for val in values:
...     n += val
>>> print(n)
504

>>> # keys and values are iterated over in the same order (insertion order)
>>> list(keys)
['eggs', 'sausage', 'bacon', 'spam']
>>> list(values)
[2, 1, 1, 500]

>>> # view objects are dynamic and reflect dict changes
>>> del dishes['eggs']
>>> del dishes['sausage']
>>> list(keys)
['bacon', 'spam']

>>> # set operations
>>> keys & {'eggs', 'bacon', 'salad'}
{'bacon'}
>>> keys ^ {'sausage', 'juice'}
{'juice', 'sausage', 'bacon', 'spam'}
```

4.11 Context Manager Types

Python's `with` statement supports the concept of a runtime context defined by a context manager. This is implemented using a pair of methods that allow user-defined classes to define a runtime context that is entered before the statement body is executed and exited when the statement ends:

`contextmanager.__enter__()`
Enter the runtime context and return either this object or another object related to the runtime context. The value returned by this method is bound to the identifier in the `as` clause of `with` statements using this context manager.

An example of a context manager that returns itself is a *file object*. File objects return themselves from ___enter___() to allow *open()* to be used as the context expression in a `with` statement.

An example of a context manager that returns a related object is the one returned by *decimal.localcontext()*. These managers set the active decimal context to a copy of the original decimal context and then return the copy. This allows changes to be made to the current decimal context in the body of the `with` statement without affecting code outside the `with` statement.

`contextmanager.__exit__`(*exc_type*, *exc_val*, *exc_tb*)
Exit the runtime context and return a Boolean flag indicating if any exception that occurred should be suppressed. If an exception occurred while executing the body of the `with` statement, the arguments contain the exception type, value and traceback information. Otherwise, all three arguments are `None`.

Returning a true value from this method will cause the `with` statement to suppress the exception and continue execution with the statement immediately following the `with` statement. Otherwise the exception continues propagating after this method has finished executing. Exceptions that occur during execution of this method will replace any exception that occurred in the body of the `with` statement.

The exception passed in should never be reraised explicitly - instead, this method should return a false value to indicate that the method completed successfully and does not want to suppress the raised exception. This allows context management code to easily detect whether or not an *__exit__()* method has actually failed.

Python defines several context managers to support easy thread synchronisation, prompt closure of files or other objects, and simpler manipulation of the active decimal arithmetic context. The specific types are not treated specially beyond their implementation of the context management protocol. See the *contextlib* module for some examples.

Python's *generator*s and the *contextlib.contextmanager* decorator provide a convenient way to implement these protocols. If a generator function is decorated with the *contextlib.contextmanager* decorator, it will return a context manager implementing the necessary `__enter__()` and `__exit__()` methods, rather than the iterator produced by an undecorated generator function.

Note that there is no specific slot for any of these methods in the type structure for Python objects in the Python/C API. Extension types wanting to define these methods must provide them as a normal Python accessible method. Compared to the overhead of setting up the runtime context, the overhead of a single class dictionary lookup is negligible.

4.12 Other Built-in Types

The interpreter supports several other kinds of objects. Most of these support only one or two operations.

4.12.1 Modules

The only special operation on a module is attribute access: `m.name`, where *m* is a module and *name* accesses a name defined in *m*'s symbol table. Module attributes can be assigned to. (Note that the `import` statement is not, strictly speaking, an operation on a module object; `import foo` does not require a module object named *foo* to exist, rather it requires an (external) *definition* for a module named *foo* somewhere.)

A special attribute of every module is *__dict__*. This is the dictionary containing the module's symbol table. Modifying this dictionary will actually change the module's symbol table, but direct assignment to the *__dict__* attribute is not possible (you can write `m.__dict__['a'] = 1`, which defines `m.a` to be `1`, but you can't write `m.__dict__ = {}`). Modifying *__dict__* directly is not recommended.

Modules built into the interpreter are written like this: `<module 'sys' (built-in)>`. If loaded from a file, they are written as `<module 'os' from '/usr/local/lib/pythonX.Y/os.pyc'>`.

4.12.2 Classes and Class Instances

See objects and class for these.

4.12.3 Functions

Function objects are created by function definitions. The only operation on a function object is to call it: `func(argument-list)`.

There are really two flavors of function objects: built-in functions and user-defined functions. Both support the same operation (to call the function), but the implementation is different, hence the different object types.

See function for more information.

4.12.4 Methods

Methods are functions that are called using the attribute notation. There are two flavors: built-in methods (such as `append()` on lists) and class instance methods. Built-in methods are described with the types that support them.

If you access a method (a function defined in a class namespace) through an instance, you get a special object: a *bound method* (also called *instance method*) object. When called, it will add the `self` argument to the argument list. Bound methods have two special read-only attributes: `m.__self__` is the object on which the method operates, and `m.__func__` is the function implementing the method. Calling `m(arg-1, arg-2, ..., arg-n)` is completely equivalent to calling `m.__func__(m.__self__, arg-1, arg-2, ..., arg-n)`.

Like function objects, bound method objects support getting arbitrary attributes. However, since method attributes are actually stored on the underlying function object (`meth.__func__`), setting method attributes on bound methods is disallowed. Attempting to set an attribute on a method results in an *AttributeError* being raised. In order to set a method attribute, you need to explicitly set it on the underlying function object:

```
>>> class C:
...     def method(self):
...         pass
...
>>> c = C()
>>> c.method.whoami = 'my name is method'  # can't set on the method
Traceback (most recent call last):
```

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```
  File "<stdin>", line 1, in <module>
AttributeError: 'method' object has no attribute 'whoami'
>>> c.method.__func__.whoami = 'my name is method'
>>> c.method.whoami
'my name is method'
```

See types for more information.

4.12.5 Code Objects

Code objects are used by the implementation to represent "pseudo-compiled" executable Python code such as a function body. They differ from function objects because they don't contain a reference to their global execution environment. Code objects are returned by the built-in *compile()* function and can be extracted from function objects through their `__code__` attribute. See also the *code* module.

A code object can be executed or evaluated by passing it (instead of a source string) to the *exec()* or *eval()* built-in functions.

See types for more information.

4.12.6 Type Objects

Type objects represent the various object types. An object's type is accessed by the built-in function *type()*. There are no special operations on types. The standard module *types* defines names for all standard built-in types.

Types are written like this: `<class 'int'>`.

4.12.7 The Null Object

This object is returned by functions that don't explicitly return a value. It supports no special operations. There is exactly one null object, named `None` (a built-in name). `type(None)()` produces the same singleton.

It is written as `None`.

4.12.8 The Ellipsis Object

This object is commonly used by slicing (see slicings). It supports no special operations. There is exactly one ellipsis object, named *Ellipsis* (a built-in name). `type(Ellipsis)()` produces the *Ellipsis* singleton.

It is written as `Ellipsis` or `...`.

4.12.9 The NotImplemented Object

This object is returned from comparisons and binary operations when they are asked to operate on types they don't support. See comparisons for more information. There is exactly one `NotImplemented` object. `type(NotImplemented)()` produces the singleton instance.

It is written as `NotImplemented`.

4.12.10 Boolean Values

Boolean values are the two constant objects `False` and `True`. They are used to represent truth values (although other values can also be considered false or true). In numeric contexts (for example when used as the argument to an arithmetic operator), they behave like the integers 0 and 1, respectively. The built-in function *bool()* can be used to convert any value to a Boolean, if the value can be interpreted as a truth value (see section *Truth Value Testing* above).

They are written as `False` and `True`, respectively.

4.12.11 Internal Objects

See types for this information. It describes stack frame objects, traceback objects, and slice objects.

4.13 Special Attributes

The implementation adds a few special read-only attributes to several object types, where they are relevant. Some of these are not reported by the *dir()* built-in function.

`object.__dict__`
: A dictionary or other mapping object used to store an object's (writable) attributes.

`instance.__class__`
: The class to which a class instance belongs.

`class.__bases__`
: The tuple of base classes of a class object.

`definition.__name__`
: The name of the class, function, method, descriptor, or generator instance.

`definition.__qualname__`
: The *qualified name* of the class, function, method, descriptor, or generator instance.

  New in version 3.3.

`class.__mro__`
: This attribute is a tuple of classes that are considered when looking for base classes during method resolution.

`class.mro()`
: This method can be overridden by a metaclass to customize the method resolution order for its instances. It is called at class instantiation, and its result is stored in *__mro__*.

`class.__subclasses__()`
: Each class keeps a list of weak references to its immediate subclasses. This method returns a list of all those references still alive. Example:

```
>>> int.__subclasses__()
[<class 'bool'>]
```

CHAPTER

FIVE

BUILT-IN EXCEPTIONS

In Python, all exceptions must be instances of a class that derives from *BaseException*. In a `try` statement with an `except` clause that mentions a particular class, that clause also handles any exception classes derived from that class (but not exception classes from which *it* is derived). Two exception classes that are not related via subclassing are never equivalent, even if they have the same name.

The built-in exceptions listed below can be generated by the interpreter or built-in functions. Except where mentioned, they have an "associated value" indicating the detailed cause of the error. This may be a string or a tuple of several items of information (e.g., an error code and a string explaining the code). The associated value is usually passed as arguments to the exception class's constructor.

User code can raise built-in exceptions. This can be used to test an exception handler or to report an error condition "just like" the situation in which the interpreter raises the same exception; but beware that there is nothing to prevent user code from raising an inappropriate error.

The built-in exception classes can be subclassed to define new exceptions; programmers are encouraged to derive new exceptions from the *Exception* class or one of its subclasses, and not from *BaseException*. More information on defining exceptions is available in the Python Tutorial under tut-userexceptions.

When raising (or re-raising) an exception in an `except` or `finally` clause `__context__` is automatically set to the last exception caught; if the new exception is not handled the traceback that is eventually displayed will include the originating exception(s) and the final exception.

When raising a new exception (rather than using a bare `raise` to re-raise the exception currently being handled), the implicit exception context can be supplemented with an explicit cause by using `from` with `raise`:

```
raise new_exc from original_exc
```

The expression following `from` must be an exception or `None`. It will be set as `__cause__` on the raised exception. Setting `__cause__` also implicitly sets the `__suppress_context__` attribute to `True`, so that using `raise new_exc from None` effectively replaces the old exception with the new one for display purposes (e.g. converting *KeyError* to *AttributeError*, while leaving the old exception available in `__context__` for introspection when debugging.

The default traceback display code shows these chained exceptions in addition to the traceback for the exception itself. An explicitly chained exception in `__cause__` is always shown when present. An implicitly chained exception in `__context__` is shown only if `__cause__` is *None* and `__suppress_context__` is false.

In either case, the exception itself is always shown after any chained exceptions so that the final line of the traceback always shows the last exception that was raised.

5.1 Base classes

The following exceptions are used mostly as base classes for other exceptions.

exception BaseException
The base class for all built-in exceptions. It is not meant to be directly inherited by user-defined classes (for that, use *Exception*). If *str()* is called on an instance of this class, the representation of the argument(s) to the instance are returned, or the empty string when there were no arguments.

args
The tuple of arguments given to the exception constructor. Some built-in exceptions (like *OSError*) expect a certain number of arguments and assign a special meaning to the elements of this tuple, while others are usually called only with a single string giving an error message.

with_traceback(*tb*)
This method sets *tb* as the new traceback for the exception and returns the exception object. It is usually used in exception handling code like this:

```
try:
    ...
except SomeException:
    tb = sys.exc_info()[2]
    raise OtherException(...).with_traceback(tb)
```

exception Exception
All built-in, non-system-exiting exceptions are derived from this class. All user-defined exceptions should also be derived from this class.

exception ArithmeticError
The base class for those built-in exceptions that are raised for various arithmetic errors: *OverflowError*, *ZeroDivisionError*, *FloatingPointError*.

exception BufferError
Raised when a buffer related operation cannot be performed.

exception LookupError
The base class for the exceptions that are raised when a key or index used on a mapping or sequence is invalid: *IndexError*, *KeyError*. This can be raised directly by *codecs.lookup()*.

5.2 Concrete exceptions

The following exceptions are the exceptions that are usually raised.

exception AssertionError
Raised when an `assert` statement fails.

exception AttributeError
Raised when an attribute reference (see attribute-references) or assignment fails. (When an object does not support attribute references or attribute assignments at all, *TypeError* is raised.)

exception EOFError
Raised when the *input()* function hits an end-of-file condition (EOF) without reading any data. (N.B.: the `io.IOBase.read()` and *io.IOBase.readline()* methods return an empty string when they hit EOF.)

exception FloatingPointError
Not currently used.

exception GeneratorExit
Raised when a *generator* or *coroutine* is closed; see `generator.close()` and `coroutine.close()`. It directly inherits from *BaseException* instead of *Exception* since it is technically not an error.

exception ImportError
Raised when the `import` statement has troubles trying to load a module. Also raised when the "from list" in `from ... import` has a name that cannot be found.

The `name` and `path` attributes can be set using keyword-only arguments to the constructor. When set they represent the name of the module that was attempted to be imported and the path to any file which triggered the exception, respectively.

Changed in version 3.3: Added the `name` and `path` attributes.

exception ModuleNotFoundError
A subclass of *ImportError* which is raised by `import` when a module could not be located. It is also raised when `None` is found in *sys.modules*.

New in version 3.6.

exception IndexError
Raised when a sequence subscript is out of range. (Slice indices are silently truncated to fall in the allowed range; if an index is not an integer, *TypeError* is raised.)

exception KeyError
Raised when a mapping (dictionary) key is not found in the set of existing keys.

exception KeyboardInterrupt
Raised when the user hits the interrupt key (normally `Control-C` or `Delete`). During execution, a check for interrupts is made regularly. The exception inherits from *BaseException* so as to not be accidentally caught by code that catches *Exception* and thus prevent the interpreter from exiting.

exception MemoryError
Raised when an operation runs out of memory but the situation may still be rescued (by deleting some objects). The associated value is a string indicating what kind of (internal) operation ran out of memory. Note that because of the underlying memory management architecture (C's `malloc()` function), the interpreter may not always be able to completely recover from this situation; it nevertheless raises an exception so that a stack traceback can be printed, in case a run-away program was the cause.

exception NameError
Raised when a local or global name is not found. This applies only to unqualified names. The associated value is an error message that includes the name that could not be found.

exception NotImplementedError
This exception is derived from *RuntimeError*. In user defined base classes, abstract methods should raise this exception when they require derived classes to override the method, or while the class is being developed to indicate that the real implementation still needs to be added.

Note: It should not be used to indicate that an operator or method is not meant to be supported at all – in that case either leave the operator / method undefined or, if a subclass, set it to *None*.

Note: `NotImplementedError` and `NotImplemented` are not interchangeable, even though they have similar names and purposes. See *NotImplemented* for details on when to use it.

---

exception OSError([*arg*]**)**
exception OSError(*errno*, *strerror*[, *filename*[, *winerror*[, *filename2*]]]**)**
This exception is raised when a system function returns a system-related error, including I/O failures such as "file not found" or "disk full" (not for illegal argument types or other incidental errors).

The second form of the constructor sets the corresponding attributes, described below. The attributes default to *None* if not specified. For backwards compatibility, if three arguments are passed, the *args* attribute contains only a 2-tuple of the first two constructor arguments.

The constructor often actually returns a subclass of *OSError*, as described in *OS exceptions* below. The particular subclass depends on the final *errno* value. This behaviour only occurs when constructing *OSError* directly or via an alias, and is not inherited when subclassing.

errno
A numeric error code from the C variable `errno`.

winerror
Under Windows, this gives you the native Windows error code. The *errno* attribute is then an approximate translation, in POSIX terms, of that native error code.

Under Windows, if the *winerror* constructor argument is an integer, the *errno* attribute is determined from the Windows error code, and the *errno* argument is ignored. On other platforms, the *winerror* argument is ignored, and the *winerror* attribute does not exist.

strerror
The corresponding error message, as provided by the operating system. It is formatted by the C functions `perror()` under POSIX, and `FormatMessage()` under Windows.

filename
filename2
For exceptions that involve a file system path (such as *open()* or *os.unlink()*), *filename* is the file name passed to the function. For functions that involve two file system paths (such as *os.rename()*), *filename2* corresponds to the second file name passed to the function.

Changed in version 3.3: *EnvironmentError*, *IOError*, *WindowsError*, *socket.error*, *select.error* and `mmap.error` have been merged into *OSError*, and the constructor may return a subclass.

Changed in version 3.4: The *filename* attribute is now the original file name passed to the function, instead of the name encoded to or decoded from the filesystem encoding. Also, the *filename2* constructor argument and attribute was added.

exception OverflowError
Raised when the result of an arithmetic operation is too large to be represented. This cannot occur for integers (which would rather raise *MemoryError* than give up). However, for historical reasons, OverflowError is sometimes raised for integers that are outside a required range. Because of the lack of standardization of floating point exception handling in C, most floating point operations are not checked.

exception RecursionError
This exception is derived from *RuntimeError*. It is raised when the interpreter detects that the maximum recursion depth (see *sys.getrecursionlimit()*) is exceeded.

New in version 3.5: Previously, a plain *RuntimeError* was raised.

exception ReferenceError
This exception is raised when a weak reference proxy, created by the *weakref.proxy()* function, is used to access an attribute of the referent after it has been garbage collected. For more information on weak references, see the *weakref* module.

exception RuntimeError
Raised when an error is detected that doesn't fall in any of the other categories. The associated value is a string indicating what precisely went wrong.

exception StopIteration
Raised by built-in function *next()* and an *iterator*'s *__next__()* method to signal that there are no further items produced by the iterator.

The exception object has a single attribute `value`, which is given as an argument when constructing the exception, and defaults to *None*.

When a *generator* or *coroutine* function returns, a new *StopIteration* instance is raised, and the value returned by the function is used as the `value` parameter to the constructor of the exception.

If a generator code directly or indirectly raises *StopIteration*, it is converted into a *RuntimeError* (retaining the *StopIteration* as the new exception's cause).

Changed in version 3.3: Added `value` attribute and the ability for generator functions to use it to return a value.

Changed in version 3.5: Introduced the RuntimeError transformation via `from __future__ import generator_stop`, see **PEP 479**.

Changed in version 3.7: Enable **PEP 479** for all code by default: a *StopIteration* error raised in a generator is transformed into a *RuntimeError*.

exception StopAsyncIteration
Must be raised by `__anext__()` method of an *asynchronous iterator* object to stop the iteration.

New in version 3.5.

exception SyntaxError
Raised when the parser encounters a syntax error. This may occur in an `import` statement, in a call to the built-in functions *exec()* or *eval()*, or when reading the initial script or standard input (also interactively).

Instances of this class have attributes `filename`, `lineno`, `offset` and `text` for easier access to the details. *str()* of the exception instance returns only the message.

exception IndentationError
Base class for syntax errors related to incorrect indentation. This is a subclass of *SyntaxError*.

exception TabError
Raised when indentation contains an inconsistent use of tabs and spaces. This is a subclass of *IndentationError*.

exception SystemError
Raised when the interpreter finds an internal error, but the situation does not look so serious to cause it to abandon all hope. The associated value is a string indicating what went wrong (in low-level terms).

You should report this to the author or maintainer of your Python interpreter. Be sure to report the version of the Python interpreter (`sys.version`; it is also printed at the start of an interactive Python session), the exact error message (the exception's associated value) and if possible the source of the program that triggered the error.

exception SystemExit
This exception is raised by the *sys.exit()* function. It inherits from *BaseException* instead of *Exception* so that it is not accidentally caught by code that catches *Exception*. This allows the exception to properly propagate up and cause the interpreter to exit. When it is not handled, the Python interpreter exits; no stack traceback is printed. The constructor accepts the same optional argument passed to *sys.exit()*. If the value is an integer, it specifies the system exit status (passed to C's `exit()` function); if it is `None`, the exit status is zero; if it has another type (such as a string), the object's value is printed and the exit status is one.

A call to *sys.exit()* is translated into an exception so that clean-up handlers (`finally` clauses of `try` statements) can be executed, and so that a debugger can execute a script without running the risk of losing control. The *os._exit()* function can be used if it is absolutely positively necessary to exit immediately (for example, in the child process after a call to *os.fork()*).

code
The exit status or error message that is passed to the constructor. (Defaults to `None`.)

exception TypeError
Raised when an operation or function is applied to an object of inappropriate type. The associated value is a string giving details about the type mismatch.

This exception may be raised by user code to indicate that an attempted operation on an object is not supported, and is not meant to be. If an object is meant to support a given operation but has not yet provided an implementation, *NotImplementedError* is the proper exception to raise.

Passing arguments of the wrong type (e.g. passing a *list* when an *int* is expected) should result in a *TypeError*, but passing arguments with the wrong value (e.g. a number outside expected boundaries) should result in a *ValueError*.

exception UnboundLocalError
Raised when a reference is made to a local variable in a function or method, but no value has been bound to that variable. This is a subclass of *NameError*.

exception UnicodeError
Raised when a Unicode-related encoding or decoding error occurs. It is a subclass of *ValueError*.

UnicodeError has attributes that describe the encoding or decoding error. For example, `err.object[err.start:err.end]` gives the particular invalid input that the codec failed on.

encoding
The name of the encoding that raised the error.

reason
A string describing the specific codec error.

object
The object the codec was attempting to encode or decode.

start
The first index of invalid data in *object*.

end
The index after the last invalid data in *object*.

exception UnicodeEncodeError
Raised when a Unicode-related error occurs during encoding. It is a subclass of *UnicodeError*.

exception UnicodeDecodeError
Raised when a Unicode-related error occurs during decoding. It is a subclass of *UnicodeError*.

exception UnicodeTranslateError
Raised when a Unicode-related error occurs during translating. It is a subclass of *UnicodeError*.

exception ValueError
Raised when a built-in operation or function receives an argument that has the right type but an inappropriate value, and the situation is not described by a more precise exception such as *IndexError*.

exception ZeroDivisionError
Raised when the second argument of a division or modulo operation is zero. The associated value is a string indicating the type of the operands and the operation.

The following exceptions are kept for compatibility with previous versions; starting from Python 3.3, they are aliases of *OSError*.

exception EnvironmentError

exception IOError

exception WindowsError
Only available on Windows.

5.2.1 OS exceptions

The following exceptions are subclasses of *OSError*, they get raised depending on the system error code.

exception BlockingIOError
Raised when an operation would block on an object (e.g. socket) set for non-blocking operation. Corresponds to `errno` `EAGAIN`, `EALREADY`, `EWOULDBLOCK` and `EINPROGRESS`.

In addition to those of *OSError*, *BlockingIOError* can have one more attribute:

characters_written
An integer containing the number of characters written to the stream before it blocked. This attribute is available when using the buffered I/O classes from the *io* module.

exception ChildProcessError
Raised when an operation on a child process failed. Corresponds to `errno` `ECHILD`.

exception ConnectionError
A base class for connection-related issues.

Subclasses are *BrokenPipeError*, *ConnectionAbortedError*, *ConnectionRefusedError* and *ConnectionResetError*.

exception BrokenPipeError
A subclass of *ConnectionError*, raised when trying to write on a pipe while the other end has been closed, or trying to write on a socket which has been shutdown for writing. Corresponds to `errno` `EPIPE` and `ESHUTDOWN`.

exception ConnectionAbortedError
A subclass of *ConnectionError*, raised when a connection attempt is aborted by the peer. Corresponds to `errno` `ECONNABORTED`.

exception ConnectionRefusedError
A subclass of *ConnectionError*, raised when a connection attempt is refused by the peer. Corresponds to `errno` `ECONNREFUSED`.

exception ConnectionResetError
A subclass of *ConnectionError*, raised when a connection is reset by the peer. Corresponds to `errno` `ECONNRESET`.

exception FileExistsError
Raised when trying to create a file or directory which already exists. Corresponds to `errno` `EEXIST`.

exception FileNotFoundError
Raised when a file or directory is requested but doesn't exist. Corresponds to `errno` `ENOENT`.

exception InterruptedError
Raised when a system call is interrupted by an incoming signal. Corresponds to `errno` *EINTR*.

Changed in version 3.5: Python now retries system calls when a syscall is interrupted by a signal, except if the signal handler raises an exception (see **PEP 475** for the rationale), instead of raising *InterruptedError*.

exception IsADirectoryError
Raised when a file operation (such as *os.remove()*) is requested on a directory. Corresponds to `errno` `EISDIR`.

exception NotADirectoryError
Raised when a directory operation (such as *os.listdir()*) is requested on something which is not a directory. Corresponds to `errno` `ENOTDIR`.

exception PermissionError
Raised when trying to run an operation without the adequate access rights - for example filesystem permissions. Corresponds to `errno` `EACCES` and `EPERM`.

exception ProcessLookupError
Raised when a given process doesn't exist. Corresponds to `errno` `ESRCH`.

exception TimeoutError
Raised when a system function timed out at the system level. Corresponds to `errno` `ETIMEDOUT`.

New in version 3.3: All the above *OSError* subclasses were added.

See also:

PEP 3151 - Reworking the OS and IO exception hierarchy

5.3 Warnings

The following exceptions are used as warning categories; see the *Warning Categories* documentation for more details.

exception Warning
Base class for warning categories.

exception UserWarning
Base class for warnings generated by user code.

exception DeprecationWarning
Base class for warnings about deprecated features when those warnings are intended for other Python developers.

exception PendingDeprecationWarning
Base class for warnings about features which will be deprecated in the future.

exception SyntaxWarning
Base class for warnings about dubious syntax.

exception RuntimeWarning
Base class for warnings about dubious runtime behavior.

exception FutureWarning
Base class for warnings about deprecated features when those warnings are intended for end users of applications that are written in Python.

exception ImportWarning
Base class for warnings about probable mistakes in module imports.

exception UnicodeWarning
Base class for warnings related to Unicode.

exception BytesWarning
Base class for warnings related to *bytes* and *bytearray*.

exception ResourceWarning
Base class for warnings related to resource usage. Ignored by the default warning filters.

New in version 3.2.

5.4 Exception hierarchy

The class hierarchy for built-in exceptions is:

```
BaseException
 +-- SystemExit
 +-- KeyboardInterrupt
 +-- GeneratorExit
```

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```
+-- Exception
     +-- StopIteration
     +-- StopAsyncIteration
     +-- ArithmeticError
     |    +-- FloatingPointError
     |    +-- OverflowError
     |    +-- ZeroDivisionError
     +-- AssertionError
     +-- AttributeError
     +-- BufferError
     +-- EOFError
     +-- ImportError
     |    +-- ModuleNotFoundError
     +-- LookupError
     |    +-- IndexError
     |    +-- KeyError
     +-- MemoryError
     +-- NameError
     |    +-- UnboundLocalError
     +-- OSError
     |    +-- BlockingIOError
     |    +-- ChildProcessError
     |    +-- ConnectionError
     |    |    +-- BrokenPipeError
     |    |    +-- ConnectionAbortedError
     |    |    +-- ConnectionRefusedError
     |    |    +-- ConnectionResetError
     |    +-- FileExistsError
     |    +-- FileNotFoundError
     |    +-- InterruptedError
     |    +-- IsADirectoryError
     |    +-- NotADirectoryError
     |    +-- PermissionError
     |    +-- ProcessLookupError
     |    +-- TimeoutError
     +-- ReferenceError
     +-- RuntimeError
     |    +-- NotImplementedError
     |    +-- RecursionError
     +-- SyntaxError
     |    +-- IndentationError
     |         +-- TabError
     +-- SystemError
     +-- TypeError
     +-- ValueError
     |    +-- UnicodeError
     |         +-- UnicodeDecodeError
     |         +-- UnicodeEncodeError
     |         +-- UnicodeTranslateError
     +-- Warning
          +-- DeprecationWarning
          +-- PendingDeprecationWarning
          +-- RuntimeWarning
          +-- SyntaxWarning
          +-- UserWarning
          +-- FutureWarning
```

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```
          +-- ImportWarning
          +-- UnicodeWarning
          +-- BytesWarning
          +-- ResourceWarning
```

CHAPTER

SIX

TEXT PROCESSING SERVICES

The modules described in this chapter provide a wide range of string manipulation operations and other text processing services.

The *codecs* module described under *Binary Data Services* is also highly relevant to text processing. In addition, see the documentation for Python's built-in string type in *Text Sequence Type — str*.

6.1 string — Common string operations

Source code: Lib/string.py

See also:

Text Sequence Type — str

String Methods

6.1.1 String constants

The constants defined in this module are:

string.ascii_letters
The concatenation of the *ascii_lowercase* and *ascii_uppercase* constants described below. This value is not locale-dependent.

string.ascii_lowercase
The lowercase letters `'abcdefghijklmnopqrstuvwxyz'`. This value is not locale-dependent and will not change.

string.ascii_uppercase
The uppercase letters `'ABCDEFGHIJKLMNOPQRSTUVWXYZ'`. This value is not locale-dependent and will not change.

string.digits
The string `'0123456789'`.

string.hexdigits
The string `'0123456789abcdefABCDEF'`.

string.octdigits
The string `'01234567'`.

string.punctuation
String of ASCII characters which are considered punctuation characters in the `C` locale.

string.printable
String of ASCII characters which are considered printable. This is a combination of *digits*, *ascii_letters*, *punctuation*, and *whitespace*.

string.whitespace
A string containing all ASCII characters that are considered whitespace. This includes the characters space, tab, linefeed, return, formfeed, and vertical tab.

6.1.2 Custom String Formatting

The built-in string class provides the ability to do complex variable substitutions and value formatting via the *format()* method described in **PEP 3101**. The *Formatter* class in the *string* module allows you to create and customize your own string formatting behaviors using the same implementation as the built-in *format()* method.

class string.Formatter
The *Formatter* class has the following public methods:

format(*format_string*, **args*, ***kwargs*)
The primary API method. It takes a format string and an arbitrary set of positional and keyword arguments. It is just a wrapper that calls *vformat()*.

Changed in version 3.7: A format string argument is now *positional-only*.

vformat(*format_string*, *args*, *kwargs*)
This function does the actual work of formatting. It is exposed as a separate function for cases where you want to pass in a predefined dictionary of arguments, rather than unpacking and repacking the dictionary as individual arguments using the ***args** and ****kwargs** syntax. *vformat()* does the work of breaking up the format string into character data and replacement fields. It calls the various methods described below.

In addition, the *Formatter* defines a number of methods that are intended to be replaced by subclasses:

parse(*format_string*)
Loop over the format_string and return an iterable of tuples (*literal_text*, *field_name*, *format_spec*, *conversion*). This is used by *vformat()* to break the string into either literal text, or replacement fields.

The values in the tuple conceptually represent a span of literal text followed by a single replacement field. If there is no literal text (which can happen if two replacement fields occur consecutively), then *literal_text* will be a zero-length string. If there is no replacement field, then the values of *field_name*, *format_spec* and *conversion* will be `None`.

get_field(*field_name*, *args*, *kwargs*)
Given *field_name* as returned by *parse()* (see above), convert it to an object to be formatted. Returns a tuple (obj, used_key). The default version takes strings of the form defined in **PEP 3101**, such as "0[name]" or "label.title". *args* and *kwargs* are as passed in to *vformat()*. The return value *used_key* has the same meaning as the *key* parameter to *get_value()*.

get_value(*key*, *args*, *kwargs*)
Retrieve a given field value. The *key* argument will be either an integer or a string. If it is an integer, it represents the index of the positional argument in *args*; if it is a string, then it represents a named argument in *kwargs*.

The *args* parameter is set to the list of positional arguments to *vformat()*, and the *kwargs* parameter is set to the dictionary of keyword arguments.

For compound field names, these functions are only called for the first component of the field name; Subsequent components are handled through normal attribute and indexing operations.

So for example, the field expression '0.name' would cause *get_value()* to be called with a *key* argument of 0. The `name` attribute will be looked up after *get_value()* returns by calling the built-in *getattr()* function.

If the index or keyword refers to an item that does not exist, then an *IndexError* or *KeyError* should be raised.

check_unused_args(*used_args*, *args*, *kwargs*)
Implement checking for unused arguments if desired. The arguments to this function is the set of all argument keys that were actually referred to in the format string (integers for positional arguments, and strings for named arguments), and a reference to the *args* and *kwargs* that was passed to vformat. The set of unused args can be calculated from these parameters. *check_unused_args()* is assumed to raise an exception if the check fails.

format_field(*value*, *format_spec*)
format_field() simply calls the global *format()* built-in. The method is provided so that subclasses can override it.

convert_field(*value*, *conversion*)
Converts the value (returned by *get_field()*) given a conversion type (as in the tuple returned by the *parse()* method). The default version understands 's' (str), 'r' (repr) and 'a' (ascii) conversion types.

6.1.3 Format String Syntax

The *str.format()* method and the *Formatter* class share the same syntax for format strings (although in the case of *Formatter*, subclasses can define their own format string syntax). The syntax is related to that of formatted string literals, but there are differences.

Format strings contain "replacement fields" surrounded by curly braces `{}`. Anything that is not contained in braces is considered literal text, which is copied unchanged to the output. If you need to include a brace character in the literal text, it can be escaped by doubling: `{{` and `}}`.

The grammar for a replacement field is as follows:

```
replacement_field  ::=   "{" [field_name] ["!" conversion] [":" format_spec] "}"
field_name         ::=   arg_name ("." attribute_name | "[" element_index "]")*
arg_name           ::=   [identifier | digit+]
attribute_name     ::=   identifier
element_index      ::=   digit+ | index_string
index_string       ::=   <any source character except "]"> +
conversion         ::=   "r" | "s" | "a"
format_spec        ::=   <described in the next section>
```

In less formal terms, the replacement field can start with a *field_name* that specifies the object whose value is to be formatted and inserted into the output instead of the replacement field. The *field_name* is optionally followed by a *conversion* field, which is preceded by an exclamation point `'!'`, and a *format_spec*, which is preceded by a colon `':'`. These specify a non-default format for the replacement value.

See also the *Format Specification Mini-Language* section.

The *field_name* itself begins with an *arg_name* that is either a number or a keyword. If it's a number, it refers to a positional argument, and if it's a keyword, it refers to a named keyword argument. If the numerical arg_names in a format string are 0, 1, 2, ... in sequence, they can all be omitted (not just some) and the numbers 0, 1, 2, ... will be automatically inserted in that order. Because *arg_name* is not quote-delimited, it is not possible to specify arbitrary dictionary keys (e.g., the strings `'10'` or `':-]'`) within a format string. The *arg_name* can be followed by any number of index or attribute expressions. An expression of the form

`'.name'` selects the named attribute using *getattr()*, while an expression of the form `'[index]'` does an index lookup using `__getitem__()`.

Changed in version 3.1: The positional argument specifiers can be omitted for *str.format()*, so `'{} {}'.format(a, b)` is equivalent to `'{0} {1}'.format(a, b)`.

Changed in version 3.4: The positional argument specifiers can be omitted for *Formatter*.

Some simple format string examples:

```
"First, thou shalt count to {0}"  # References first positional argument
"Bring me a {}"                   # Implicitly references the first positional argument
"From {} to {}"                   # Same as "From {0} to {1}"
"My quest is {name}"              # References keyword argument 'name'
"Weight in tons {0.weight}"       # 'weight' attribute of first positional arg
"Units destroyed: {players[0]}"   # First element of keyword argument 'players'.
```

The *conversion* field causes a type coercion before formatting. Normally, the job of formatting a value is done by the `__format__()` method of the value itself. However, in some cases it is desirable to force a type to be formatted as a string, overriding its own definition of formatting. By converting the value to a string before calling `__format__()`, the normal formatting logic is bypassed.

Three conversion flags are currently supported: `'!s'` which calls *str()* on the value, `'!r'` which calls *repr()* and `'!a'` which calls *ascii()*.

Some examples:

```
"Harold's a clever {0!s}"         # Calls str() on the argument first
"Bring out the holy {name!r}"     # Calls repr() on the argument first
"More {!a}"                       # Calls ascii() on the argument first
```

The *format_spec* field contains a specification of how the value should be presented, including such details as field width, alignment, padding, decimal precision and so on. Each value type can define its own "formatting mini-language" or interpretation of the *format_spec*.

Most built-in types support a common formatting mini-language, which is described in the next section.

A *format_spec* field can also include nested replacement fields within it. These nested replacement fields may contain a field name, conversion flag and format specification, but deeper nesting is not allowed. The replacement fields within the format_spec are substituted before the *format_spec* string is interpreted. This allows the formatting of a value to be dynamically specified.

See the *Format examples* section for some examples.

Format Specification Mini-Language

"Format specifications" are used within replacement fields contained within a format string to define how individual values are presented (see *Format String Syntax* and f-strings). They can also be passed directly to the built-in *format()* function. Each formattable type may define how the format specification is to be interpreted.

Most built-in types implement the following options for format specifications, although some of the formatting options are only supported by the numeric types.

A general convention is that an empty format string (`""`) produces the same result as if you had called *str()* on the value. A non-empty format string typically modifies the result.

The general form of a *standard format specifier* is:

```
format_spec     ::=  [[fill]align][sign][#][0][width][grouping_option][.precision][type]
```

```
fill            ::=  <any character>
align           ::=  "<" | ">" | "=" | "^"
sign            ::=  "+" | "-" | " "
width           ::=  digit+
grouping_option ::=  "_" | ","
precision       ::=  digit+
type            ::=  "b" | "c" | "d" | "e" | "E" | "f" | "F" | "g" | "G" | "n" | "o" | "s" | "x" | "
```

If a valid *align* value is specified, it can be preceded by a *fill* character that can be any character and defaults to a space if omitted. It is not possible to use a literal curly brace ("`{`" or "`}`") as the *fill* character in a formatted string literal or when using the *str.format()* method. However, it is possible to insert a curly brace with a nested replacement field. This limitation doesn't affect the *format()* function.

The meaning of the various alignment options is as follows:

Option	Meaning
`'<'`	Forces the field to be left-aligned within the available space (this is the default for most objects).
`'>'`	Forces the field to be right-aligned within the available space (this is the default for numbers).
`'='`	Forces the padding to be placed after the sign (if any) but before the digits. This is used for printing fields in the form '+000000120'. This alignment option is only valid for numeric types. It becomes the default when '0' immediately precedes the field width.
`'^'`	Forces the field to be centered within the available space.

Note that unless a minimum field width is defined, the field width will always be the same size as the data to fill it, so that the alignment option has no meaning in this case.

The *sign* option is only valid for number types, and can be one of the following:

Option	Meaning
`'+'`	indicates that a sign should be used for both positive as well as negative numbers.
`'-'`	indicates that a sign should be used only for negative numbers (this is the default behavior).
space	indicates that a leading space should be used on positive numbers, and a minus sign on negative numbers.

The `'#'` option causes the "alternate form" to be used for the conversion. The alternate form is defined differently for different types. This option is only valid for integer, float, complex and Decimal types. For integers, when binary, octal, or hexadecimal output is used, this option adds the prefix respective `'0b'`, `'0o'`, or `'0x'` to the output value. For floats, complex and Decimal the alternate form causes the result of the conversion to always contain a decimal-point character, even if no digits follow it. Normally, a decimal-point character appears in the result of these conversions only if a digit follows it. In addition, for `'g'` and `'G'` conversions, trailing zeros are not removed from the result.

The `','` option signals the use of a comma for a thousands separator. For a locale aware separator, use the `'n'` integer presentation type instead.

Changed in version 3.1: Added the `','` option (see also **PEP 378**).

The `'_'` option signals the use of an underscore for a thousands separator for floating point presentation types and for integer presentation type `'d'`. For integer presentation types `'b'`, `'o'`, `'x'`, and `'X'`, underscores will be inserted every 4 digits. For other presentation types, specifying this option is an error.

Changed in version 3.6: Added the `'_'` option (see also **PEP 515**).

width is a decimal integer defining the minimum field width. If not specified, then the field width will be determined by the content.

When no explicit alignment is given, preceding the *width* field by a zero (`'0'`) character enables sign-aware zero-padding for numeric types. This is equivalent to a *fill* character of `'0'` with an *alignment* type of `'='`.

The *precision* is a decimal number indicating how many digits should be displayed after the decimal point for a floating point value formatted with `'f'` and `'F'`, or before and after the decimal point for a floating point value formatted with `'g'` or `'G'`. For non-number types the field indicates the maximum field size - in other words, how many characters will be used from the field content. The *precision* is not allowed for integer values.

Finally, the *type* determines how the data should be presented.

The available string presentation types are:

Type	Meaning
`'s'`	String format. This is the default type for strings and may be omitted.
None	The same as `'s'`.

The available integer presentation types are:

Type	Meaning
`'b'`	Binary format. Outputs the number in base 2.
`'c'`	Character. Converts the integer to the corresponding unicode character before printing.
`'d'`	Decimal Integer. Outputs the number in base 10.
`'o'`	Octal format. Outputs the number in base 8.
`'x'`	Hex format. Outputs the number in base 16, using lower- case letters for the digits above 9.
`'X'`	Hex format. Outputs the number in base 16, using upper- case letters for the digits above 9.
`'n'`	Number. This is the same as `'d'`, except that it uses the current locale setting to insert the appropriate number separator characters.
None	The same as `'d'`.

In addition to the above presentation types, integers can be formatted with the floating point presentation types listed below (except `'n'` and `None`). When doing so, *`float()`* is used to convert the integer to a floating point number before formatting.

The available presentation types for floating point and decimal values are:

Type	Meaning
`'e'`	Exponent notation. Prints the number in scientific notation using the letter 'e' to indicate the exponent. The default precision is `6`.
`'E'`	Exponent notation. Same as `'e'` except it uses an upper case 'E' as the separator character.
`'f'`	Fixed point. Displays the number as a fixed-point number. The default precision is `6`.
`'F'`	Fixed point. Same as `'f'`, but converts `nan` to `NAN` and `inf` to `INF`.
`'g'`	General format. For a given precision `p >= 1`, this rounds the number to `p` significant digits and then formats the result in either fixed-point format or in scientific notation, depending on its magnitude. The precise rules are as follows: suppose that the result formatted with presentation type `'e'` and precision `p-1` would have exponent `exp`. Then if `-4 <= exp < p`, the number is formatted with presentation type `'f'` and precision `p-1-exp`. Otherwise, the number is formatted with presentation type `'e'` and precision `p-1`. In both cases insignificant trailing zeros are removed from the significand, and the decimal point is also removed if there are no remaining digits following it. Positive and negative infinity, positive and negative zero, and nans, are formatted as `inf`, `-inf`, `0`, `-0` and `nan` respectively, regardless of the precision. A precision of `0` is treated as equivalent to a precision of `1`. The default precision is `6`.
`'G'`	General format. Same as `'g'` except switches to `'E'` if the number gets too large. The representations of infinity and NaN are uppercased, too.
`'n'`	Number. This is the same as `'g'`, except that it uses the current locale setting to insert the appropriate number separator characters.
`'%'`	Percentage. Multiplies the number by 100 and displays in fixed (`'f'`) format, followed by a percent sign.
None	Similar to `'g'`, except that fixed-point notation, when used, has at least one digit past the decimal point. The default precision is as high as needed to represent the particular value. The overall effect is to match the output of *str()* as altered by the other format modifiers.

Format examples

This section contains examples of the *str.format()* syntax and comparison with the old `%`-formatting.

In most of the cases the syntax is similar to the old `%`-formatting, with the addition of the `{}` and with `:` used instead of `%`. For example, `'%03.2f'` can be translated to `'{:03.2f}'`.

The new format syntax also supports new and different options, shown in the follow examples.

Accessing arguments by position:

```
>>> '{0}, {1}, {2}'.format('a', 'b', 'c')
'a, b, c'
>>> '{}, {}, {}'.format('a', 'b', 'c')  # 3.1+ only
'a, b, c'
>>> '{2}, {1}, {0}'.format('a', 'b', 'c')
'c, b, a'
>>> '{2}, {1}, {0}'.format(*'abc')      # unpacking argument sequence
'c, b, a'
>>> '{0}{1}{0}'.format('abra', 'cad')   # arguments' indices can be repeated
'abracadabra'
```

Accessing arguments by name:

```
>>> 'Coordinates: {latitude}, {longitude}'.format(latitude='37.24N', longitude='-115.81W')
'Coordinates: 37.24N, -115.81W'
>>> coord = {'latitude': '37.24N', 'longitude': '-115.81W'}
>>> 'Coordinates: {latitude}, {longitude}'.format(**coord)
'Coordinates: 37.24N, -115.81W'
```

Accessing arguments' attributes:

```
>>> c = 3-5j
>>> ('The complex number {0} is formed from the real part {0.real} '
...  'and the imaginary part {0.imag}.').format(c)
'The complex number (3-5j) is formed from the real part 3.0 and the imaginary part -5.0.'
>>> class Point:
...     def __init__(self, x, y):
...         self.x, self.y = x, y
...     def __str__(self):
...         return 'Point({self.x}, {self.y})'.format(self=self)
...
>>> str(Point(4, 2))
'Point(4, 2)'
```

Accessing arguments' items:

```
>>> coord = (3, 5)
>>> 'X: {0[0]};  Y: {0[1]}'.format(coord)
'X: 3;  Y: 5'
```

Replacing `%s` and `%r`:

```
>>> "repr() shows quotes: {!r}; str() doesn't: {!s}".format('test1', 'test2')
"repr() shows quotes: 'test1'; str() doesn't: test2"
```

Aligning the text and specifying a width:

```
>>> '{:<30}'.format('left aligned')
'left aligned                  '
>>> '{:>30}'.format('right aligned')
'                 right aligned'
>>> '{:^30}'.format('centered')
'           centered           '
>>> '{:*^30}'.format('centered')  # use '*' as a fill char
'***********centered***********'
```

Replacing `%+f`, `%-f`, and `% f` and specifying a sign:

```
>>> '{:+f}; {:+f}'.format(3.14, -3.14)  # show it always
'+3.140000; -3.140000'
>>> '{: f}; {: f}'.format(3.14, -3.14)  # show a space for positive numbers
' 3.140000; -3.140000'
>>> '{:-f}; {:-f}'.format(3.14, -3.14)  # show only the minus -- same as '{:f}; {:f}'
'3.140000; -3.140000'
```

Replacing `%x` and `%o` and converting the value to different bases:

```
>>> # format also supports binary numbers
>>> "int: {0:d};  hex: {0:x};  oct: {0:o};  bin: {0:b}".format(42)
'int: 42;  hex: 2a;  oct: 52;  bin: 101010'
>>> # with 0x, 0o, or 0b as prefix:
```

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```
>>> "int: {0:d};  hex: {0:#x};  oct: {0:#o};  bin: {0:#b}".format(42)
'int: 42;  hex: 0x2a;  oct: 0o52;  bin: 0b101010'
```

Using the comma as a thousands separator:

```
>>> '{:,}'.format(1234567890)
'1,234,567,890'
```

Expressing a percentage:

```
>>> points = 19
>>> total = 22
>>> 'Correct answers: {:.2%}'.format(points/total)
'Correct answers: 86.36%'
```

Using type-specific formatting:

```
>>> import datetime
>>> d = datetime.datetime(2010, 7, 4, 12, 15, 58)
>>> '{:%Y-%m-%d %H:%M:%S}'.format(d)
'2010-07-04 12:15:58'
```

Nesting arguments and more complex examples:

```
>>> for align, text in zip('<^>', ['left', 'center', 'right']):
...     '{0:{fill}{align}16}'.format(text, fill=align, align=align)
...
'left<<<<<<<<<<<<'
'^^^^^center^^^^^'
'>>>>>>>>>>>right'
>>>
>>> octets = [192, 168, 0, 1]
>>> '{:02X}{:02X}{:02X}{:02X}'.format(*octets)
'C0A80001'
>>> int(_, 16)
3232235521
>>>
>>> width = 5
>>> for num in range(5,12):
...     for base in 'dXob':
...         print('{0:{width}{base}}'.format(num, base=base, width=width), end=' ')
...     print()
...
    5     5     5   101
    6     6     6   110
    7     7     7   111
    8     8    10  1000
    9     9    11  1001
   10     A    12  1010
   11     B    13  1011
```

6.1.4 Template strings

Template strings provide simpler string substitutions as described in **PEP 292**. A primary use case for template strings is for internationalization (i18n) since in that context, the simpler syntax and functionality

makes it easier to translate than other built-in string formatting facilities in Python. As an example of a library built on template strings for i18n, see the flufl.i18n package.

Template strings support `$`-based substitutions, using the following rules:

- `$$` is an escape; it is replaced with a single `$`.
- `$identifier` names a substitution placeholder matching a mapping key of `"identifier"`. By default, `"identifier"` is restricted to any case-insensitive ASCII alphanumeric string (including underscores) that starts with an underscore or ASCII letter. The first non-identifier character after the `$` character terminates this placeholder specification.
- `${identifier}` is equivalent to `$identifier`. It is required when valid identifier characters follow the placeholder but are not part of the placeholder, such as `"${noun}ification"`.

Any other appearance of `$` in the string will result in a *ValueError* being raised.

The *string* module provides a *Template* class that implements these rules. The methods of *Template* are:

class string.Template(*template*)

The constructor takes a single argument which is the template string.

substitute(*mapping*, ***kwds*)

Performs the template substitution, returning a new string. *mapping* is any dictionary-like object with keys that match the placeholders in the template. Alternatively, you can provide keyword arguments, where the keywords are the placeholders. When both *mapping* and *kwds* are given and there are duplicates, the placeholders from *kwds* take precedence.

safe_substitute(*mapping*, ***kwds*)

Like *substitute()*, except that if placeholders are missing from *mapping* and *kwds*, instead of raising a *KeyError* exception, the original placeholder will appear in the resulting string intact. Also, unlike with *substitute()*, any other appearances of the `$` will simply return `$` instead of raising *ValueError*.

While other exceptions may still occur, this method is called "safe" because substitutions always tries to return a usable string instead of raising an exception. In another sense, *safe_substitute()* may be anything other than safe, since it will silently ignore malformed templates containing dangling delimiters, unmatched braces, or placeholders that are not valid Python identifiers.

Template instances also provide one public data attribute:

template

This is the object passed to the constructor's *template* argument. In general, you shouldn't change it, but read-only access is not enforced.

Here is an example of how to use a Template:

```
>>> from string import Template
>>> s = Template('$who likes $what')
>>> s.substitute(who='tim', what='kung pao')
'tim likes kung pao'
>>> d = dict(who='tim')
>>> Template('Give $who $100').substitute(d)
Traceback (most recent call last):
...
ValueError: Invalid placeholder in string: line 1, col 11
>>> Template('$who likes $what').substitute(d)
Traceback (most recent call last):
...
KeyError: 'what'
```

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```
>>> Template('$who likes $what').safe_substitute(d)
'tim likes $what'
```

Advanced usage: you can derive subclasses of *Template* to customize the placeholder syntax, delimiter character, or the entire regular expression used to parse template strings. To do this, you can override these class attributes:

- *delimiter* – This is the literal string describing a placeholder introducing delimiter. The default value is `$`. Note that this should *not* be a regular expression, as the implementation will call *re.escape()* on this string as needed. Note further that you cannot change the delimiter after class creation (i.e. a different delimiter must be set in the subclass's class namespace).
- *idpattern* – This is the regular expression describing the pattern for non-braced placeholders. The default value is the regular expression `(?a:[_a-z][_a-z0-9]*)`. If this is given and *braceidpattern* is `None` this pattern will also apply to braced placeholders.

  Note: Since default *flags* is `re.IGNORECASE`, pattern `[a-z]` can match with some non-ASCII characters. That's why we use the local `a` flag here.

  Changed in version 3.7: *braceidpattern* can be used to define separate patterns used inside and outside the braces.
- *braceidpattern* – This is like *idpattern* but describes the pattern for braced placeholders. Defaults to `None` which means to fall back to *idpattern* (i.e. the same pattern is used both inside and outside braces). If given, this allows you to define different patterns for braced and unbraced placeholders.

  New in version 3.7.
- *flags* – The regular expression flags that will be applied when compiling the regular expression used for recognizing substitutions. The default value is `re.IGNORECASE`. Note that `re.VERBOSE` will always be added to the flags, so custom *idpattern*s must follow conventions for verbose regular expressions.

  New in version 3.2.

Alternatively, you can provide the entire regular expression pattern by overriding the class attribute *pattern*. If you do this, the value must be a regular expression object with four named capturing groups. The capturing groups correspond to the rules given above, along with the invalid placeholder rule:

- *escaped* – This group matches the escape sequence, e.g. `$$`, in the default pattern.
- *named* – This group matches the unbraced placeholder name; it should not include the delimiter in capturing group.
- *braced* – This group matches the brace enclosed placeholder name; it should not include either the delimiter or braces in the capturing group.
- *invalid* – This group matches any other delimiter pattern (usually a single delimiter), and it should appear last in the regular expression.

6.1.5 Helper functions

`string.capwords(`*s*, *sep=None*`)`

Split the argument into words using *str.split()*, capitalize each word using *str.capitalize()*, and join the capitalized words using *str.join()*. If the optional second argument *sep* is absent or `None`, runs of whitespace characters are replaced by a single space and leading and trailing whitespace are removed, otherwise *sep* is used to split and join the words.

6.2 re — Regular expression operations

Source code: Lib/re.py

This module provides regular expression matching operations similar to those found in Perl.

Both patterns and strings to be searched can be Unicode strings (*str*) as well as 8-bit strings (*bytes*). However, Unicode strings and 8-bit strings cannot be mixed: that is, you cannot match a Unicode string with a byte pattern or vice-versa; similarly, when asking for a substitution, the replacement string must be of the same type as both the pattern and the search string.

Regular expressions use the backslash character (`'\'`) to indicate special forms or to allow special characters to be used without invoking their special meaning. This collides with Python's usage of the same character for the same purpose in string literals; for example, to match a literal backslash, one might have to write `'\\\\'` as the pattern string, because the regular expression must be \\, and each backslash must be expressed as \\ inside a regular Python string literal.

The solution is to use Python's raw string notation for regular expression patterns; backslashes are not handled in any special way in a string literal prefixed with `'r'`. So `r"\n"` is a two-character string containing `'\'` and `'n'`, while `"\n"` is a one-character string containing a newline. Usually patterns will be expressed in Python code using this raw string notation.

It is important to note that most regular expression operations are available as module-level functions and methods on *compiled regular expressions*. The functions are shortcuts that don't require you to compile a regex object first, but miss some fine-tuning parameters.

See also:

The third-party regex module, which has an API compatible with the standard library *re* module, but offers additional functionality and a more thorough Unicode support.

6.2.1 Regular Expression Syntax

A regular expression (or RE) specifies a set of strings that matches it; the functions in this module let you check if a particular string matches a given regular expression (or if a given regular expression matches a particular string, which comes down to the same thing).

Regular expressions can be concatenated to form new regular expressions; if A and B are both regular expressions, then AB is also a regular expression. In general, if a string p matches A and another string q matches B, the string pq will match AB. This holds unless A or B contain low precedence operations; boundary conditions between A and B; or have numbered group references. Thus, complex expressions can easily be constructed from simpler primitive expressions like the ones described here. For details of the theory and implementation of regular expressions, consult the Friedl book *[Frie09]*, or almost any textbook about compiler construction.

A brief explanation of the format of regular expressions follows. For further information and a gentler presentation, consult the regex-howto.

Regular expressions can contain both special and ordinary characters. Most ordinary characters, like `'A'`, `'a'`, or `'0'`, are the simplest regular expressions; they simply match themselves. You can concatenate ordinary characters, so `last` matches the string `'last'`. (In the rest of this section, we'll write RE's in `this special style`, usually without quotes, and strings to be matched `'in single quotes'`.)

Some characters, like `'|'` or `'('`, are special. Special characters either stand for classes of ordinary characters, or affect how the regular expressions around them are interpreted.

Repetition qualifiers (`*`, `+`, `?`, `{m,n}`, etc) cannot be directly nested. This avoids ambiguity with the non-greedy modifier suffix `?`, and with other modifiers in other implementations. To apply a second repetition to

an inner repetition, parentheses may be used. For example, the expression `(?:a{6})*` matches any multiple of six `'a'` characters.

The special characters are:

`.` (Dot.) In the default mode, this matches any character except a newline. If the *DOTALL* flag has been specified, this matches any character including a newline.

`^` (Caret.) Matches the start of the string, and in *MULTILINE* mode also matches immediately after each newline.

`$` Matches the end of the string or just before the newline at the end of the string, and in *MULTILINE* mode also matches before a newline. `foo` matches both 'foo' and 'foobar', while the regular expression `foo$` matches only 'foo'. More interestingly, searching for `foo.$` in `'foo1\nfoo2\n'` matches 'foo2' normally, but 'foo1' in *MULTILINE* mode; searching for a single `$` in `'foo\n'` will find two (empty) matches: one just before the newline, and one at the end of the string.

`*` Causes the resulting RE to match 0 or more repetitions of the preceding RE, as many repetitions as are possible. `ab*` will match 'a', 'ab', or 'a' followed by any number of 'b's.

`+` Causes the resulting RE to match 1 or more repetitions of the preceding RE. `ab+` will match 'a' followed by any non-zero number of 'b's; it will not match just 'a'.

`?` Causes the resulting RE to match 0 or 1 repetitions of the preceding RE. `ab?` will match either 'a' or 'ab'.

`*?, +?, ??` The `'*'`, `'+'`, and `'?'` qualifiers are all *greedy*; they match as much text as possible. Sometimes this behaviour isn't desired; if the RE `<.*>` is matched against `'<a> b <c>'`, it will match the entire string, and not just `'<a>'`. Adding `?` after the qualifier makes it perform the match in *non-greedy* or *minimal* fashion; as *few* characters as possible will be matched. Using the RE `<.*?>` will match only `'<a>'`.

`{m}` Specifies that exactly m copies of the previous RE should be matched; fewer matches cause the entire RE not to match. For example, `a{6}` will match exactly six `'a'` characters, but not five.

`{m,n}` Causes the resulting RE to match from m to n repetitions of the preceding RE, attempting to match as many repetitions as possible. For example, `a{3,5}` will match from 3 to 5 `'a'` characters. Omitting m specifies a lower bound of zero, and omitting n specifies an infinite upper bound. As an example, `a{4,}b` will match `'aaaab'` or a thousand `'a'` characters followed by a `'b'`, but not `'aaab'`. The comma may not be omitted or the modifier would be confused with the previously described form.

`{m,n}?` Causes the resulting RE to match from m to n repetitions of the preceding RE, attempting to match as *few* repetitions as possible. This is the non-greedy version of the previous qualifier. For example, on the 6-character string `'aaaaaa'`, `a{3,5}` will match 5 `'a'` characters, while `a{3,5}?` will only match 3 characters.

`\` Either escapes special characters (permitting you to match characters like `'*'`, `'?'`, and so forth), or signals a special sequence; special sequences are discussed below.

If you're not using a raw string to express the pattern, remember that Python also uses the backslash as an escape sequence in string literals; if the escape sequence isn't recognized by Python's parser, the backslash and subsequent character are included in the resulting string. However, if Python would recognize the resulting sequence, the backslash should be repeated twice. This is complicated and hard to understand, so it's highly recommended that you use raw strings for all but the simplest expressions.

`[]` Used to indicate a set of characters. In a set:

- Characters can be listed individually, e.g. `[amk]` will match `'a'`, `'m'`, or `'k'`.
- Ranges of characters can be indicated by giving two characters and separating them by a `'-'`, for example `[a-z]` will match any lowercase ASCII letter, `[0-5][0-9]` will match all the two-digits numbers from `00` to `59`, and `[0-9A-Fa-f]` will match any hexadecimal digit. If `-` is escaped (e.g. `[a\-z]`) or if it's placed as the first or last character (e.g. `[-a]` or `[a-]`), it will match a literal `'-'`.

- Special characters lose their special meaning inside sets. For example, `[(+*)]` will match any of the literal characters `'('`, `'+'`, `'*'`, or `')'`.
- Character classes such as `\w` or `\S` (defined below) are also accepted inside a set, although the characters they match depends on whether *ASCII* or *LOCALE* mode is in force.
- Characters that are not within a range can be matched by *complementing* the set. If the first character of the set is `'^'`, all the characters that are *not* in the set will be matched. For example, `[^5]` will match any character except `'5'`, and `[^^]` will match any character except `'^'`. `^` has no special meaning if it's not the first character in the set.
- To match a literal `']'` inside a set, precede it with a backslash, or place it at the beginning of the set. For example, both `[()[\]{}]` and `[]()[{}]` will both match a parenthesis.
- Support of nested sets and set operations as in Unicode Technical Standard #18 might be added in the future. This would change the syntax, so to facilitate this change a *FutureWarning* will be raised in ambiguous cases for the time being. That include sets starting with a literal `'['` or containing literal character sequences `'--'`, `'&&'`, `'~~'`, and `'||'`. To avoid a warning escape them with a backslash.

Changed in version 3.7: *FutureWarning* is raised if a character set contains constructs that will change semantically in the future.

`| A|B`, where *A* and *B* can be arbitrary REs, creates a regular expression that will match either *A* or *B*. An arbitrary number of REs can be separated by the `'|'` in this way. This can be used inside groups (see below) as well. As the target string is scanned, REs separated by `'|'` are tried from left to right. When one pattern completely matches, that branch is accepted. This means that once *A* matches, *B* will not be tested further, even if it would produce a longer overall match. In other words, the `'|'` operator is never greedy. To match a literal `'|'`, use `\|`, or enclose it inside a character class, as in `[|]`.

`(...)` Matches whatever regular expression is inside the parentheses, and indicates the start and end of a group; the contents of a group can be retrieved after a match has been performed, and can be matched later in the string with the `\number` special sequence, described below. To match the literals `'('` or `')'`, use `\(` or `\)`, or enclose them inside a character class: `[(]`, `[)]`.

`(?...)` This is an extension notation (a `'?'` following a `'('` is not meaningful otherwise). The first character after the `'?'` determines what the meaning and further syntax of the construct is. Extensions usually do not create a new group; `(?P<name>...)` is the only exception to this rule. Following are the currently supported extensions.

`(?aiLmsux)` (One or more letters from the set `'a'`, `'i'`, `'L'`, `'m'`, `'s'`, `'u'`, `'x'`.) The group matches the empty string; the letters set the corresponding flags: *re.A* (ASCII-only matching), *re.I* (ignore case), *re.L* (locale dependent), *re.M* (multi-line), *re.S* (dot matches all), `re.U` (Unicode matching), and *re.X* (verbose), for the entire regular expression. (The flags are described in *Module Contents*.) This is useful if you wish to include the flags as part of the regular expression, instead of passing a *flag* argument to the *re.compile()* function. Flags should be used first in the expression string.

`(?:...)` A non-capturing version of regular parentheses. Matches whatever regular expression is inside the parentheses, but the substring matched by the group *cannot* be retrieved after performing a match or referenced later in the pattern.

`(?aiLmsux-imsx:...)` (Zero or more letters from the set `'a'`, `'i'`, `'L'`, `'m'`, `'s'`, `'u'`, `'x'`, optionally followed by `'-'` followed by one or more letters from the `'i'`, `'m'`, `'s'`, `'x'`.) The letters set or remove the corresponding flags: *re.A* (ASCII-only matching), *re.I* (ignore case), *re.L* (locale dependent), *re.M* (multi-line), *re.S* (dot matches all), `re.U` (Unicode matching), and *re.X* (verbose), for the part of the expression. (The flags are described in *Module Contents*.)

The letters `'a'`, `'L'` and `'u'` are mutually exclusive when used as inline flags, so they can't be combined or follow `'-'`. Instead, when one of them appears in an inline group, it overrides the matching mode

in the enclosing group. In Unicode patterns `(?a:...)` switches to ASCII-only matching, and `(?u:...)` switches to Unicode matching (default). In byte pattern `(?L:...)` switches to locale depending matching, and `(?a:...)` switches to ASCII-only matching (default). This override is only in effect for the narrow inline group, and the original matching mode is restored outside of the group.

New in version 3.6.

Changed in version 3.7: The letters `'a'`, `'L'` and `'u'` also can be used in a group.

`(?P<name>...)` Similar to regular parentheses, but the substring matched by the group is accessible via the symbolic group name *name*. Group names must be valid Python identifiers, and each group name must be defined only once within a regular expression. A symbolic group is also a numbered group, just as if the group were not named.

Named groups can be referenced in three contexts. If the pattern is `(?P<quote>['"]).*?(?P=quote)` (i.e. matching a string quoted with either single or double quotes):

Context of reference to group "quote"	Ways to reference it
in the same pattern itself	• `(?P=quote)` (as shown) • `\1`
when processing match object *m*	• `m.group('quote')` • `m.end('quote')` (etc.)
in a string passed to the *repl* argument of `re.sub()`	• `\g<quote>` • `\g<1>` • `\1`

`(?P=name)` A backreference to a named group; it matches whatever text was matched by the earlier group named *name*.

`(?#...)` A comment; the contents of the parentheses are simply ignored.

`(?=...)` Matches if `...` matches next, but doesn't consume any of the string. This is called a *lookahead assertion*. For example, `Isaac (?=Asimov)` will match `'Isaac '` only if it's followed by `'Asimov'`.

`(?!...)` Matches if `...` doesn't match next. This is a *negative lookahead assertion*. For example, `Isaac (?!Asimov)` will match `'Isaac '` only if it's *not* followed by `'Asimov'`.

`(?<=...)` Matches if the current position in the string is preceded by a match for `...` that ends at the current position. This is called a *positive lookbehind assertion*. `(?<=abc)def` will find a match in `'abcdef'`, since the lookbehind will back up 3 characters and check if the contained pattern matches. The contained pattern must only match strings of some fixed length, meaning that `abc` or `a|b` are allowed, but `a*` and `a{3,4}` are not. Note that patterns which start with positive lookbehind assertions will not match at the beginning of the string being searched; you will most likely want to use the *search()* function rather than the *match()* function:

```
>>> import re
>>> m = re.search('(?<=abc)def', 'abcdef')
>>> m.group(0)
'def'
```

This example looks for a word following a hyphen:

```
>>> m = re.search(r'(?<=-)\w+', 'spam-egg')
>>> m.group(0)
'egg'
```

Changed in version 3.5: Added support for group references of fixed length.

`(?<!...)` Matches if the current position in the string is not preceded by a match for `...`. This is called a *negative lookbehind assertion*. Similar to positive lookbehind assertions, the contained pattern must only match strings of some fixed length. Patterns which start with negative lookbehind assertions may match at the beginning of the string being searched.

`(?(id/name)yes-pattern|no-pattern)` Will try to match with `yes-pattern` if the group with given *id* or *name* exists, and with `no-pattern` if it doesn't. `no-pattern` is optional and can be omitted. For example, `(<)?(\w+@\w+(?:\.\w+)+)(?(1)>|$)` is a poor email matching pattern, which will match with `'<user@host.com>'` as well as `'user@host.com'`, but not with `'<user@host.com'` nor `'user@host.com>'`.

The special sequences consist of `'\'` and a character from the list below. If the ordinary character is not an ASCII digit or an ASCII letter, then the resulting RE will match the second character. For example, `\$` matches the character `'$'`.

`\number` Matches the contents of the group of the same number. Groups are numbered starting from 1. For example, `(.+) \1` matches `'the the'` or `'55 55'`, but not `'thethe'` (note the space after the group). This special sequence can only be used to match one of the first 99 groups. If the first digit of *number* is 0, or *number* is 3 octal digits long, it will not be interpreted as a group match, but as the character with octal value *number*. Inside the `'['` and `']'` of a character class, all numeric escapes are treated as characters.

`\A` Matches only at the start of the string.

`\b` Matches the empty string, but only at the beginning or end of a word. A word is defined as a sequence of word characters. Note that formally, `\b` is defined as the boundary between a `\w` and a `\W` character (or vice versa), or between `\w` and the beginning/end of the string. This means that `r'\bfoo\b'` matches `'foo'`, `'foo.'`, `'(foo)'`, `'bar foo baz'` but not `'foobar'` or `'foo3'`.

By default Unicode alphanumerics are the ones used in Unicode patterns, but this can be changed by using the *ASCII* flag. Word boundaries are determined by the current locale if the *LOCALE* flag is used. Inside a character range, `\b` represents the backspace character, for compatibility with Python's string literals.

`\B` Matches the empty string, but only when it is *not* at the beginning or end of a word. This means that `r'py\B'` matches `'python'`, `'py3'`, `'py2'`, but not `'py'`, `'py.'`, or `'py!'`. `\B` is just the opposite of `\b`, so word characters in Unicode patterns are Unicode alphanumerics or the underscore, although this can be changed by using the *ASCII* flag. Word boundaries are determined by the current locale if the *LOCALE* flag is used.

`\d`

For Unicode (str) patterns: Matches any Unicode decimal digit (that is, any character in Unicode character category [Nd]). This includes `[0-9]`, and also many other digit characters. If the *ASCII* flag is used only `[0-9]` is matched.

For 8-bit (bytes) patterns: Matches any decimal digit; this is equivalent to `[0-9]`.

`\D` Matches any character which is not a decimal digit. This is the opposite of `\d`. If the *ASCII* flag is used this becomes the equivalent of `[^0-9]`.

`\s`

For Unicode (str) patterns: Matches Unicode whitespace characters (which includes `[ \t\n\r\f\v]`, and also many other characters, for example the non-breaking spaces man-

dated by typography rules in many languages). If the *ASCII* flag is used, only `[ \t\n\r\f\v]` is matched.

For 8-bit (bytes) patterns: Matches characters considered whitespace in the ASCII character set; this is equivalent to `[ \t\n\r\f\v]`.

`\S` Matches any character which is not a whitespace character. This is the opposite of `\s`. If the *ASCII* flag is used this becomes the equivalent of `[^ \t\n\r\f\v]`.

`\w`

For Unicode (str) patterns: Matches Unicode word characters; this includes most characters that can be part of a word in any language, as well as numbers and the underscore. If the *ASCII* flag is used, only `[a-zA-Z0-9_]` is matched.

For 8-bit (bytes) patterns: Matches characters considered alphanumeric in the ASCII character set; this is equivalent to `[a-zA-Z0-9_]`. If the *LOCALE* flag is used, matches characters considered alphanumeric in the current locale and the underscore.

`\W` Matches any character which is not a word character. This is the opposite of `\w`. If the *ASCII* flag is used this becomes the equivalent of `[^a-zA-Z0-9_]`. If the *LOCALE* flag is used, matches characters considered alphanumeric in the current locale and the underscore.

`\Z` Matches only at the end of the string.

Most of the standard escapes supported by Python string literals are also accepted by the regular expression parser:

```
\a      \b      \f      \n
\r      \t      \u      \U
\v      \x      \\
```

(Note that `\b` is used to represent word boundaries, and means "backspace" only inside character classes.)

`'\u'` and `'\U'` escape sequences are only recognized in Unicode patterns. In bytes patterns they are errors.

Octal escapes are included in a limited form. If the first digit is a 0, or if there are three octal digits, it is considered an octal escape. Otherwise, it is a group reference. As for string literals, octal escapes are always at most three digits in length.

Changed in version 3.3: The `'\u'` and `'\U'` escape sequences have been added.

Changed in version 3.6: Unknown escapes consisting of `'\'` and an ASCII letter now are errors.

6.2.2 Module Contents

The module defines several functions, constants, and an exception. Some of the functions are simplified versions of the full featured methods for compiled regular expressions. Most non-trivial applications always use the compiled form.

Changed in version 3.6: Flag constants are now instances of `RegexFlag`, which is a subclass of *enum.IntFlag*.

`re.compile(`*pattern*, *flags=0*`)`

Compile a regular expression pattern into a *regular expression object*, which can be used for matching using its *match()*, *search()* and other methods, described below.

The expression's behaviour can be modified by specifying a *flags* value. Values can be any of the following variables, combined using bitwise OR (the `|` operator).

The sequence

```
prog = re.compile(pattern)
result = prog.match(string)
```

is equivalent to

```
result = re.match(pattern, string)
```

but using *re.compile()* and saving the resulting regular expression object for reuse is more efficient when the expression will be used several times in a single program.

Note: The compiled versions of the most recent patterns passed to *re.compile()* and the module-level matching functions are cached, so programs that use only a few regular expressions at a time needn't worry about compiling regular expressions.

---

re.A
re.ASCII

Make `\w`, `\W`, `\b`, `\B`, `\d`, `\D`, `\s` and `\S` perform ASCII-only matching instead of full Unicode matching. This is only meaningful for Unicode patterns, and is ignored for byte patterns. Corresponds to the inline flag `(?a)`.

Note that for backward compatibility, the `re.U` flag still exists (as well as its synonym `re.UNICODE` and its embedded counterpart `(?u)`), but these are redundant in Python 3 since matches are Unicode by default for strings (and Unicode matching isn't allowed for bytes).

re.DEBUG

Display debug information about compiled expression. No corresponding inline flag.

re.I
re.IGNORECASE

Perform case-insensitive matching; expressions like `[A-Z]` will also match lowercase letters. Full Unicode matching (such as Ü matching ü) also works unless the *re.ASCII* flag is used to disable non-ASCII matches. The current locale does not change the effect of this flag unless the *re.LOCALE* flag is also used. Corresponds to the inline flag `(?i)`.

Note that when the Unicode patterns `[a-z]` or `[A-Z]` are used in combination with the *IGNORECASE* flag, they will match the 52 ASCII letters and 4 additional non-ASCII letters: 'İ' (U+0130, Latin capital letter I with dot above), 'ı' (U+0131, Latin small letter dotless i), 'ſ' (U+017F, Latin small letter long s) and 'K' (U+212A, Kelvin sign). If the *ASCII* flag is used, only letters 'a' to 'z' and 'A' to 'Z' are matched.

re.L
re.LOCALE

Make `\w`, `\W`, `\b`, `\B` and case-insensitive matching dependent on the current locale. This flag can be used only with bytes patterns. The use of this flag is discouraged as the locale mechanism is very unreliable, it only handles one "culture" at a time, and it only works with 8-bit locales. Unicode matching is already enabled by default in Python 3 for Unicode (str) patterns, and it is able to handle different locales/languages. Corresponds to the inline flag `(?L)`.

Changed in version 3.6: *re.LOCALE* can be used only with bytes patterns and is not compatible with *re.ASCII*.

Changed in version 3.7: Compiled regular expression objects with the *re.LOCALE* flag no longer depend on the locale at compile time. Only the locale at matching time affects the result of matching.

re.M
re.MULTILINE

When specified, the pattern character `'^'` matches at the beginning of the string and at the beginning of each line (immediately following each newline); and the pattern character `'$'` matches at the end of

the string and at the end of each line (immediately preceding each newline). By default, `'^'` matches only at the beginning of the string, and `'$'` only at the end of the string and immediately before the newline (if any) at the end of the string. Corresponds to the inline flag `(?m)`.

re.S
re.DOTALL
Make the `'.'` special character match any character at all, including a newline; without this flag, `'.'` will match anything *except* a newline. Corresponds to the inline flag `(?s)`.

re.X
re.VERBOSE
This flag allows you to write regular expressions that look nicer and are more readable by allowing you to visually separate logical sections of the pattern and add comments. Whitespace within the pattern is ignored, except when in a character class, or when preceded by an unescaped backslash, or within tokens like `*?`, `(?:` or `(?P<...>`. When a line contains a `#` that is not in a character class and is not preceded by an unescaped backslash, all characters from the leftmost such `#` through the end of the line are ignored.

This means that the two following regular expression objects that match a decimal number are functionally equal:

```
a = re.compile(r"""\d +  # the integral part
                  \.    # the decimal point
                  \d *  # some fractional digits""", re.X)
b = re.compile(r"\d+\.\d*")
```

Corresponds to the inline flag `(?x)`.

re.search(*pattern*, *string*, *flags=0*)
Scan through *string* looking for the first location where the regular expression *pattern* produces a match, and return a corresponding *match object*. Return `None` if no position in the string matches the pattern; note that this is different from finding a zero-length match at some point in the string.

re.match(*pattern*, *string*, *flags=0*)
If zero or more characters at the beginning of *string* match the regular expression *pattern*, return a corresponding *match object*. Return `None` if the string does not match the pattern; note that this is different from a zero-length match.

Note that even in *MULTILINE* mode, *re.match()* will only match at the beginning of the string and not at the beginning of each line.

If you want to locate a match anywhere in *string*, use *search()* instead (see also *search() vs. match()*).

re.fullmatch(*pattern*, *string*, *flags=0*)
If the whole *string* matches the regular expression *pattern*, return a corresponding *match object*. Return `None` if the string does not match the pattern; note that this is different from a zero-length match.

New in version 3.4.

re.split(*pattern*, *string*, *maxsplit=0*, *flags=0*)
Split *string* by the occurrences of *pattern*. If capturing parentheses are used in *pattern*, then the text of all groups in the pattern are also returned as part of the resulting list. If *maxsplit* is nonzero, at most *maxsplit* splits occur, and the remainder of the string is returned as the final element of the list.

```
>>> re.split(r'\W+', 'Words, words, words.')
['Words', 'words', 'words', '']
>>> re.split(r'(\W+)', 'Words, words, words.')
['Words', ', ', 'words', ', ', 'words', '.', '']
>>> re.split(r'\W+', 'Words, words, words.', 1)
['Words', 'words, words.']
```

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```
>>> re.split('[a-f]+', '0a3B9', flags=re.IGNORECASE)
['0', '3', '9']
```

If there are capturing groups in the separator and it matches at the start of the string, the result will start with an empty string. The same holds for the end of the string:

```
>>> re.split(r'(\W+)', '...words, words...')
['', '...', 'words', ', ', 'words', '...', '']
```

That way, separator components are always found at the same relative indices within the result list.

Empty matches for the pattern split the string only when not adjacent to a previous empty match.

```
>>> re.split(r'\b', 'Words, words, words.')
['', 'Words', ', ', 'words', ', ', 'words', '.']
>>> re.split(r'\W*', '...words...')
['', '', 'w', 'o', 'r', 'd', 's', '', '']
>>> re.split(r'(\W*)', '...words...')
['', '...', '', '', 'w', '', 'o', '', 'r', '', 'd', '', 's', '...', '', '', '']
```

Changed in version 3.1: Added the optional flags argument.

Changed in version 3.7: Added support of splitting on a pattern that could match an empty string.

re.findall(*pattern*, *string*, *flags=0*)

Return all non-overlapping matches of *pattern* in *string*, as a list of strings. The *string* is scanned left-to-right, and matches are returned in the order found. If one or more groups are present in the pattern, return a list of groups; this will be a list of tuples if the pattern has more than one group. Empty matches are included in the result.

Changed in version 3.7: Non-empty matches can now start just after a previous empty match.

re.finditer(*pattern*, *string*, *flags=0*)

Return an *iterator* yielding *match objects* over all non-overlapping matches for the RE *pattern* in *string*. The *string* is scanned left-to-right, and matches are returned in the order found. Empty matches are included in the result.

Changed in version 3.7: Non-empty matches can now start just after a previous empty match.

re.sub(*pattern*, *repl*, *string*, *count=0*, *flags=0*)

Return the string obtained by replacing the leftmost non-overlapping occurrences of *pattern* in *string* by the replacement *repl*. If the pattern isn't found, *string* is returned unchanged. *repl* can be a string or a function; if it is a string, any backslash escapes in it are processed. That is, `\n` is converted to a single newline character, `\r` is converted to a carriage return, and so forth. Unknown escapes such as `\&` are left alone. Backreferences, such as `\6`, are replaced with the substring matched by group 6 in the pattern. For example:

```
>>> re.sub(r'def\s+([a-zA-Z_][a-zA-Z_0-9]*)\s*\(\s*\):',
...        r'static PyObject*\npy_\1(void)\n{',
...        'def myfunc():')
'static PyObject*\npy_myfunc(void)\n{'
```

If *repl* is a function, it is called for every non-overlapping occurrence of *pattern*. The function takes a single *match object* argument, and returns the replacement string. For example:

```
>>> def dashrepl(matchobj):
...     if matchobj.group(0) == '-': return ' '
...     else: return '-'
```

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```
>>> re.sub('-{1,2}', dashrepl, 'pro----gram-files')
'pro--gram files'
>>> re.sub(r'\sAND\s', ' & ', 'Baked Beans And Spam', flags=re.IGNORECASE)
'Baked Beans & Spam'
```

The pattern may be a string or a *pattern object*.

The optional argument *count* is the maximum number of pattern occurrences to be replaced; *count* must be a non-negative integer. If omitted or zero, all occurrences will be replaced. Empty matches for the pattern are replaced only when not adjacent to a previous empty match, so `sub('x*', '-', 'abxd')` returns `'-a-b--d-'`.

In string-type *repl* arguments, in addition to the character escapes and backreferences described above, `\g<name>` will use the substring matched by the group named `name`, as defined by the `(?P<name>...)` syntax. `\g<number>` uses the corresponding group number; `\g<2>` is therefore equivalent to `\2`, but isn't ambiguous in a replacement such as `\g<2>0`. `\20` would be interpreted as a reference to group 20, not a reference to group 2 followed by the literal character `'0'`. The backreference `\g<0>` substitutes in the entire substring matched by the RE.

Changed in version 3.1: Added the optional flags argument.

Changed in version 3.5: Unmatched groups are replaced with an empty string.

Changed in version 3.6: Unknown escapes in *pattern* consisting of `'\'` and an ASCII letter now are errors.

Changed in version 3.7: Unknown escapes in *repl* consisting of `'\'` and an ASCII letter now are errors.

Empty matches for the pattern are replaced when adjacent to a previous non-empty match.

re.subn(*pattern*, *repl*, *string*, *count=0*, *flags=0*)

Perform the same operation as *sub()*, but return a tuple `(new_string, number_of_subs_made)`.

Changed in version 3.1: Added the optional flags argument.

Changed in version 3.5: Unmatched groups are replaced with an empty string.

re.escape(*pattern*)

Escape special characters in *pattern*. This is useful if you want to match an arbitrary literal string that may have regular expression metacharacters in it. For example:

```
>>> print(re.escape('python.exe'))
python\.exe

>>> legal_chars = string.ascii_lowercase + string.digits + "!#$%&'*+-.^_`|~:"
>>> print('[%s]+' % re.escape(legal_chars))
[abcdefghijklmnopqrstuvwxyz0123456789!\#\$%\&'\*\+\-\.\^_`\|\~:]+

>>> operators = ['+', '-', '*', '/', '**']
>>> print('|'.join(map(re.escape, sorted(operators, reverse=True))))
/|\-|\+|\*\*|\*
```

This functions must not be used for the replacement string in *sub()* and *subn()*, only backslashes should be escaped. For example:

```
>>> digits_re = r'\d+'
>>> sample = '/usr/sbin/sendmail - 0 errors, 12 warnings'
>>> print(re.sub(digits_re, digits_re.replace('\\', r'\\'), sample))
/usr/sbin/sendmail - \d+ errors, \d+ warnings
```

Changed in version 3.3: The `'_'` character is no longer escaped.

Changed in version 3.7: Only characters that can have special meaning in a regular expression are escaped.

`re.purge()`
Clear the regular expression cache.

exception `re.error`(*msg*, *pattern=None*, *pos=None*)
Exception raised when a string passed to one of the functions here is not a valid regular expression (for example, it might contain unmatched parentheses) or when some other error occurs during compilation or matching. It is never an error if a string contains no match for a pattern. The error instance has the following additional attributes:

msg
The unformatted error message.

pattern
The regular expression pattern.

pos
The index in *pattern* where compilation failed (may be `None`).

lineno
The line corresponding to *pos* (may be `None`).

colno
The column corresponding to *pos* (may be `None`).

Changed in version 3.5: Added additional attributes.

6.2.3 Regular Expression Objects

Compiled regular expression objects support the following methods and attributes:

`Pattern.search`(*string*[, *pos*[, *endpos*]])
Scan through *string* looking for the first location where this regular expression produces a match, and return a corresponding *match object*. Return `None` if no position in the string matches the pattern; note that this is different from finding a zero-length match at some point in the string.

The optional second parameter *pos* gives an index in the string where the search is to start; it defaults to `0`. This is not completely equivalent to slicing the string; the `'^'` pattern character matches at the real beginning of the string and at positions just after a newline, but not necessarily at the index where the search is to start.

The optional parameter *endpos* limits how far the string will be searched; it will be as if the string is *endpos* characters long, so only the characters from *pos* to `endpos - 1` will be searched for a match. If *endpos* is less than *pos*, no match will be found; otherwise, if *rx* is a compiled regular expression object, `rx.search(string, 0, 50)` is equivalent to `rx.search(string[:50], 0)`.

```
>>> pattern = re.compile("d")
>>> pattern.search("dog")     # Match at index 0
<re.Match object; span=(0, 1), match='d'>
>>> pattern.search("dog", 1)  # No match; search doesn't include the "d"
```

`Pattern.match`(*string*[, *pos*[, *endpos*]])
If zero or more characters at the *beginning* of *string* match this regular expression, return a corresponding *match object*. Return `None` if the string does not match the pattern; note that this is different from a zero-length match.

The optional *pos* and *endpos* parameters have the same meaning as for the *search()* method.

```
>>> pattern = re.compile("o")
>>> pattern.match("dog")      # No match as "o" is not at the start of "dog".
>>> pattern.match("dog", 1)   # Match as "o" is the 2nd character of "dog".
<re.Match object; span=(1, 2), match='o'>
```

If you want to locate a match anywhere in *string*, use *search()* instead (see also *search() vs. match()*).

Pattern.fullmatch(*string*[, *pos*[, *endpos*]])

If the whole *string* matches this regular expression, return a corresponding *match object*. Return None if the string does not match the pattern; note that this is different from a zero-length match.

The optional *pos* and *endpos* parameters have the same meaning as for the *search()* method.

```
>>> pattern = re.compile("o[gh]")
>>> pattern.fullmatch("dog")      # No match as "o" is not at the start of "dog".
>>> pattern.fullmatch("ogre")     # No match as not the full string matches.
>>> pattern.fullmatch("doggie", 1, 3)   # Matches within given limits.
<re.Match object; span=(1, 3), match='og'>
```

New in version 3.4.

Pattern.split(*string*, *maxsplit=0*)

Identical to the *split()* function, using the compiled pattern.

Pattern.findall(*string*[, *pos*[, *endpos*]])

Similar to the *findall()* function, using the compiled pattern, but also accepts optional *pos* and *endpos* parameters that limit the search region like for *search()*.

Pattern.finditer(*string*[, *pos*[, *endpos*]])

Similar to the *finditer()* function, using the compiled pattern, but also accepts optional *pos* and *endpos* parameters that limit the search region like for *search()*.

Pattern.sub(*repl*, *string*, *count=0*)

Identical to the *sub()* function, using the compiled pattern.

Pattern.subn(*repl*, *string*, *count=0*)

Identical to the *subn()* function, using the compiled pattern.

Pattern.flags

The regex matching flags. This is a combination of the flags given to *compile()*, any (?...) inline flags in the pattern, and implicit flags such as UNICODE if the pattern is a Unicode string.

Pattern.groups

The number of capturing groups in the pattern.

Pattern.groupindex

A dictionary mapping any symbolic group names defined by (?P<id>) to group numbers. The dictionary is empty if no symbolic groups were used in the pattern.

Pattern.pattern

The pattern string from which the pattern object was compiled.

Changed in version 3.7: Added support of *copy.copy()* and *copy.deepcopy()*. Compiled regular expression objects are considered atomic.

6.2.4 Match Objects

Match objects always have a boolean value of True. Since *match()* and *search()* return None when there is no match, you can test whether there was a match with a simple if statement:

```
match = re.search(pattern, string)
if match:
    process(match)
```

Match objects support the following methods and attributes:

`Match.expand(`*template*`)`
: Return the string obtained by doing backslash substitution on the template string *template*, as done by the *sub()* method. Escapes such as `\n` are converted to the appropriate characters, and numeric backreferences (`\1`, `\2`) and named backreferences (`\g<1>`, `\g<name>`) are replaced by the contents of the corresponding group.

  Changed in version 3.5: Unmatched groups are replaced with an empty string.

`Match.group(`[*group1*, ...]`)`
: Returns one or more subgroups of the match. If there is a single argument, the result is a single string; if there are multiple arguments, the result is a tuple with one item per argument. Without arguments, *group1* defaults to zero (the whole match is returned). If a *groupN* argument is zero, the corresponding return value is the entire matching string; if it is in the inclusive range [1..99], it is the string matching the corresponding parenthesized group. If a group number is negative or larger than the number of groups defined in the pattern, an *IndexError* exception is raised. If a group is contained in a part of the pattern that did not match, the corresponding result is `None`. If a group is contained in a part of the pattern that matched multiple times, the last match is returned.

  ```
  >>> m = re.match(r"(\w+) (\w+)", "Isaac Newton, physicist")
  >>> m.group(0)       # The entire match
  'Isaac Newton'
  >>> m.group(1)       # The first parenthesized subgroup.
  'Isaac'
  >>> m.group(2)       # The second parenthesized subgroup.
  'Newton'
  >>> m.group(1, 2)    # Multiple arguments give us a tuple.
  ('Isaac', 'Newton')
  ```

  If the regular expression uses the `(?P<name>...)` syntax, the *groupN* arguments may also be strings identifying groups by their group name. If a string argument is not used as a group name in the pattern, an *IndexError* exception is raised.

  A moderately complicated example:

  ```
  >>> m = re.match(r"(?P<first_name>\w+) (?P<last_name>\w+)", "Malcolm Reynolds")
  >>> m.group('first_name')
  'Malcolm'
  >>> m.group('last_name')
  'Reynolds'
  ```

  Named groups can also be referred to by their index:

  ```
  >>> m.group(1)
  'Malcolm'
  >>> m.group(2)
  'Reynolds'
  ```

  If a group matches multiple times, only the last match is accessible:

  ```
  >>> m = re.match(r"(..)+", "a1b2c3")  # Matches 3 times.
  >>> m.group(1)                        # Returns only the last match.
  'c3'
  ```

Match.__getitem__(*g*)
This is identical to `m.group(g)`. This allows easier access to an individual group from a match:

```
>>> m = re.match(r"(\w+) (\w+)", "Isaac Newton, physicist")
>>> m[0]       # The entire match
'Isaac Newton'
>>> m[1]       # The first parenthesized subgroup.
'Isaac'
>>> m[2]       # The second parenthesized subgroup.
'Newton'
```

New in version 3.6.

Match.groups(*default=None*)
Return a tuple containing all the subgroups of the match, from 1 up to however many groups are in the pattern. The *default* argument is used for groups that did not participate in the match; it defaults to `None`.

For example:

```
>>> m = re.match(r"(\d+)\.(\d+)", "24.1632")
>>> m.groups()
('24', '1632')
```

If we make the decimal place and everything after it optional, not all groups might participate in the match. These groups will default to `None` unless the *default* argument is given:

```
>>> m = re.match(r"(\d+)\.?(\d+)?", "24")
>>> m.groups()      # Second group defaults to None.
('24', None)
>>> m.groups('0')   # Now, the second group defaults to '0'.
('24', '0')
```

Match.groupdict(*default=None*)
Return a dictionary containing all the *named* subgroups of the match, keyed by the subgroup name. The *default* argument is used for groups that did not participate in the match; it defaults to `None`. For example:

```
>>> m = re.match(r"(?P<first_name>\w+) (?P<last_name>\w+)", "Malcolm Reynolds")
>>> m.groupdict()
{'first_name': 'Malcolm', 'last_name': 'Reynolds'}
```

Match.start(*[group]*)
Match.end(*[group]*)
Return the indices of the start and end of the substring matched by *group*; *group* defaults to zero (meaning the whole matched substring). Return `-1` if *group* exists but did not contribute to the match. For a match object *m*, and a group *g* that did contribute to the match, the substring matched by group *g* (equivalent to `m.group(g)`) is

```
m.string[m.start(g):m.end(g)]
```

Note that `m.start(group)` will equal `m.end(group)` if *group* matched a null string. For example, after `m = re.search('b(c?)', 'cba')`, `m.start(0)` is 1, `m.end(0)` is 2, `m.start(1)` and `m.end(1)` are both 2, and `m.start(2)` raises an *IndexError* exception.

An example that will remove *remove_this* from email addresses:

```
>>> email = "tony@tiremove_thisger.net"
>>> m = re.search("remove_this", email)
>>> email[:m.start()] + email[m.end():]
'tony@tiger.net'
```

`Match.span([group])`
For a match *m*, return the 2-tuple `(m.start(group), m.end(group))`. Note that if *group* did not contribute to the match, this is `(-1, -1)`. *group* defaults to zero, the entire match.

`Match.pos`
The value of *pos* which was passed to the *search()* or *match()* method of a *regex object*. This is the index into the string at which the RE engine started looking for a match.

`Match.endpos`
The value of *endpos* which was passed to the *search()* or *match()* method of a *regex object*. This is the index into the string beyond which the RE engine will not go.

`Match.lastindex`
The integer index of the last matched capturing group, or `None` if no group was matched at all. For example, the expressions `(a)b`, `((a)(b))`, and `((ab))` will have `lastindex == 1` if applied to the string `'ab'`, while the expression `(a)(b)` will have `lastindex == 2`, if applied to the same string.

`Match.lastgroup`
The name of the last matched capturing group, or `None` if the group didn't have a name, or if no group was matched at all.

`Match.re`
The *regular expression object* whose *match()* or *search()* method produced this match instance.

`Match.string`
The string passed to *match()* or *search()*.

Changed in version 3.7: Added support of *copy.copy()* and *copy.deepcopy()*. Match objects are considered atomic.

6.2.5 Regular Expression Examples

Checking for a Pair

In this example, we'll use the following helper function to display match objects a little more gracefully:

```
def displaymatch(match):
    if match is None:
        return None
    return '<Match: %r, groups=%r>' % (match.group(), match.groups())
```

Suppose you are writing a poker program where a player's hand is represented as a 5-character string with each character representing a card, "a" for ace, "k" for king, "q" for queen, "j" for jack, "t" for 10, and "2" through "9" representing the card with that value.

To see if a given string is a valid hand, one could do the following:

```
>>> valid = re.compile(r"^[a2-9tjqk]{5}$")
>>> displaymatch(valid.match("akt5q"))  # Valid.
"<Match: 'akt5q', groups=()>"
>>> displaymatch(valid.match("akt5e"))  # Invalid.
>>> displaymatch(valid.match("akt"))    # Invalid.
>>> displaymatch(valid.match("727ak"))  # Valid.
"<Match: '727ak', groups=()>"
```

That last hand, "727ak", contained a pair, or two of the same valued cards. To match this with a regular expression, one could use backreferences as such:

```
>>> pair = re.compile(r".*(.).*\1")
>>> displaymatch(pair.match("717ak"))     # Pair of 7s.
"<Match: '717', groups=('7',)>"
>>> displaymatch(pair.match("718ak"))     # No pairs.
>>> displaymatch(pair.match("354aa"))     # Pair of aces.
"<Match: '354aa', groups=('a',)>"
```

To find out what card the pair consists of, one could use the *group()* method of the match object in the following manner:

```
>>> pair.match("717ak").group(1)
'7'

# Error because re.match() returns None, which doesn't have a group() method:
>>> pair.match("718ak").group(1)
Traceback (most recent call last):
  File "<pyshell#23>", line 1, in <module>
    re.match(r".*(.).*\1", "718ak").group(1)
AttributeError: 'NoneType' object has no attribute 'group'

>>> pair.match("354aa").group(1)
'a'
```

Simulating scanf()

Python does not currently have an equivalent to `scanf()`. Regular expressions are generally more powerful, though also more verbose, than `scanf()` format strings. The table below offers some more-or-less equivalent mappings between `scanf()` format tokens and regular expressions.

scanf() Token	Regular Expression
%c	.
%5c	.{5}
%d	[-+]?\d+
%e, %E, %f, %g	[-+]?(\d+(\.\d*)?|\.\d+)([eE][-+]?\d+)?
%i	[-+]?(0[xX][\dA-Fa-f]+|0[0-7]*|\d+)
%o	[-+]?[0-7]+
%s	\S+
%u	\d+
%x, %X	[-+]?(0[xX])?[\dA-Fa-f]+

To extract the filename and numbers from a string like

```
/usr/sbin/sendmail - 0 errors, 4 warnings
```

you would use a `scanf()` format like

```
%s - %d errors, %d warnings
```

The equivalent regular expression would be

```
(\S+) - (\d+) errors, (\d+) warnings
```

search() vs. match()

Python offers two different primitive operations based on regular expressions: *re.match()* checks for a match only at the beginning of the string, while *re.search()* checks for a match anywhere in the string (this is what Perl does by default).

For example:

```
>>> re.match("c", "abcdef")    # No match
>>> re.search("c", "abcdef")   # Match
<re.Match object; span=(2, 3), match='c'>
```

Regular expressions beginning with `'^'` can be used with *search()* to restrict the match at the beginning of the string:

```
>>> re.match("c", "abcdef")    # No match
>>> re.search("^c", "abcdef")  # No match
>>> re.search("^a", "abcdef")  # Match
<re.Match object; span=(0, 1), match='a'>
```

Note however that in *MULTILINE* mode *match()* only matches at the beginning of the string, whereas using *search()* with a regular expression beginning with `'^'` will match at the beginning of each line.

```
>>> re.match('X', 'A\nB\nX', re.MULTILINE)  # No match
>>> re.search('^X', 'A\nB\nX', re.MULTILINE)  # Match
<re.Match object; span=(4, 5), match='X'>
```

Making a Phonebook

split() splits a string into a list delimited by the passed pattern. The method is invaluable for converting textual data into data structures that can be easily read and modified by Python as demonstrated in the following example that creates a phonebook.

First, here is the input. Normally it may come from a file, here we are using triple-quoted string syntax:

```
>>> text = """Ross McFluff: 834.345.1254 155 Elm Street
...
... Ronald Heathmore: 892.345.3428 436 Finley Avenue
... Frank Burger: 925.541.7625 662 South Dogwood Way
...
...
... Heather Albrecht: 548.326.4584 919 Park Place"""
```

The entries are separated by one or more newlines. Now we convert the string into a list with each nonempty line having its own entry:

```
>>> entries = re.split("\n+", text)
>>> entries
['Ross McFluff: 834.345.1254 155 Elm Street',
'Ronald Heathmore: 892.345.3428 436 Finley Avenue',
'Frank Burger: 925.541.7625 662 South Dogwood Way',
'Heather Albrecht: 548.326.4584 919 Park Place']
```

Finally, split each entry into a list with first name, last name, telephone number, and address. We use the `maxsplit` parameter of *split()* because the address has spaces, our splitting pattern, in it:

```
>>> [re.split(":? ", entry, 3) for entry in entries]
[['Ross', 'McFluff', '834.345.1254', '155 Elm Street'],
['Ronald', 'Heathmore', '892.345.3428', '436 Finley Avenue'],
['Frank', 'Burger', '925.541.7625', '662 South Dogwood Way'],
['Heather', 'Albrecht', '548.326.4584', '919 Park Place']]
```

The `:?` pattern matches the colon after the last name, so that it does not occur in the result list. With a `maxsplit` of `4`, we could separate the house number from the street name:

```
>>> [re.split(":? ", entry, 4) for entry in entries]
[['Ross', 'McFluff', '834.345.1254', '155', 'Elm Street'],
['Ronald', 'Heathmore', '892.345.3428', '436', 'Finley Avenue'],
['Frank', 'Burger', '925.541.7625', '662', 'South Dogwood Way'],
['Heather', 'Albrecht', '548.326.4584', '919', 'Park Place']]
```

Text Munging

sub() replaces every occurrence of a pattern with a string or the result of a function. This example demonstrates using *sub()* with a function to "munge" text, or randomize the order of all the characters in each word of a sentence except for the first and last characters:

```
>>> def repl(m):
...     inner_word = list(m.group(2))
...     random.shuffle(inner_word)
...     return m.group(1) + "".join(inner_word) + m.group(3)
>>> text = "Professor Abdolmalek, please report your absences promptly."
>>> re.sub(r"(\w)(\w+)(\w)", repl, text)
'Poefsrosr Aealmlobdk, pslaee reorpt your abnseces plmrptoy.'
>>> re.sub(r"(\w)(\w+)(\w)", repl, text)
'Pofsroser Aodlambelk, plasee reoprt yuor asnebces potlmrpy.'
```

Finding all Adverbs

findall() matches *all* occurrences of a pattern, not just the first one as *search()* does. For example, if a writer wanted to find all of the adverbs in some text, they might use *findall()* in the following manner:

```
>>> text = "He was carefully disguised but captured quickly by police."
>>> re.findall(r"\w+ly", text)
['carefully', 'quickly']
```

Finding all Adverbs and their Positions

If one wants more information about all matches of a pattern than the matched text, *finditer()* is useful as it provides *match objects* instead of strings. Continuing with the previous example, if a writer wanted to find all of the adverbs *and their positions* in some text, they would use *finditer()* in the following manner:

```
>>> text = "He was carefully disguised but captured quickly by police."
>>> for m in re.finditer(r"\w+ly", text):
...     print('%02d-%02d: %s' % (m.start(), m.end(), m.group(0)))
07-16: carefully
40-47: quickly
```

Raw String Notation

Raw string notation (`r"text"`) keeps regular expressions sane. Without it, every backslash (`'\'`) in a regular expression would have to be prefixed with another one to escape it. For example, the two following lines of code are functionally identical:

```
>>> re.match(r"\W(.)\1\W", " ff ")
<re.Match object; span=(0, 4), match=' ff '>
>>> re.match("\\W(.)\\1\\W", " ff ")
<re.Match object; span=(0, 4), match=' ff '>
```

When one wants to match a literal backslash, it must be escaped in the regular expression. With raw string notation, this means `r"\\"`. Without raw string notation, one must use `"\\\\"`, making the following lines of code functionally identical:

```
>>> re.match(r"\\", r"\\")
<re.Match object; span=(0, 1), match='\\'>
>>> re.match("\\\\", r"\\")
<re.Match object; span=(0, 1), match='\\'>
```

Writing a Tokenizer

A tokenizer or scanner analyzes a string to categorize groups of characters. This is a useful first step in writing a compiler or interpreter.

The text categories are specified with regular expressions. The technique is to combine those into a single master regular expression and to loop over successive matches:

```
import collections
import re

Token = collections.namedtuple('Token', ['typ', 'value', 'line', 'column'])

def tokenize(code):
    keywords = {'IF', 'THEN', 'ENDIF', 'FOR', 'NEXT', 'GOSUB', 'RETURN'}
    token_specification = [
        ('NUMBER',  r'\d+(\.\d*)?'),  # Integer or decimal number
        ('ASSIGN',  r':='),           # Assignment operator
        ('END',     r';'),            # Statement terminator
        ('ID',      r'[A-Za-z]+'),    # Identifiers
        ('OP',      r'[+\-*/]'),      # Arithmetic operators
        ('NEWLINE', r'\n'),           # Line endings
        ('SKIP',    r'[ \t]+'),       # Skip over spaces and tabs
        ('MISMATCH',r'.'),            # Any other character
    ]
    tok_regex = '|'.join('(?P<%s>%s)' % pair for pair in token_specification)
    line_num = 1
    line_start = 0
    for mo in re.finditer(tok_regex, code):
        kind = mo.lastgroup
        value = mo.group(kind)
        if kind == 'NEWLINE':
            line_start = mo.end()
            line_num += 1
        elif kind == 'SKIP':
            pass
```

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```
        elif kind == 'MISMATCH':
            raise RuntimeError(f'{value!r} unexpected on line {line_num}')
        else:
            if kind == 'ID' and value in keywords:
                kind = value
            column = mo.start() - line_start
            yield Token(kind, value, line_num, column)

statements = '''
    IF quantity THEN
        total := total + price * quantity;
        tax := price * 0.05;
    ENDIF;
'''

for token in tokenize(statements):
    print(token)
```

The tokenizer produces the following output:

```
Token(typ='IF', value='IF', line=2, column=4)
Token(typ='ID', value='quantity', line=2, column=7)
Token(typ='THEN', value='THEN', line=2, column=16)
Token(typ='ID', value='total', line=3, column=8)
Token(typ='ASSIGN', value=':=', line=3, column=14)
Token(typ='ID', value='total', line=3, column=17)
Token(typ='OP', value='+', line=3, column=23)
Token(typ='ID', value='price', line=3, column=25)
Token(typ='OP', value='*', line=3, column=31)
Token(typ='ID', value='quantity', line=3, column=33)
Token(typ='END', value=';', line=3, column=41)
Token(typ='ID', value='tax', line=4, column=8)
Token(typ='ASSIGN', value=':=', line=4, column=12)
Token(typ='ID', value='price', line=4, column=15)
Token(typ='OP', value='*', line=4, column=21)
Token(typ='NUMBER', value='0.05', line=4, column=23)
Token(typ='END', value=';', line=4, column=27)
Token(typ='ENDIF', value='ENDIF', line=5, column=4)
Token(typ='END', value=';', line=5, column=9)
```

6.3 `difflib` — Helpers for computing deltas

Source code: Lib/difflib.py

This module provides classes and functions for comparing sequences. It can be used for example, for comparing files, and can produce difference information in various formats, including HTML and context and unified diffs. For comparing directories and files, see also, the *filecmp* module.

class difflib.SequenceMatcher

This is a flexible class for comparing pairs of sequences of any type, so long as the sequence elements are *hashable*. The basic algorithm predates, and is a little fancier than, an algorithm published in the late 1980's by Ratcliff and Obershelp under the hyperbolic name "gestalt pattern matching." The idea is to find the longest contiguous matching subsequence that contains no "junk" elements; these "junk"

elements are ones that are uninteresting in some sense, such as blank lines or whitespace. (Handling junk is an extension to the Ratcliff and Obershelp algorithm.) The same idea is then applied recursively to the pieces of the sequences to the left and to the right of the matching subsequence. This does not yield minimal edit sequences, but does tend to yield matches that "look right" to people.

Timing: The basic Ratcliff-Obershelp algorithm is cubic time in the worst case and quadratic time in the expected case. *SequenceMatcher* is quadratic time for the worst case and has expected-case behavior dependent in a complicated way on how many elements the sequences have in common; best case time is linear.

Automatic junk heuristic: *SequenceMatcher* supports a heuristic that automatically treats certain sequence items as junk. The heuristic counts how many times each individual item appears in the sequence. If an item's duplicates (after the first one) account for more than 1% of the sequence and the sequence is at least 200 items long, this item is marked as "popular" and is treated as junk for the purpose of sequence matching. This heuristic can be turned off by setting the `autojunk` argument to `False` when creating the *SequenceMatcher*.

New in version 3.2: The *autojunk* parameter.

class difflib.Differ

This is a class for comparing sequences of lines of text, and producing human-readable differences or deltas. Differ uses *SequenceMatcher* both to compare sequences of lines, and to compare sequences of characters within similar (near-matching) lines.

Each line of a *Differ* delta begins with a two-letter code:

Code	Meaning
`'- '`	line unique to sequence 1
`'+ '`	line unique to sequence 2
`'  '`	line common to both sequences
`'? '`	line not present in either input sequence

Lines beginning with '`?`' attempt to guide the eye to intraline differences, and were not present in either input sequence. These lines can be confusing if the sequences contain tab characters.

class difflib.HtmlDiff

This class can be used to create an HTML table (or a complete HTML file containing the table) showing a side by side, line by line comparison of text with inter-line and intra-line change highlights. The table can be generated in either full or contextual difference mode.

The constructor for this class is:

__init__(*tabsize=8*, *wrapcolumn=None*, *linejunk=None*, *charjunk=IS_CHARACTER_JUNK*)

Initializes instance of *HtmlDiff*.

tabsize is an optional keyword argument to specify tab stop spacing and defaults to `8`.

wrapcolumn is an optional keyword to specify column number where lines are broken and wrapped, defaults to `None` where lines are not wrapped.

linejunk and *charjunk* are optional keyword arguments passed into *ndiff()* (used by *HtmlDiff* to generate the side by side HTML differences). See *ndiff()* documentation for argument default values and descriptions.

The following methods are public:

make_file(*fromlines*, *tolines*, *fromdesc=''*, *todesc=''*, *context=False*, *numlines=5*, ***, *charset='utf-8'*)

Compares *fromlines* and *tolines* (lists of strings) and returns a string which is a complete HTML file containing a table showing line by line differences with inter-line and intra-line changes highlighted.

fromdesc and *todesc* are optional keyword arguments to specify from/to file column header strings (both default to an empty string).

context and *numlines* are both optional keyword arguments. Set *context* to `True` when contextual differences are to be shown, else the default is `False` to show the full files. *numlines* defaults to `5`. When *context* is `True` *numlines* controls the number of context lines which surround the difference highlights. When *context* is `False` *numlines* controls the number of lines which are shown before a difference highlight when using the "next" hyperlinks (setting to zero would cause the "next" hyperlinks to place the next difference highlight at the top of the browser without any leading context).

Changed in version 3.5: *charset* keyword-only argument was added. The default charset of HTML document changed from `'ISO-8859-1'` to `'utf-8'`.

make_table(*fromlines*, *tolines*, *fromdesc=''*, *todesc=''*, *context=False*, *numlines=5*)
Compares *fromlines* and *tolines* (lists of strings) and returns a string which is a complete HTML table showing line by line differences with inter-line and intra-line changes highlighted.

The arguments for this method are the same as those for the *make_file()* method.

`Tools/scripts/diff.py` is a command-line front-end to this class and contains a good example of its use.

difflib.context_diff(*a*, *b*, *fromfile=''*, *tofile=''*, *fromfiledate=''*, *tofiledate=''*, *n=3*, *lineterm='\n'*)
Compare *a* and *b* (lists of strings); return a delta (a *generator* generating the delta lines) in context diff format.

Context diffs are a compact way of showing just the lines that have changed plus a few lines of context. The changes are shown in a before/after style. The number of context lines is set by *n* which defaults to three.

By default, the diff control lines (those with `***` or `---`) are created with a trailing newline. This is helpful so that inputs created from *io.IOBase.readlines()* result in diffs that are suitable for use with *io.IOBase.writelines()* since both the inputs and outputs have trailing newlines.

For inputs that do not have trailing newlines, set the *lineterm* argument to `""` so that the output will be uniformly newline free.

The context diff format normally has a header for filenames and modification times. Any or all of these may be specified using strings for *fromfile*, *tofile*, *fromfiledate*, and *tofiledate*. The modification times are normally expressed in the ISO 8601 format. If not specified, the strings default to blanks.

```
>>> s1 = ['bacon\n', 'eggs\n', 'ham\n', 'guido\n']
>>> s2 = ['python\n', 'eggy\n', 'hamster\n', 'guido\n']
>>> sys.stdout.writelines(context_diff(s1, s2, fromfile='before.py', tofile='after.py'))
*** before.py
--- after.py
***************
*** 1,4 ****
! bacon
! eggs
! ham
  guido
--- 1,4 ----
! python
! eggy
! hamster
  guido
```

See *A command-line interface to difflib* for a more detailed example.

difflib.**get_close_matches**(*word*, *possibilities*, *n=3*, *cutoff=0.6*)

Return a list of the best "good enough" matches. *word* is a sequence for which close matches are desired (typically a string), and *possibilities* is a list of sequences against which to match *word* (typically a list of strings).

Optional argument *n* (default `3`) is the maximum number of close matches to return; *n* must be greater than `0`.

Optional argument *cutoff* (default `0.6`) is a float in the range [0, 1]. Possibilities that don't score at least that similar to *word* are ignored.

The best (no more than *n*) matches among the possibilities are returned in a list, sorted by similarity score, most similar first.

```
>>> get_close_matches('appel', ['ape', 'apple', 'peach', 'puppy'])
['apple', 'ape']
>>> import keyword
>>> get_close_matches('wheel', keyword.kwlist)
['while']
>>> get_close_matches('pineapple', keyword.kwlist)
[]
>>> get_close_matches('accept', keyword.kwlist)
['except']
```

difflib.**ndiff**(*a*, *b*, *linejunk=None*, *charjunk=IS_CHARACTER_JUNK*)

Compare *a* and *b* (lists of strings); return a *Differ*-style delta (a *generator* generating the delta lines).

Optional keyword parameters *linejunk* and *charjunk* are filtering functions (or `None`):

linejunk: A function that accepts a single string argument, and returns true if the string is junk, or false if not. The default is `None`. There is also a module-level function *IS_LINE_JUNK()*, which filters out lines without visible characters, except for at most one pound character (`'#'`) – however the underlying *SequenceMatcher* class does a dynamic analysis of which lines are so frequent as to constitute noise, and this usually works better than using this function.

charjunk: A function that accepts a character (a string of length 1), and returns if the character is junk, or false if not. The default is module-level function *IS_CHARACTER_JUNK()*, which filters out whitespace characters (a blank or tab; it's a bad idea to include newline in this!).

`Tools/scripts/ndiff.py` is a command-line front-end to this function.

```
>>> diff = ndiff('one\ntwo\nthree\n'.splitlines(keepends=True),
...              'ore\ntree\nemu\n'.splitlines(keepends=True))
>>> print(''.join(diff), end="")
- one
?  ^
+ ore
?  ^
- two
- three
?  -
+ tree
+ emu
```

difflib.**restore**(*sequence*, *which*)

Return one of the two sequences that generated a delta.

Given a *sequence* produced by *Differ.compare()* or *ndiff()*, extract lines originating from file 1 or 2 (parameter *which*), stripping off line prefixes.

Example:

```
>>> diff = ndiff('one\ntwo\nthree\n'.splitlines(keepends=True),
...              'ore\ntree\nemu\n'.splitlines(keepends=True))
>>> diff = list(diff) # materialize the generated delta into a list
>>> print(''.join(restore(diff, 1)), end="")
one
two
three
>>> print(''.join(restore(diff, 2)), end="")
ore
tree
emu
```

difflib.**unified_diff**(*a*, *b*, *fromfile=''*, *tofile=''*, *fromfiledate=''*, *tofiledate=''*, *n=3*, *lineterm='\n'*)

Compare *a* and *b* (lists of strings); return a delta (a *generator* generating the delta lines) in unified diff format.

Unified diffs are a compact way of showing just the lines that have changed plus a few lines of context. The changes are shown in an inline style (instead of separate before/after blocks). The number of context lines is set by *n* which defaults to three.

By default, the diff control lines (those with `---`, `+++`, or `@@`) are created with a trailing newline. This is helpful so that inputs created from *io.IOBase.readlines()* result in diffs that are suitable for use with *io.IOBase.writelines()* since both the inputs and outputs have trailing newlines.

For inputs that do not have trailing newlines, set the *lineterm* argument to `""` so that the output will be uniformly newline free.

The context diff format normally has a header for filenames and modification times. Any or all of these may be specified using strings for *fromfile*, *tofile*, *fromfiledate*, and *tofiledate*. The modification times are normally expressed in the ISO 8601 format. If not specified, the strings default to blanks.

```
>>> s1 = ['bacon\n', 'eggs\n', 'ham\n', 'guido\n']
>>> s2 = ['python\n', 'eggy\n', 'hamster\n', 'guido\n']
>>> sys.stdout.writelines(unified_diff(s1, s2, fromfile='before.py', tofile='after.py'))
--- before.py
+++ after.py
@@ -1,4 +1,4 @@
-bacon
-eggs
-ham
+python
+eggy
+hamster
 guido
```

See *A command-line interface to difflib* for a more detailed example.

difflib.**diff_bytes**(*dfunc*, *a*, *b*, *fromfile=b''*, *tofile=b''*, *fromfiledate=b''*, *tofiledate=b''*, *n=3*, *lineterm=b'\n'*)

Compare *a* and *b* (lists of bytes objects) using *dfunc*; yield a sequence of delta lines (also bytes) in the format returned by *dfunc*. *dfunc* must be a callable, typically either *unified_diff()* or *context_diff()*.

Allows you to compare data with unknown or inconsistent encoding. All inputs except *n* must be bytes objects, not str. Works by losslessly converting all inputs (except *n*) to str, and calling `dfunc(a, b, fromfile, tofile, fromfiledate, tofiledate, n, lineterm)`. The output of *dfunc* is then converted back to bytes, so the delta lines that you receive have the same unknown/inconsistent encodings as *a* and *b*.

New in version 3.5.

`difflib.IS_LINE_JUNK(line)`
Return true for ignorable lines. The line *line* is ignorable if *line* is blank or contains a single `'#'`, otherwise it is not ignorable. Used as a default for parameter *linejunk* in *ndiff()* in older versions.

`difflib.IS_CHARACTER_JUNK(ch)`
Return true for ignorable characters. The character *ch* is ignorable if *ch* is a space or tab, otherwise it is not ignorable. Used as a default for parameter *charjunk* in *ndiff()*.

See also:

Pattern Matching: The Gestalt Approach Discussion of a similar algorithm by John W. Ratcliff and D. E. Metzener. This was published in Dr. Dobb's Journal in July, 1988.

6.3.1 SequenceMatcher Objects

The *SequenceMatcher* class has this constructor:

`class difflib.SequenceMatcher(isjunk=None, a='', b='', autojunk=True)`
Optional argument *isjunk* must be `None` (the default) or a one-argument function that takes a sequence element and returns true if and only if the element is "junk" and should be ignored. Passing `None` for *isjunk* is equivalent to passing `lambda x: 0`; in other words, no elements are ignored. For example, pass:

```
lambda x: x in " \t"
```

if you're comparing lines as sequences of characters, and don't want to synch up on blanks or hard tabs.

The optional arguments *a* and *b* are sequences to be compared; both default to empty strings. The elements of both sequences must be *hashable*.

The optional argument *autojunk* can be used to disable the automatic junk heuristic.

New in version 3.2: The *autojunk* parameter.

SequenceMatcher objects get three data attributes: *bjunk* is the set of elements of *b* for which *isjunk* is `True`; *bpopular* is the set of non-junk elements considered popular by the heuristic (if it is not disabled); *b2j* is a dict mapping the remaining elements of *b* to a list of positions where they occur. All three are reset whenever *b* is reset with *set_seqs()* or *set_seq2()*.

New in version 3.2: The *bjunk* and *bpopular* attributes.

SequenceMatcher objects have the following methods:

`set_seqs(a, b)`
Set the two sequences to be compared.

SequenceMatcher computes and caches detailed information about the second sequence, so if you want to compare one sequence against many sequences, use *set_seq2()* to set the commonly used sequence once and call *set_seq1()* repeatedly, once for each of the other sequences.

`set_seq1(a)`
Set the first sequence to be compared. The second sequence to be compared is not changed.

`set_seq2(b)`
Set the second sequence to be compared. The first sequence to be compared is not changed.

`find_longest_match(alo, ahi, blo, bhi)`
Find longest matching block in `a[alo:ahi]` and `b[blo:bhi]`.

If *isjunk* was omitted or `None`, *find_longest_match()* returns `(i, j, k)` such that `a[i:i+k]` is equal to `b[j:j+k]`, where `alo <= i <= i+k <= ahi` and `blo <= j <= j+k <= bhi`. For all `(i', j', k')` meeting those conditions, the additional conditions `k >= k'`, `i <= i'`, and if `i`

`== i'`, `j <= j'` are also met. In other words, of all maximal matching blocks, return one that starts earliest in *a*, and of all those maximal matching blocks that start earliest in *a*, return the one that starts earliest in *b*.

```
>>> s = SequenceMatcher(None, " abcd", "abcd abcd")
>>> s.find_longest_match(0, 5, 0, 9)
Match(a=0, b=4, size=5)
```

If *isjunk* was provided, first the longest matching block is determined as above, but with the additional restriction that no junk element appears in the block. Then that block is extended as far as possible by matching (only) junk elements on both sides. So the resulting block never matches on junk except as identical junk happens to be adjacent to an interesting match.

Here's the same example as before, but considering blanks to be junk. That prevents `' abcd'` from matching the `' abcd'` at the tail end of the second sequence directly. Instead only the `'abcd'` can match, and matches the leftmost `'abcd'` in the second sequence:

```
>>> s = SequenceMatcher(lambda x: x==" ", " abcd", "abcd abcd")
>>> s.find_longest_match(0, 5, 0, 9)
Match(a=1, b=0, size=4)
```

If no blocks match, this returns `(alo, blo, 0)`.

This method returns a *named tuple* `Match(a, b, size)`.

get_matching_blocks()

Return list of triples describing matching subsequences. Each triple is of the form `(i, j, n)`, and means that `a[i:i+n] == b[j:j+n]`. The triples are monotonically increasing in *i* and *j*.

The last triple is a dummy, and has the value `(len(a), len(b), 0)`. It is the only triple with `n == 0`. If `(i, j, n)` and `(i', j', n')` are adjacent triples in the list, and the second is not the last triple in the list, then `i+n != i'` or `j+n != j'`; in other words, adjacent triples always describe non-adjacent equal blocks.

```
>>> s = SequenceMatcher(None, "abxcd", "abcd")
>>> s.get_matching_blocks()
[Match(a=0, b=0, size=2), Match(a=3, b=2, size=2), Match(a=5, b=4, size=0)]
```

get_opcodes()

Return list of 5-tuples describing how to turn *a* into *b*. Each tuple is of the form `(tag, i1, i2, j1, j2)`. The first tuple has `i1 == j1 == 0`, and remaining tuples have *i1* equal to the *i2* from the preceding tuple, and, likewise, *j1* equal to the previous *j2*.

The *tag* values are strings, with these meanings:

Value	Meaning
`'replace'`	`a[i1:i2]` should be replaced by `b[j1:j2]`.
`'delete'`	`a[i1:i2]` should be deleted. Note that `j1 == j2` in this case.
`'insert'`	`b[j1:j2]` should be inserted at `a[i1:i1]`. Note that `i1 == i2` in this case.
`'equal'`	`a[i1:i2] == b[j1:j2]` (the sub-sequences are equal).

For example:

```
>>> a = "qabxcd"
>>> b = "abycdf"
>>> s = SequenceMatcher(None, a, b)
>>> for tag, i1, i2, j1, j2 in s.get_opcodes():
...     print('{:7}   a[{}:{}] --> b[{}:{}] {!r:>8} --> {!r}'.format(
```

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```
...          tag, i1, i2, j1, j2, a[i1:i2], b[j1:j2]))
delete    a[0:1] --> b[0:0]      'q' --> ''
equal     a[1:3] --> b[0:2]     'ab' --> 'ab'
replace   a[3:4] --> b[2:3]      'x' --> 'y'
equal     a[4:6] --> b[3:5]     'cd' --> 'cd'
insert    a[6:6] --> b[5:6]       '' --> 'f'
```

get_grouped_opcodes(*n=3*)
Return a *generator* of groups with up to *n* lines of context.

Starting with the groups returned by *get_opcodes()*, this method splits out smaller change clusters and eliminates intervening ranges which have no changes.

The groups are returned in the same format as *get_opcodes()*.

ratio()
Return a measure of the sequences' similarity as a float in the range [0, 1].

Where T is the total number of elements in both sequences, and M is the number of matches, this is 2.0*M / T. Note that this is `1.0` if the sequences are identical, and `0.0` if they have nothing in common.

This is expensive to compute if *get_matching_blocks()* or *get_opcodes()* hasn't already been called, in which case you may want to try *quick_ratio()* or *real_quick_ratio()* first to get an upper bound.

quick_ratio()
Return an upper bound on *ratio()* relatively quickly.

real_quick_ratio()
Return an upper bound on *ratio()* very quickly.

The three methods that return the ratio of matching to total characters can give different results due to differing levels of approximation, although `quick_ratio()` and `real_quick_ratio()` are always at least as large as `ratio()`:

```
>>> s = SequenceMatcher(None, "abcd", "bcde")
>>> s.ratio()
0.75
>>> s.quick_ratio()
0.75
>>> s.real_quick_ratio()
1.0
```

6.3.2 SequenceMatcher Examples

This example compares two strings, considering blanks to be "junk":

```
>>> s = SequenceMatcher(lambda x: x == " ",
...                     "private Thread currentThread;",
...                     "private volatile Thread currentThread;")
```

`ratio()` returns a float in [0, 1], measuring the similarity of the sequences. As a rule of thumb, a `ratio()` value over 0.6 means the sequences are close matches:

```
>>> print(round(s.ratio(), 3))
0.866
```

If you're only interested in where the sequences match, `get_matching_blocks()` is handy:

```
>>> for block in s.get_matching_blocks():
...     print("a[%d] and b[%d] match for %d elements" % block)
a[0] and b[0] match for 8 elements
a[8] and b[17] match for 21 elements
a[29] and b[38] match for 0 elements
```

Note that the last tuple returned by `get_matching_blocks()` is always a dummy, `(len(a), len(b), 0)`, and this is the only case in which the last tuple element (number of elements matched) is `0`.

If you want to know how to change the first sequence into the second, use `get_opcodes()`:

```
>>> for opcode in s.get_opcodes():
...     print("%6s a[%d:%d] b[%d:%d]" % opcode)
 equal a[0:8] b[0:8]
insert a[8:8] b[8:17]
 equal a[8:29] b[17:38]
```

See also:

- The *get_close_matches()* function in this module which shows how simple code building on *SequenceMatcher* can be used to do useful work.
- Simple version control recipe for a small application built with *SequenceMatcher*.

6.3.3 Differ Objects

Note that *Differ*-generated deltas make no claim to be **minimal** diffs. To the contrary, minimal diffs are often counter-intuitive, because they synch up anywhere possible, sometimes accidental matches 100 pages apart. Restricting synch points to contiguous matches preserves some notion of locality, at the occasional cost of producing a longer diff.

The *Differ* class has this constructor:

class difflib.Differ(*linejunk=None*, *charjunk=None*)

Optional keyword parameters *linejunk* and *charjunk* are for filter functions (or `None`):

linejunk: A function that accepts a single string argument, and returns true if the string is junk. The default is `None`, meaning that no line is considered junk.

charjunk: A function that accepts a single character argument (a string of length 1), and returns true if the character is junk. The default is `None`, meaning that no character is considered junk.

These junk-filtering functions speed up matching to find differences and do not cause any differing lines or characters to be ignored. Read the description of the *find_longest_match()* method's *isjunk* parameter for an explanation.

Differ objects are used (deltas generated) via a single method:

compare(*a*, *b*)

Compare two sequences of lines, and generate the delta (a sequence of lines).

Each sequence must contain individual single-line strings ending with newlines. Such sequences can be obtained from the *readlines()* method of file-like objects. The delta generated also consists of newline-terminated strings, ready to be printed as-is via the *writelines()* method of a file-like object.

6.3.4 Differ Example

This example compares two texts. First we set up the texts, sequences of individual single-line strings ending with newlines (such sequences can also be obtained from the `readlines()` method of file-like objects):

```
>>> text1 = '''  1. Beautiful is better than ugly.
...   2. Explicit is better than implicit.
...   3. Simple is better than complex.
...   4. Complex is better than complicated.
... '''.splitlines(keepends=True)
>>> len(text1)
4
>>> text1[0][-1]
'\n'
>>> text2 = '''  1. Beautiful is better than ugly.
...   3.   Simple is better than complex.
...   4. Complicated is better than complex.
...   5. Flat is better than nested.
... '''.splitlines(keepends=True)
```

Next we instantiate a Differ object:

```
>>> d = Differ()
```

Note that when instantiating a *Differ* object we may pass functions to filter out line and character "junk." See the *Differ()* constructor for details.

Finally, we compare the two:

```
>>> result = list(d.compare(text1, text2))
```

`result` is a list of strings, so let's pretty-print it:

```
>>> from pprint import pprint
>>> pprint(result)
['    1. Beautiful is better than ugly.\n',
 '-   2. Explicit is better than implicit.\n',
 '-   3. Simple is better than complex.\n',
 '+   3.   Simple is better than complex.\n',
 '?     ++\n',
 '-   4. Complex is better than complicated.\n',
 '?            ^                     ---- ^\n',
 '+   4. Complicated is better than complex.\n',
 '?           ++++ ^                     ^\n',
 '+   5. Flat is better than nested.\n']
```

As a single multi-line string it looks like this:

```
>>> import sys
>>> sys.stdout.writelines(result)
    1. Beautiful is better than ugly.
-   2. Explicit is better than implicit.
-   3. Simple is better than complex.
+   3.   Simple is better than complex.
?     ++
-   4. Complex is better than complicated.
?            ^                     ---- ^
+   4. Complicated is better than complex.
```

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```
?           ++++ ^                         ^
+   5. Flat is better than nested.
```

6.3.5 A command-line interface to difflib

This example shows how to use difflib to create a `diff`-like utility. It is also contained in the Python source distribution, as `Tools/scripts/diff.py`.

```
#!/usr/bin/env python3
""" Command line interface to difflib.py providing diffs in four formats:

* ndiff:    lists every line and highlights interline changes.
* context:  highlights clusters of changes in a before/after format.
* unified:  highlights clusters of changes in an inline format.
* html:     generates side by side comparison with change highlights.

"""

import sys, os, difflib, argparse
from datetime import datetime, timezone

def file_mtime(path):
    t = datetime.fromtimestamp(os.stat(path).st_mtime,
                               timezone.utc)
    return t.astimezone().isoformat()

def main():

    parser = argparse.ArgumentParser()
    parser.add_argument('-c', action='store_true', default=False,
                        help='Produce a context format diff (default)')
    parser.add_argument('-u', action='store_true', default=False,
                        help='Produce a unified format diff')
    parser.add_argument('-m', action='store_true', default=False,
                        help='Produce HTML side by side diff '
                             '(can use -c and -l in conjunction)')
    parser.add_argument('-n', action='store_true', default=False,
                        help='Produce a ndiff format diff')
    parser.add_argument('-l', '--lines', type=int, default=3,
                        help='Set number of context lines (default 3)')
    parser.add_argument('fromfile')
    parser.add_argument('tofile')
    options = parser.parse_args()

    n = options.lines
    fromfile = options.fromfile
    tofile = options.tofile

    fromdate = file_mtime(fromfile)
    todate = file_mtime(tofile)
    with open(fromfile) as ff:
        fromlines = ff.readlines()
    with open(tofile) as tf:
        tolines = tf.readlines()
```

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```
    if options.u:
        diff = difflib.unified_diff(fromlines, tolines, fromfile, tofile, fromdate, todate, n=n)
    elif options.n:
        diff = difflib.ndiff(fromlines, tolines)
    elif options.m:
        diff = difflib.HtmlDiff().make_file(fromlines,tolines,fromfile,tofile,context=options.c,
↪numlines=n)
    else:
        diff = difflib.context_diff(fromlines, tolines, fromfile, tofile, fromdate, todate, n=n)

    sys.stdout.writelines(diff)

if __name__ == '__main__':
    main()
```

6.4 textwrap — Text wrapping and filling

Source code: Lib/textwrap.py

The *textwrap* module provides some convenience functions, as well as *TextWrapper*, the class that does all the work. If you're just wrapping or filling one or two text strings, the convenience functions should be good enough; otherwise, you should use an instance of *TextWrapper* for efficiency.

textwrap.wrap(*text*, *width=70*, ***kwargs*)

Wraps the single paragraph in *text* (a string) so every line is at most *width* characters long. Returns a list of output lines, without final newlines.

Optional keyword arguments correspond to the instance attributes of *TextWrapper*, documented below. *width* defaults to 70.

See the *TextWrapper.wrap()* method for additional details on how *wrap()* behaves.

textwrap.fill(*text*, *width=70*, ***kwargs*)

Wraps the single paragraph in *text*, and returns a single string containing the wrapped paragraph. *fill()* is shorthand for

```
"\n".join(wrap(text, ...))
```

In particular, *fill()* accepts exactly the same keyword arguments as *wrap()*.

textwrap.shorten(*text*, *width*, ***kwargs*)

Collapse and truncate the given *text* to fit in the given *width*.

First the whitespace in *text* is collapsed (all whitespace is replaced by single spaces). If the result fits in the *width*, it is returned. Otherwise, enough words are dropped from the end so that the remaining words plus the `placeholder` fit within `width`:

```
>>> textwrap.shorten("Hello  world!", width=12)
'Hello world!'
>>> textwrap.shorten("Hello  world!", width=11)
'Hello [...]'
>>> textwrap.shorten("Hello world", width=10, placeholder="...")
'Hello...'
```

Optional keyword arguments correspond to the instance attributes of *TextWrapper*, documented below. Note that the whitespace is collapsed before the text is passed to the *TextWrapper* *fill()* function, so changing the value of *tabsize*, *expand_tabs*, *drop_whitespace*, and *replace_whitespace* will have no effect.

New in version 3.4.

textwrap.dedent(*text*)

Remove any common leading whitespace from every line in *text*.

This can be used to make triple-quoted strings line up with the left edge of the display, while still presenting them in the source code in indented form.

Note that tabs and spaces are both treated as whitespace, but they are not equal: the lines `" hello"` and `"\thello"` are considered to have no common leading whitespace.

For example:

```
def test():
    # end first line with \ to avoid the empty line!
    s = '''\
    hello
      world
    '''
    print(repr(s))          # prints '    hello\n      world\n    '
    print(repr(dedent(s)))  # prints 'hello\n  world\n'
```

textwrap.indent(*text*, *prefix*, *predicate=None*)

Add *prefix* to the beginning of selected lines in *text*.

Lines are separated by calling `text.splitlines(True)`.

By default, *prefix* is added to all lines that do not consist solely of whitespace (including any line endings).

For example:

```
>>> s = 'hello\n\n \nworld'
>>> indent(s, '  ')
'  hello\n\n \n  world'
```

The optional *predicate* argument can be used to control which lines are indented. For example, it is easy to add *prefix* to even empty and whitespace-only lines:

```
>>> print(indent(s, '+ ', lambda line: True))
+ hello
+
+
+ world
```

New in version 3.3.

wrap(), *fill()* and *shorten()* work by creating a *TextWrapper* instance and calling a single method on it. That instance is not reused, so for applications that process many text strings using *wrap()* and/or *fill()*, it may be more efficient to create your own *TextWrapper* object.

Text is preferably wrapped on whitespaces and right after the hyphens in hyphenated words; only then will long words be broken if necessary, unless *TextWrapper.break_long_words* is set to false.

class textwrap.TextWrapper(***kwargs*)

The *TextWrapper* constructor accepts a number of optional keyword arguments. Each keyword argument corresponds to an instance attribute, so for example

```
wrapper = TextWrapper(initial_indent="* ")
```

is the same as

```
wrapper = TextWrapper()
wrapper.initial_indent = "* "
```

You can re-use the same *TextWrapper* object many times, and you can change any of its options through direct assignment to instance attributes between uses.

The *TextWrapper* instance attributes (and keyword arguments to the constructor) are as follows:

width
(default: `70`) The maximum length of wrapped lines. As long as there are no individual words in the input text longer than *width*, *TextWrapper* guarantees that no output line will be longer than *width* characters.

expand_tabs
(default: `True`) If true, then all tab characters in *text* will be expanded to spaces using the `expandtabs()` method of *text*.

tabsize
(default: `8`) If *expand_tabs* is true, then all tab characters in *text* will be expanded to zero or more spaces, depending on the current column and the given tab size.

New in version 3.3.

replace_whitespace
(default: `True`) If true, after tab expansion but before wrapping, the *wrap()* method will replace each whitespace character with a single space. The whitespace characters replaced are as follows: tab, newline, vertical tab, formfeed, and carriage return (`'\t\n\v\f\r'`).

Note: If *expand_tabs* is false and *replace_whitespace* is true, each tab character will be replaced by a single space, which is *not* the same as tab expansion.

Note: If *replace_whitespace* is false, newlines may appear in the middle of a line and cause strange output. For this reason, text should be split into paragraphs (using *str.splitlines()* or similar) which are wrapped separately.

---

drop_whitespace
(default: `True`) If true, whitespace at the beginning and ending of every line (after wrapping but before indenting) is dropped. Whitespace at the beginning of the paragraph, however, is not dropped if non-whitespace follows it. If whitespace being dropped takes up an entire line, the whole line is dropped.

initial_indent
(default: `''`) String that will be prepended to the first line of wrapped output. Counts towards the length of the first line. The empty string is not indented.

subsequent_indent
(default: `''`) String that will be prepended to all lines of wrapped output except the first. Counts towards the length of each line except the first.

fix_sentence_endings
(default: `False`) If true, *TextWrapper* attempts to detect sentence endings and ensure that sentences are always separated by exactly two spaces. This is generally desired for text in a

monospaced font. However, the sentence detection algorithm is imperfect: it assumes that a sentence ending consists of a lowercase letter followed by one of `'.'`, `'!'`, or `'?'`, possibly followed by one of `'"'` or `"'"`, followed by a space. One problem with this is algorithm is that it is unable to detect the difference between "Dr." in

```
[...] Dr. Frankenstein's monster [...]
```

and "Spot." in

```
[...] See Spot. See Spot run [...]
```

fix_sentence_endings is false by default.

Since the sentence detection algorithm relies on `string.lowercase` for the definition of "lowercase letter," and a convention of using two spaces after a period to separate sentences on the same line, it is specific to English-language texts.

break_long_words
(default: `True`) If true, then words longer than *width* will be broken in order to ensure that no lines are longer than *width*. If it is false, long words will not be broken, and some lines may be longer than *width*. (Long words will be put on a line by themselves, in order to minimize the amount by which *width* is exceeded.)

break_on_hyphens
(default: `True`) If true, wrapping will occur preferably on whitespaces and right after hyphens in compound words, as it is customary in English. If false, only whitespaces will be considered as potentially good places for line breaks, but you need to set *break_long_words* to false if you want truly insecable words. Default behaviour in previous versions was to always allow breaking hyphenated words.

max_lines
(default: `None`) If not `None`, then the output will contain at most *max_lines* lines, with *placeholder* appearing at the end of the output.

New in version 3.4.

placeholder
(default: `' [...]'`) String that will appear at the end of the output text if it has been truncated.

New in version 3.4.

TextWrapper also provides some public methods, analogous to the module-level convenience functions:

wrap(*text*)
Wraps the single paragraph in *text* (a string) so every line is at most *width* characters long. All wrapping options are taken from instance attributes of the *TextWrapper* instance. Returns a list of output lines, without final newlines. If the wrapped output has no content, the returned list is empty.

fill(*text*)
Wraps the single paragraph in *text*, and returns a single string containing the wrapped paragraph.

6.5 unicodedata — Unicode Database

This module provides access to the Unicode Character Database (UCD) which defines character properties for all Unicode characters. The data contained in this database is compiled from the UCD version 11.0.0.

The module uses the same names and symbols as defined by Unicode Standard Annex #44, "Unicode Character Database". It defines the following functions:

unicodedata.lookup(*name*)
Look up character by name. If a character with the given name is found, return the corresponding character. If not found, *KeyError* is raised.

Changed in version 3.3: Support for name aliases[1] and named sequences[2] has been added.

unicodedata.name(*chr*[, *default*])
Returns the name assigned to the character *chr* as a string. If no name is defined, *default* is returned, or, if not given, *ValueError* is raised.

unicodedata.decimal(*chr*[, *default*])
Returns the decimal value assigned to the character *chr* as integer. If no such value is defined, *default* is returned, or, if not given, *ValueError* is raised.

unicodedata.digit(*chr*[, *default*])
Returns the digit value assigned to the character *chr* as integer. If no such value is defined, *default* is returned, or, if not given, *ValueError* is raised.

unicodedata.numeric(*chr*[, *default*])
Returns the numeric value assigned to the character *chr* as float. If no such value is defined, *default* is returned, or, if not given, *ValueError* is raised.

unicodedata.category(*chr*)
Returns the general category assigned to the character *chr* as string.

unicodedata.bidirectional(*chr*)
Returns the bidirectional class assigned to the character *chr* as string. If no such value is defined, an empty string is returned.

unicodedata.combining(*chr*)
Returns the canonical combining class assigned to the character *chr* as integer. Returns `0` if no combining class is defined.

unicodedata.east_asian_width(*chr*)
Returns the east asian width assigned to the character *chr* as string.

unicodedata.mirrored(*chr*)
Returns the mirrored property assigned to the character *chr* as integer. Returns `1` if the character has been identified as a "mirrored" character in bidirectional text, `0` otherwise.

unicodedata.decomposition(*chr*)
Returns the character decomposition mapping assigned to the character *chr* as string. An empty string is returned in case no such mapping is defined.

unicodedata.normalize(*form*, *unistr*)
Return the normal form *form* for the Unicode string *unistr*. Valid values for *form* are 'NFC', 'NFKC', 'NFD', and 'NFKD'.

The Unicode standard defines various normalization forms of a Unicode string, based on the definition of canonical equivalence and compatibility equivalence. In Unicode, several characters can be expressed in various way. For example, the character U+00C7 (LATIN CAPITAL LETTER C WITH CEDILLA) can also be expressed as the sequence U+0043 (LATIN CAPITAL LETTER C) U+0327 (COMBINING CEDILLA).

For each character, there are two normal forms: normal form C and normal form D. Normal form D (NFD) is also known as canonical decomposition, and translates each character into its decomposed

[1] http://www.unicode.org/Public/11.0.0/ucd/NameAliases.txt
[2] http://www.unicode.org/Public/11.0.0/ucd/NamedSequences.txt

form. Normal form C (NFC) first applies a canonical decomposition, then composes pre-combined characters again.

In addition to these two forms, there are two additional normal forms based on compatibility equivalence. In Unicode, certain characters are supported which normally would be unified with other characters. For example, U+2160 (ROMAN NUMERAL ONE) is really the same thing as U+0049 (LATIN CAPITAL LETTER I). However, it is supported in Unicode for compatibility with existing character sets (e.g. gb2312).

The normal form KD (NFKD) will apply the compatibility decomposition, i.e. replace all compatibility characters with their equivalents. The normal form KC (NFKC) first applies the compatibility decomposition, followed by the canonical composition.

Even if two unicode strings are normalized and look the same to a human reader, if one has combining characters and the other doesn't, they may not compare equal.

In addition, the module exposes the following constant:

unicodedata.unidata_version
The version of the Unicode database used in this module.

unicodedata.ucd_3_2_0
This is an object that has the same methods as the entire module, but uses the Unicode database version 3.2 instead, for applications that require this specific version of the Unicode database (such as IDNA).

Examples:

```
>>> import unicodedata
>>> unicodedata.lookup('LEFT CURLY BRACKET')
'{'
>>> unicodedata.name('/')
'SOLIDUS'
>>> unicodedata.decimal('9')
9
>>> unicodedata.decimal('a')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: not a decimal
>>> unicodedata.category('A')  # 'L'etter, 'u'ppercase
'Lu'
>>> unicodedata.bidirectional('\u0660') # 'A'rabic, 'N'umber
'AN'
```

6.6 stringprep — Internet String Preparation

Source code: Lib/stringprep.py

When identifying things (such as host names) in the internet, it is often necessary to compare such identifications for "equality". Exactly how this comparison is executed may depend on the application domain, e.g. whether it should be case-insensitive or not. It may be also necessary to restrict the possible identifications, to allow only identifications consisting of "printable" characters.

RFC 3454 defines a procedure for "preparing" Unicode strings in internet protocols. Before passing strings onto the wire, they are processed with the preparation procedure, after which they have a certain normalized form. The RFC defines a set of tables, which can be combined into profiles. Each profile must define which

tables it uses, and what other optional parts of the `stringprep` procedure are part of the profile. One example of a `stringprep` profile is `nameprep`, which is used for internationalized domain names.

The module *stringprep* only exposes the tables from **RFC 3454**. As these tables would be very large to represent them as dictionaries or lists, the module uses the Unicode character database internally. The module source code itself was generated using the `mkstringprep.py` utility.

As a result, these tables are exposed as functions, not as data structures. There are two kinds of tables in the RFC: sets and mappings. For a set, *stringprep* provides the "characteristic function", i.e. a function that returns true if the parameter is part of the set. For mappings, it provides the mapping function: given the key, it returns the associated value. Below is a list of all functions available in the module.

`stringprep.in_table_a1(`*code*`)`
Determine whether *code* is in tableA.1 (Unassigned code points in Unicode 3.2).

`stringprep.in_table_b1(`*code*`)`
Determine whether *code* is in tableB.1 (Commonly mapped to nothing).

`stringprep.map_table_b2(`*code*`)`
Return the mapped value for *code* according to tableB.2 (Mapping for case-folding used with NFKC).

`stringprep.map_table_b3(`*code*`)`
Return the mapped value for *code* according to tableB.3 (Mapping for case-folding used with no normalization).

`stringprep.in_table_c11(`*code*`)`
Determine whether *code* is in tableC.1.1 (ASCII space characters).

`stringprep.in_table_c12(`*code*`)`
Determine whether *code* is in tableC.1.2 (Non-ASCII space characters).

`stringprep.in_table_c11_c12(`*code*`)`
Determine whether *code* is in tableC.1 (Space characters, union of C.1.1 and C.1.2).

`stringprep.in_table_c21(`*code*`)`
Determine whether *code* is in tableC.2.1 (ASCII control characters).

`stringprep.in_table_c22(`*code*`)`
Determine whether *code* is in tableC.2.2 (Non-ASCII control characters).

`stringprep.in_table_c21_c22(`*code*`)`
Determine whether *code* is in tableC.2 (Control characters, union of C.2.1 and C.2.2).

`stringprep.in_table_c3(`*code*`)`
Determine whether *code* is in tableC.3 (Private use).

`stringprep.in_table_c4(`*code*`)`
Determine whether *code* is in tableC.4 (Non-character code points).

`stringprep.in_table_c5(`*code*`)`
Determine whether *code* is in tableC.5 (Surrogate codes).

`stringprep.in_table_c6(`*code*`)`
Determine whether *code* is in tableC.6 (Inappropriate for plain text).

`stringprep.in_table_c7(`*code*`)`
Determine whether *code* is in tableC.7 (Inappropriate for canonical representation).

`stringprep.in_table_c8(`*code*`)`
Determine whether *code* is in tableC.8 (Change display properties or are deprecated).

`stringprep.in_table_c9(`*code*`)`
Determine whether *code* is in tableC.9 (Tagging characters).

`stringprep.in_table_d1(`*code*`)`
Determine whether *code* is in tableD.1 (Characters with bidirectional property "R" or "AL").

`stringprep.in_table_d2(`*code*`)`
Determine whether *code* is in tableD.2 (Characters with bidirectional property "L").

6.7 `readline` — GNU readline interface

The *readline* module defines a number of functions to facilitate completion and reading/writing of history files from the Python interpreter. This module can be used directly, or via the *rlcompleter* module, which supports completion of Python identifiers at the interactive prompt. Settings made using this module affect the behaviour of both the interpreter's interactive prompt and the prompts offered by the built-in *input()* function.

Readline keybindings may be configured via an initialization file, typically `.inputrc` in your home directory. See Readline Init File in the GNU Readline manual for information about the format and allowable constructs of that file, and the capabilities of the Readline library in general.

Note: The underlying Readline library API may be implemented by the `libedit` library instead of GNU readline. On macOS the *readline* module detects which library is being used at run time.

The configuration file for `libedit` is different from that of GNU readline. If you programmatically load configuration strings you can check for the text "libedit" in `readline.__doc__` to differentiate between GNU readline and libedit.

If you use *editline*/`libedit` readline emulation on macOS, the initialization file located in your home directory is named `.editrc`. For example, the following content in `~/.editrc` will turn ON *vi* keybindings and TAB completion:

```
python:bind -v
python:bind ^I rl_complete
```

6.7.1 Init file

The following functions relate to the init file and user configuration:

`readline.parse_and_bind(`*string*`)`
Execute the init line provided in the *string* argument. This calls `rl_parse_and_bind()` in the underlying library.

`readline.read_init_file(`[*filename*]`)`
Execute a readline initialization file. The default filename is the last filename used. This calls `rl_read_init_file()` in the underlying library.

6.7.2 Line buffer

The following functions operate on the line buffer:

`readline.get_line_buffer()`
Return the current contents of the line buffer (`rl_line_buffer` in the underlying library).

`readline.insert_text(`*string*`)`
Insert text into the line buffer at the cursor position. This calls `rl_insert_text()` in the underlying library, but ignores the return value.

readline.redisplay()
Change what's displayed on the screen to reflect the current contents of the line buffer. This calls rl_redisplay() in the underlying library.

6.7.3 History file

The following functions operate on a history file:

readline.read_history_file([*filename*])
Load a readline history file, and append it to the history list. The default filename is ~/.history. This calls read_history() in the underlying library.

readline.write_history_file([*filename*])
Save the history list to a readline history file, overwriting any existing file. The default filename is ~/.history. This calls write_history() in the underlying library.

readline.append_history_file(*nelements*[, *filename*])
Append the last *nelements* items of history to a file. The default filename is ~/.history. The file must already exist. This calls append_history() in the underlying library. This function only exists if Python was compiled for a version of the library that supports it.

New in version 3.5.

readline.get_history_length()
readline.set_history_length(*length*)
Set or return the desired number of lines to save in the history file. The *write_history_file()* function uses this value to truncate the history file, by calling history_truncate_file() in the underlying library. Negative values imply unlimited history file size.

6.7.4 History list

The following functions operate on a global history list:

readline.clear_history()
Clear the current history. This calls clear_history() in the underlying library. The Python function only exists if Python was compiled for a version of the library that supports it.

readline.get_current_history_length()
Return the number of items currently in the history. (This is different from *get_history_length()*, which returns the maximum number of lines that will be written to a history file.)

readline.get_history_item(*index*)
Return the current contents of history item at *index*. The item index is one-based. This calls history_get() in the underlying library.

readline.remove_history_item(*pos*)
Remove history item specified by its position from the history. The position is zero-based. This calls remove_history() in the underlying library.

readline.replace_history_item(*pos*, *line*)
Replace history item specified by its position with *line*. The position is zero-based. This calls replace_history_entry() in the underlying library.

readline.add_history(*line*)
Append *line* to the history buffer, as if it was the last line typed. This calls add_history() in the underlying library.

readline.set_auto_history(*enabled*)
Enable or disable automatic calls to add_history() when reading input via readline. The *enabled*

argument should be a Boolean value that when true, enables auto history, and that when false, disables auto history.

New in version 3.6.

CPython implementation detail: Auto history is enabled by default, and changes to this do not persist across multiple sessions.

6.7.5 Startup hooks

`readline.set_startup_hook([function])`
Set or remove the function invoked by the `rl_startup_hook` callback of the underlying library. If *function* is specified, it will be used as the new hook function; if omitted or `None`, any function already installed is removed. The hook is called with no arguments just before readline prints the first prompt.

`readline.set_pre_input_hook([function])`
Set or remove the function invoked by the `rl_pre_input_hook` callback of the underlying library. If *function* is specified, it will be used as the new hook function; if omitted or `None`, any function already installed is removed. The hook is called with no arguments after the first prompt has been printed and just before readline starts reading input characters. This function only exists if Python was compiled for a version of the library that supports it.

6.7.6 Completion

The following functions relate to implementing a custom word completion function. This is typically operated by the Tab key, and can suggest and automatically complete a word being typed. By default, Readline is set up to be used by *rlcompleter* to complete Python identifiers for the interactive interpreter. If the *readline* module is to be used with a custom completer, a different set of word delimiters should be set.

`readline.set_completer([function])`
Set or remove the completer function. If *function* is specified, it will be used as the new completer function; if omitted or `None`, any completer function already installed is removed. The completer function is called as `function(text, state)`, for *state* in `0`, `1`, `2`, ..., until it returns a non-string value. It should return the next possible completion starting with *text*.

The installed completer function is invoked by the *entry_func* callback passed to `rl_completion_matches()` in the underlying library. The *text* string comes from the first parameter to the `rl_attempted_completion_function` callback of the underlying library.

`readline.get_completer()`
Get the completer function, or `None` if no completer function has been set.

`readline.get_completion_type()`
Get the type of completion being attempted. This returns the `rl_completion_type` variable in the underlying library as an integer.

`readline.get_begidx()`
`readline.get_endidx()`
Get the beginning or ending index of the completion scope. These indexes are the *start* and *end* arguments passed to the `rl_attempted_completion_function` callback of the underlying library.

`readline.set_completer_delims(string)`
`readline.get_completer_delims()`
Set or get the word delimiters for completion. These determine the start of the word to be considered for completion (the completion scope). These functions access the `rl_completer_word_break_characters` variable in the underlying library.

readline.set_completion_display_matches_hook([*function*])
: Set or remove the completion display function. If *function* is specified, it will be used as the new completion display function; if omitted or `None`, any completion display function already installed is removed. This sets or clears the `rl_completion_display_matches_hook` callback in the underlying library. The completion display function is called as `function(substitution, [matches], longest_match_length)` once each time matches need to be displayed.

6.7.7 Example

The following example demonstrates how to use the *readline* module's history reading and writing functions to automatically load and save a history file named `.python_history` from the user's home directory. The code below would normally be executed automatically during interactive sessions from the user's `PYTHONSTARTUP` file.

```
import atexit
import os
import readline

histfile = os.path.join(os.path.expanduser("~"), ".python_history")
try:
    readline.read_history_file(histfile)
    # default history len is -1 (infinite), which may grow unruly
    readline.set_history_length(1000)
except FileNotFoundError:
    pass

atexit.register(readline.write_history_file, histfile)
```

This code is actually automatically run when Python is run in interactive mode (see *Readline configuration*).

The following example achieves the same goal but supports concurrent interactive sessions, by only appending the new history.

```
import atexit
import os
import readline
histfile = os.path.join(os.path.expanduser("~"), ".python_history")

try:
    readline.read_history_file(histfile)
    h_len = readline.get_current_history_length()
except FileNotFoundError:
    open(histfile, 'wb').close()
    h_len = 0

def save(prev_h_len, histfile):
    new_h_len = readline.get_current_history_length()
    readline.set_history_length(1000)
    readline.append_history_file(new_h_len - prev_h_len, histfile)
atexit.register(save, h_len, histfile)
```

The following example extends the *code.InteractiveConsole* class to support history save/restore.

```
import atexit
import code
import os
```

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```
import readline

class HistoryConsole(code.InteractiveConsole):
    def __init__(self, locals=None, filename="<console>",
                 histfile=os.path.expanduser("~/.console-history")):
        code.InteractiveConsole.__init__(self, locals, filename)
        self.init_history(histfile)

    def init_history(self, histfile):
        readline.parse_and_bind("tab: complete")
        if hasattr(readline, "read_history_file"):
            try:
                readline.read_history_file(histfile)
            except FileNotFoundError:
                pass
            atexit.register(self.save_history, histfile)

    def save_history(self, histfile):
        readline.set_history_length(1000)
        readline.write_history_file(histfile)
```

6.8 `rlcompleter` — Completion function for GNU readline

Source code: Lib/rlcompleter.py

The *rlcompleter* module defines a completion function suitable for the *readline* module by completing valid Python identifiers and keywords.

When this module is imported on a Unix platform with the *readline* module available, an instance of the `Completer` class is automatically created and its `complete()` method is set as the *readline* completer.

Example:

```
>>> import rlcompleter
>>> import readline
>>> readline.parse_and_bind("tab: complete")
>>> readline. <TAB PRESSED>
readline.__doc__          readline.get_line_buffer(  readline.read_init_file(
readline.__file__         readline.insert_text(      readline.set_completer(
readline.__name__         readline.parse_and_bind(
>>> readline.
```

The *rlcompleter* module is designed for use with Python's interactive mode. Unless Python is run with the `-S` option, the module is automatically imported and configured (see *Readline configuration*).

On platforms without *readline*, the `Completer` class defined by this module can still be used for custom purposes.

6.8.1 Completer Objects

Completer objects have the following method:

`Completer.complete`(*text*, *state*)

Return the *state*th completion for *text*.

If called for *text* that doesn't include a period character (`'.'`), it will complete from names currently defined in *__main__*, *builtins* and keywords (as defined by the *keyword* module).

If called for a dotted name, it will try to evaluate anything without obvious side-effects (functions will not be evaluated, but it can generate calls to `__getattr__()`) up to the last part, and find matches for the rest via the *dir()* function. Any exception raised during the evaluation of the expression is caught, silenced and *None* is returned.

CHAPTER

SEVEN

BINARY DATA SERVICES

The modules described in this chapter provide some basic services operations for manipulation of binary data. Other operations on binary data, specifically in relation to file formats and network protocols, are described in the relevant sections.

Some libraries described under *Text Processing Services* also work with either ASCII-compatible binary formats (for example, *re*) or all binary data (for example, *difflib*).

In addition, see the documentation for Python's built-in binary data types in *Binary Sequence Types — bytes, bytearray, memoryview*.

7.1 struct — Interpret bytes as packed binary data

Source code: Lib/struct.py

This module performs conversions between Python values and C structs represented as Python *bytes* objects. This can be used in handling binary data stored in files or from network connections, among other sources. It uses *Format Strings* as compact descriptions of the layout of the C structs and the intended conversion to/from Python values.

Note: By default, the result of packing a given C struct includes pad bytes in order to maintain proper alignment for the C types involved; similarly, alignment is taken into account when unpacking. This behavior is chosen so that the bytes of a packed struct correspond exactly to the layout in memory of the corresponding C struct. To handle platform-independent data formats or omit implicit pad bytes, use `standard` size and alignment instead of `native` size and alignment: see *Byte Order, Size, and Alignment* for details.

Several *struct* functions (and methods of *Struct*) take a *buffer* argument. This refers to objects that implement the bufferobjects and provide either a readable or read-writable buffer. The most common types used for that purpose are *bytes* and *bytearray*, but many other types that can be viewed as an array of bytes implement the buffer protocol, so that they can be read/filled without additional copying from a *bytes* object.

7.1.1 Functions and Exceptions

The module defines the following exception and functions:

exception struct.error

Exception raised on various occasions; argument is a string describing what is wrong.

`struct.pack`(*format*, *v1*, *v2*, ...)
Return a bytes object containing the values *v1*, *v2*, ... packed according to the format string *format*. The arguments must match the values required by the format exactly.

`struct.pack_into`(*format*, *buffer*, *offset*, *v1*, *v2*, ...)
Pack the values *v1*, *v2*, ... according to the format string *format* and write the packed bytes into the writable buffer *buffer* starting at position *offset*. Note that *offset* is a required argument.

`struct.unpack`(*format*, *buffer*)
Unpack from the buffer *buffer* (presumably packed by `pack(format, ...)`) according to the format string *format*. The result is a tuple even if it contains exactly one item. The buffer's size in bytes must match the size required by the format, as reflected by *calcsize()*.

`struct.unpack_from`(*format*, *buffer*, *offset=0*)
Unpack from *buffer* starting at position *offset*, according to the format string *format*. The result is a tuple even if it contains exactly one item. The buffer's size in bytes, minus *offset*, must be at least the size required by the format, as reflected by *calcsize()*.

`struct.iter_unpack`(*format*, *buffer*)
Iteratively unpack from the buffer *buffer* according to the format string *format*. This function returns an iterator which will read equally-sized chunks from the buffer until all its contents have been consumed. The buffer's size in bytes must be a multiple of the size required by the format, as reflected by *calcsize()*.

Each iteration yields a tuple as specified by the format string.

New in version 3.4.

`struct.calcsize`(*format*)
Return the size of the struct (and hence of the bytes object produced by `pack(format, ...)`) corresponding to the format string *format*.

7.1.2 Format Strings

Format strings are the mechanism used to specify the expected layout when packing and unpacking data. They are built up from *Format Characters*, which specify the type of data being packed/unpacked. In addition, there are special characters for controlling the *Byte Order, Size, and Alignment*.

Byte Order, Size, and Alignment

By default, C types are represented in the machine's native format and byte order, and properly aligned by skipping pad bytes if necessary (according to the rules used by the C compiler).

Alternatively, the first character of the format string can be used to indicate the byte order, size and alignment of the packed data, according to the following table:

Character	Byte order	Size	Alignment
`@`	native	native	native
`=`	native	standard	none
`<`	little-endian	standard	none
`>`	big-endian	standard	none
`!`	network (= big-endian)	standard	none

If the first character is not one of these, `'@'` is assumed.

Native byte order is big-endian or little-endian, depending on the host system. For example, Intel x86 and AMD64 (x86-64) are little-endian; Motorola 68000 and PowerPC G5 are big-endian; ARM and Intel Itanium feature switchable endianness (bi-endian). Use `sys.byteorder` to check the endianness of your system.

Native size and alignment are determined using the C compiler's `sizeof` expression. This is always combined with native byte order.

Standard size depends only on the format character; see the table in the *Format Characters* section.

Note the difference between `'@'` and `'='`: both use native byte order, but the size and alignment of the latter is standardized.

The form `'!'` is available for those poor souls who claim they can't remember whether network byte order is big-endian or little-endian.

There is no way to indicate non-native byte order (force byte-swapping); use the appropriate choice of `'<'` or `'>'`.

Notes:

1. Padding is only automatically added between successive structure members. No padding is added at the beginning or the end of the encoded struct.
2. No padding is added when using non-native size and alignment, e.g. with '<', '>', '=', and '!'.
3. To align the end of a structure to the alignment requirement of a particular type, end the format with the code for that type with a repeat count of zero. See *Examples*.

Format Characters

Format characters have the following meaning; the conversion between C and Python values should be obvious given their types. The 'Standard size' column refers to the size of the packed value in bytes when using standard size; that is, when the format string starts with one of `'<'`, `'>'`, `'!'` or `'='`. When using native size, the size of the packed value is platform-dependent.

Format	C Type	Python type	Standard size	Notes
`x`	pad byte	no value		
`c`	`char`	bytes of length 1	1	
`b`	`signed char`	integer	1	(1),(3)
`B`	`unsigned char`	integer	1	(3)
`?`	`_Bool`	bool	1	(1)
`h`	`short`	integer	2	(3)
`H`	`unsigned short`	integer	2	(3)
`i`	`int`	integer	4	(3)
`I`	`unsigned int`	integer	4	(3)
`l`	`long`	integer	4	(3)
`L`	`unsigned long`	integer	4	(3)
`q`	`long long`	integer	8	(2), (3)
`Q`	`unsigned long long`	integer	8	(2), (3)
`n`	`ssize_t`	integer		(4)
`N`	`size_t`	integer		(4)
`e`	(7)	float	2	(5)
`f`	`float`	float	4	(5)
`d`	`double`	float	8	(5)
`s`	`char[]`	bytes		
`p`	`char[]`	bytes		
`P`	`void *`	integer		(6)

Changed in version 3.3: Added support for the `'n'` and `'N'` formats.

Changed in version 3.6: Added support for the `'e'` format.

Notes:

1. The `'?'` conversion code corresponds to the `_Bool` type defined by C99. If this type is not available, it is simulated using a `char`. In standard mode, it is always represented by one byte.
2. The `'q'` and `'Q'` conversion codes are available in native mode only if the platform C compiler supports C `long long`, or, on Windows, `__int64`. They are always available in standard modes.
3. When attempting to pack a non-integer using any of the integer conversion codes, if the non-integer has a `__index__()` method then that method is called to convert the argument to an integer before packing.

   Changed in version 3.2: Use of the `__index__()` method for non-integers is new in 3.2.
4. The `'n'` and `'N'` conversion codes are only available for the native size (selected as the default or with the `'@'` byte order character). For the standard size, you can use whichever of the other integer formats fits your application.
5. For the `'f'`, `'d'` and `'e'` conversion codes, the packed representation uses the IEEE 754 binary32, binary64 or binary16 format (for `'f'`, `'d'` or `'e'` respectively), regardless of the floating-point format used by the platform.
6. The `'P'` format character is only available for the native byte ordering (selected as the default or with the `'@'` byte order character). The byte order character `'='` chooses to use little- or big-endian ordering based on the host system. The struct module does not interpret this as native ordering, so the `'P'` format is not available.
7. The IEEE 754 binary16 "half precision" type was introduced in the 2008 revision of the IEEE 754 standard. It has a sign bit, a 5-bit exponent and 11-bit precision (with 10 bits explicitly stored), and can represent numbers between approximately `6.1e-05` and `6.5e+04` at full precision. This type is not widely supported by C compilers: on a typical machine, an unsigned short can be used for storage, but not for math operations. See the Wikipedia page on the half-precision floating-point format for more information.

A format character may be preceded by an integral repeat count. For example, the format string `'4h'` means exactly the same as `'hhhh'`.

Whitespace characters between formats are ignored; a count and its format must not contain whitespace though.

For the `'s'` format character, the count is interpreted as the length of the bytes, not a repeat count like for the other format characters; for example, `'10s'` means a single 10-byte string, while `'10c'` means 10 characters. If a count is not given, it defaults to 1. For packing, the string is truncated or padded with null bytes as appropriate to make it fit. For unpacking, the resulting bytes object always has exactly the specified number of bytes. As a special case, `'0s'` means a single, empty string (while `'0c'` means 0 characters).

When packing a value `x` using one of the integer formats (`'b'`, `'B'`, `'h'`, `'H'`, `'i'`, `'I'`, `'l'`, `'L'`, `'q'`, `'Q'`), if `x` is outside the valid range for that format then *struct.error* is raised.

Changed in version 3.1: In 3.0, some of the integer formats wrapped out-of-range values and raised *DeprecationWarning* instead of *struct.error*.

The `'p'` format character encodes a "Pascal string", meaning a short variable-length string stored in a *fixed number of bytes*, given by the count. The first byte stored is the length of the string, or 255, whichever is smaller. The bytes of the string follow. If the string passed in to *pack()* is too long (longer than the count minus 1), only the leading `count-1` bytes of the string are stored. If the string is shorter than `count-1`, it is padded with null bytes so that exactly count bytes in all are used. Note that for *unpack()*, the `'p'` format character consumes `count` bytes, but that the string returned can never contain more than 255 bytes.

For the `'?'` format character, the return value is either *True* or *False*. When packing, the truth value of the argument object is used. Either 0 or 1 in the native or standard bool representation will be packed, and any non-zero value will be `True` when unpacking.

Examples

Note: All examples assume a native byte order, size, and alignment with a big-endian machine.

A basic example of packing/unpacking three integers:

```
>>> from struct import *
>>> pack('hhl', 1, 2, 3)
b'\x00\x01\x00\x02\x00\x00\x00\x03'
>>> unpack('hhl', b'\x00\x01\x00\x02\x00\x00\x00\x03')
(1, 2, 3)
>>> calcsize('hhl')
8
```

Unpacked fields can be named by assigning them to variables or by wrapping the result in a named tuple:

```
>>> record = b'raymond   \x32\x12\x08\x01\x08'
>>> name, serialnum, school, gradelevel = unpack('<10sHHb', record)

>>> from collections import namedtuple
>>> Student = namedtuple('Student', 'name serialnum school gradelevel')
>>> Student._make(unpack('<10sHHb', record))
Student(name=b'raymond   ', serialnum=4658, school=264, gradelevel=8)
```

The ordering of format characters may have an impact on size since the padding needed to satisfy alignment requirements is different:

```
>>> pack('ci', b'*', 0x12131415)
b'*\x00\x00\x00\x12\x13\x14\x15'
>>> pack('ic', 0x12131415, b'*')
b'\x12\x13\x14\x15*'
>>> calcsize('ci')
8
>>> calcsize('ic')
5
```

The following format `'llh0l'` specifies two pad bytes at the end, assuming longs are aligned on 4-byte boundaries:

```
>>> pack('llh0l', 1, 2, 3)
b'\x00\x00\x00\x01\x00\x00\x00\x02\x00\x03\x00\x00'
```

This only works when native size and alignment are in effect; standard size and alignment does not enforce any alignment.

See also:

Module *array* Packed binary storage of homogeneous data.

Module *xdrlib* Packing and unpacking of XDR data.

7.1.3 Classes

The *struct* module also defines the following type:

class `struct.Struct`(*format*)

Return a new Struct object which writes and reads binary data according to the format string *format*.

Creating a Struct object once and calling its methods is more efficient than calling the *struct* functions with the same format since the format string only needs to be compiled once.

Compiled Struct objects support the following methods and attributes:

pack(*v1*, *v2*, ...)
Identical to the *pack()* function, using the compiled format. (**len(result)** will equal *size*.)

pack_into(*buffer*, *offset*, *v1*, *v2*, ...)
Identical to the *pack_into()* function, using the compiled format.

unpack(*buffer*)
Identical to the *unpack()* function, using the compiled format. The buffer's size in bytes must equal *size*.

unpack_from(*buffer*, *offset=0*)
Identical to the *unpack_from()* function, using the compiled format. The buffer's size in bytes, minus *offset*, must be at least *size*.

iter_unpack(*buffer*)
Identical to the *iter_unpack()* function, using the compiled format. The buffer's size in bytes must be a multiple of *size*.

New in version 3.4.

format
The format string used to construct this Struct object.

Changed in version 3.7: The format string type is now *str* instead of *bytes*.

size
The calculated size of the struct (and hence of the bytes object produced by the *pack()* method) corresponding to *format*.

7.2 codecs — Codec registry and base classes

Source code: Lib/codecs.py

This module defines base classes for standard Python codecs (encoders and decoders) and provides access to the internal Python codec registry, which manages the codec and error handling lookup process. Most standard codecs are *text encodings*, which encode text to bytes, but there are also codecs provided that encode text to text, and bytes to bytes. Custom codecs may encode and decode between arbitrary types, but some module features are restricted to use specifically with *text encodings*, or with codecs that encode to *bytes*.

The module defines the following functions for encoding and decoding with any codec:

codecs.encode(*obj*, *encoding='utf-8'*, *errors='strict'*)
Encodes *obj* using the codec registered for *encoding*.

Errors may be given to set the desired error handling scheme. The default error handler is **'strict'** meaning that encoding errors raise *ValueError* (or a more codec specific subclass, such as *UnicodeEncodeError*). Refer to *Codec Base Classes* for more information on codec error handling.

codecs.decode(*obj*, *encoding='utf-8'*, *errors='strict'*)
Decodes *obj* using the codec registered for *encoding*.

Errors may be given to set the desired error handling scheme. The default error handler is **'strict'** meaning that decoding errors raise *ValueError* (or a more codec specific subclass, such as *UnicodeDecodeError*). Refer to *Codec Base Classes* for more information on codec error handling.

The full details for each codec can also be looked up directly:

codecs.lookup(*encoding*)
Looks up the codec info in the Python codec registry and returns a *CodecInfo* object as defined below.

Encodings are first looked up in the registry's cache. If not found, the list of registered search functions is scanned. If no *CodecInfo* object is found, a *LookupError* is raised. Otherwise, the *CodecInfo* object is stored in the cache and returned to the caller.

class codecs.CodecInfo(*encode*, *decode*, *streamreader=None*, *streamwriter=None*, *incrementalencoder=None*, *incrementaldecoder=None*, *name=None*)
Codec details when looking up the codec registry. The constructor arguments are stored in attributes of the same name:

name
The name of the encoding.

encode
decode
The stateless encoding and decoding functions. These must be functions or methods which have the same interface as the *encode()* and *decode()* methods of Codec instances (see *Codec Interface*). The functions or methods are expected to work in a stateless mode.

incrementalencoder
incrementaldecoder
Incremental encoder and decoder classes or factory functions. These have to provide the interface defined by the base classes *IncrementalEncoder* and *IncrementalDecoder*, respectively. Incremental codecs can maintain state.

streamwriter
streamreader
Stream writer and reader classes or factory functions. These have to provide the interface defined by the base classes *StreamWriter* and *StreamReader*, respectively. Stream codecs can maintain state.

To simplify access to the various codec components, the module provides these additional functions which use *lookup()* for the codec lookup:

codecs.getencoder(*encoding*)
Look up the codec for the given encoding and return its encoder function.

Raises a *LookupError* in case the encoding cannot be found.

codecs.getdecoder(*encoding*)
Look up the codec for the given encoding and return its decoder function.

Raises a *LookupError* in case the encoding cannot be found.

codecs.getincrementalencoder(*encoding*)
Look up the codec for the given encoding and return its incremental encoder class or factory function.

Raises a *LookupError* in case the encoding cannot be found or the codec doesn't support an incremental encoder.

codecs.getincrementaldecoder(*encoding*)
Look up the codec for the given encoding and return its incremental decoder class or factory function.

Raises a *LookupError* in case the encoding cannot be found or the codec doesn't support an incremental decoder.

codecs.getreader(*encoding*)
Look up the codec for the given encoding and return its *StreamReader* class or factory function.

Raises a *LookupError* in case the encoding cannot be found.

codecs.**getwriter**(*encoding*)
Look up the codec for the given encoding and return its *StreamWriter* class or factory function.

Raises a *LookupError* in case the encoding cannot be found.

Custom codecs are made available by registering a suitable codec search function:

codecs.**register**(*search_function*)
Register a codec search function. Search functions are expected to take one argument, being the encoding name in all lower case letters, and return a *CodecInfo* object. In case a search function cannot find a given encoding, it should return `None`.

Note: Search function registration is not currently reversible, which may cause problems in some cases, such as unit testing or module reloading.

While the builtin *open()* and the associated *io* module are the recommended approach for working with encoded text files, this module provides additional utility functions and classes that allow the use of a wider range of codecs when working with binary files:

codecs.**open**(*filename*, *mode='r'*, *encoding=None*, *errors='strict'*, *buffering=1*)
Open an encoded file using the given *mode* and return an instance of *StreamReaderWriter*, providing transparent encoding/decoding. The default file mode is `'r'`, meaning to open the file in read mode.

Note: Underlying encoded files are always opened in binary mode. No automatic conversion of `'\n'` is done on reading and writing. The *mode* argument may be any binary mode acceptable to the built-in *open()* function; the `'b'` is automatically added.

---

encoding specifies the encoding which is to be used for the file. Any encoding that encodes to and decodes from bytes is allowed, and the data types supported by the file methods depend on the codec used.

errors may be given to define the error handling. It defaults to `'strict'` which causes a *ValueError* to be raised in case an encoding error occurs.

buffering has the same meaning as for the built-in *open()* function. It defaults to line buffered.

codecs.**EncodedFile**(*file*, *data_encoding*, *file_encoding=None*, *errors='strict'*)
Return a *StreamRecoder* instance, a wrapped version of *file* which provides transparent transcoding. The original file is closed when the wrapped version is closed.

Data written to the wrapped file is decoded according to the given *data_encoding* and then written to the original file as bytes using *file_encoding*. Bytes read from the original file are decoded according to *file_encoding*, and the result is encoded using *data_encoding*.

If *file_encoding* is not given, it defaults to *data_encoding*.

errors may be given to define the error handling. It defaults to `'strict'`, which causes *ValueError* to be raised in case an encoding error occurs.

codecs.**iterencode**(*iterator*, *encoding*, *errors='strict'*, ***kwargs*)
Uses an incremental encoder to iteratively encode the input provided by *iterator*. This function is a *generator*. The *errors* argument (as well as any other keyword argument) is passed through to the incremental encoder.

This function requires that the codec accept text *str* objects to encode. Therefore it does not support bytes-to-bytes encoders such as `base64_codec`.

codecs.**iterdecode**(*iterator*, *encoding*, *errors='strict'*, ***kwargs*)
Uses an incremental decoder to iteratively decode the input provided by *iterator*. This function is a

generator. The *errors* argument (as well as any other keyword argument) is passed through to the incremental decoder.

This function requires that the codec accept *bytes* objects to decode. Therefore it does not support text-to-text encoders such as `rot_13`, although `rot_13` may be used equivalently with *iterencode()*.

The module also provides the following constants which are useful for reading and writing to platform dependent files:

`codecs.BOM`
`codecs.BOM_BE`
`codecs.BOM_LE`
`codecs.BOM_UTF8`
`codecs.BOM_UTF16`
`codecs.BOM_UTF16_BE`
`codecs.BOM_UTF16_LE`
`codecs.BOM_UTF32`
`codecs.BOM_UTF32_BE`
`codecs.BOM_UTF32_LE`

These constants define various byte sequences, being Unicode byte order marks (BOMs) for several encodings. They are used in UTF-16 and UTF-32 data streams to indicate the byte order used, and in UTF-8 as a Unicode signature. *BOM_UTF16* is either *BOM_UTF16_BE* or *BOM_UTF16_LE* depending on the platform's native byte order, *BOM* is an alias for *BOM_UTF16*, *BOM_LE* for *BOM_UTF16_LE* and *BOM_BE* for *BOM_UTF16_BE*. The others represent the BOM in UTF-8 and UTF-32 encodings.

7.2.1 Codec Base Classes

The *codecs* module defines a set of base classes which define the interfaces for working with codec objects, and can also be used as the basis for custom codec implementations.

Each codec has to define four interfaces to make it usable as codec in Python: stateless encoder, stateless decoder, stream reader and stream writer. The stream reader and writers typically reuse the stateless encoder/decoder to implement the file protocols. Codec authors also need to define how the codec will handle encoding and decoding errors.

Error Handlers

To simplify and standardize error handling, codecs may implement different error handling schemes by accepting the *errors* string argument. The following string values are defined and implemented by all standard Python codecs:

Value	Meaning
`'strict'`	Raise *UnicodeError* (or a subclass); this is the default. Implemented in *strict_errors()*.
`'ignore'`	Ignore the malformed data and continue without further notice. Implemented in *ignore_errors()*.

The following error handlers are only applicable to *text encodings*:

Value	Meaning
`'replace'`	Replace with a suitable replacement marker; Python will use the official `U+FFFD` REPLACEMENT CHARACTER for the built-in codecs on decoding, and '?' on encoding. Implemented in *replace_errors()*.
`'xmlcharrefreplace'`	Replace with the appropriate XML character reference (only for encoding). Implemented in *xmlcharrefreplace_errors()*.
`'backslashreplace'`	Replace with backslashed escape sequences. Implemented in *backslashreplace_errors()*.
`'namereplace'`	Replace with `\N{...}` escape sequences (only for encoding). Implemented in *namereplace_errors()*.
`'surrogateescape'`	On decoding, replace byte with individual surrogate code ranging from `U+DC80` to `U+DCFF`. This code will then be turned back into the same byte when the `'surrogateescape'` error handler is used when encoding the data. (See **PEP 383** for more.)

In addition, the following error handler is specific to the given codecs:

Value	Codecs	Meaning
`'surrogatepass'`	utf-8, utf-16, utf-32, utf-16-be, utf-16-le, utf-32-be, utf-32-le	Allow encoding and decoding of surrogate codes. These codecs normally treat the presence of surrogates as an error.

New in version 3.1: The `'surrogateescape'` and `'surrogatepass'` error handlers.

Changed in version 3.4: The `'surrogatepass'` error handlers now works with utf-16* and utf-32* codecs.

New in version 3.5: The `'namereplace'` error handler.

Changed in version 3.5: The `'backslashreplace'` error handlers now works with decoding and translating.

The set of allowed values can be extended by registering a new named error handler:

codecs.register_error(*name*, *error_handler*)

Register the error handling function *error_handler* under the name *name*. The *error_handler* argument will be called during encoding and decoding in case of an error, when *name* is specified as the errors parameter.

For encoding, *error_handler* will be called with a *UnicodeEncodeError* instance, which contains information about the location of the error. The error handler must either raise this or a different exception, or return a tuple with a replacement for the unencodable part of the input and a position where encoding should continue. The replacement may be either *str* or *bytes*. If the replacement is bytes, the encoder will simply copy them into the output buffer. If the replacement is a string, the encoder will encode the replacement. Encoding continues on original input at the specified position. Negative position values will be treated as being relative to the end of the input string. If the resulting position is out of bound an *IndexError* will be raised.

Decoding and translating works similarly, except *UnicodeDecodeError* or *UnicodeTranslateError* will be passed to the handler and that the replacement from the error handler will be put into the output directly.

Previously registered error handlers (including the standard error handlers) can be looked up by name:

codecs.lookup_error(*name*)

Return the error handler previously registered under the name *name*.

Raises a *LookupError* in case the handler cannot be found.

The following standard error handlers are also made available as module level functions:

codecs.strict_errors(*exception*)

Implements the `'strict'` error handling: each encoding or decoding error raises a *UnicodeError*.

codecs.**replace_errors**(*exception*)
Implements the 'replace' error handling (for *text encodings* only): substitutes '?' for encoding errors (to be encoded by the codec), and '\ufffd' (the Unicode replacement character) for decoding errors.

codecs.**ignore_errors**(*exception*)
Implements the 'ignore' error handling: malformed data is ignored and encoding or decoding is continued without further notice.

codecs.**xmlcharrefreplace_errors**(*exception*)
Implements the 'xmlcharrefreplace' error handling (for encoding with *text encodings* only): the unencodable character is replaced by an appropriate XML character reference.

codecs.**backslashreplace_errors**(*exception*)
Implements the 'backslashreplace' error handling (for *text encodings* only): malformed data is replaced by a backslashed escape sequence.

codecs.**namereplace_errors**(*exception*)
Implements the 'namereplace' error handling (for encoding with *text encodings* only): the unencodable character is replaced by a \N{...} escape sequence.

New in version 3.5.

Stateless Encoding and Decoding

The base Codec class defines these methods which also define the function interfaces of the stateless encoder and decoder:

Codec.**encode**(*input*[, *errors*])
Encodes the object *input* and returns a tuple (output object, length consumed). For instance, *text encoding* converts a string object to a bytes object using a particular character set encoding (e.g., cp1252 or iso-8859-1).

The *errors* argument defines the error handling to apply. It defaults to 'strict' handling.

The method may not store state in the Codec instance. Use *StreamWriter* for codecs which have to keep state in order to make encoding efficient.

The encoder must be able to handle zero length input and return an empty object of the output object type in this situation.

Codec.**decode**(*input*[, *errors*])
Decodes the object *input* and returns a tuple (output object, length consumed). For instance, for a *text encoding*, decoding converts a bytes object encoded using a particular character set encoding to a string object.

For text encodings and bytes-to-bytes codecs, *input* must be a bytes object or one which provides the read-only buffer interface – for example, buffer objects and memory mapped files.

The *errors* argument defines the error handling to apply. It defaults to 'strict' handling.

The method may not store state in the Codec instance. Use *StreamReader* for codecs which have to keep state in order to make decoding efficient.

The decoder must be able to handle zero length input and return an empty object of the output object type in this situation.

Incremental Encoding and Decoding

The *IncrementalEncoder* and *IncrementalDecoder* classes provide the basic interface for incremental encoding and decoding. Encoding/decoding the input isn't done with one call to the stateless encoder/decoder

function, but with multiple calls to the *encode()*/*decode()* method of the incremental encoder/decoder. The incremental encoder/decoder keeps track of the encoding/decoding process during method calls.

The joined output of calls to the *encode()*/*decode()* method is the same as if all the single inputs were joined into one, and this input was encoded/decoded with the stateless encoder/decoder.

IncrementalEncoder Objects

The *IncrementalEncoder* class is used for encoding an input in multiple steps. It defines the following methods which every incremental encoder must define in order to be compatible with the Python codec registry.

class codecs.IncrementalEncoder(*errors='strict'*)

Constructor for an *IncrementalEncoder* instance.

All incremental encoders must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

The *IncrementalEncoder* may implement different error handling schemes by providing the *errors* keyword argument. See *Error Handlers* for possible values.

The *errors* argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the *IncrementalEncoder* object.

encode(*object*[, *final*])

Encodes *object* (taking the current state of the encoder into account) and returns the resulting encoded object. If this is the last call to *encode()* *final* must be true (the default is false).

reset()

Reset the encoder to the initial state. The output is discarded: call `.encode(object, final=True)`, passing an empty byte or text string if necessary, to reset the encoder and to get the output.

getstate()

Return the current state of the encoder which must be an integer. The implementation should make sure that `0` is the most common state. (States that are more complicated than integers can be converted into an integer by marshaling/pickling the state and encoding the bytes of the resulting string into an integer).

setstate(*state*)

Set the state of the encoder to *state*. *state* must be an encoder state returned by *getstate()*.

IncrementalDecoder Objects

The *IncrementalDecoder* class is used for decoding an input in multiple steps. It defines the following methods which every incremental decoder must define in order to be compatible with the Python codec registry.

class codecs.IncrementalDecoder(*errors='strict'*)

Constructor for an *IncrementalDecoder* instance.

All incremental decoders must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

The *IncrementalDecoder* may implement different error handling schemes by providing the *errors* keyword argument. See *Error Handlers* for possible values.

The *errors* argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the *IncrementalDecoder* object.

decode(*object*[, *final*])
Decodes *object* (taking the current state of the decoder into account) and returns the resulting decoded object. If this is the last call to *decode()* *final* must be true (the default is false). If *final* is true the decoder must decode the input completely and must flush all buffers. If this isn't possible (e.g. because of incomplete byte sequences at the end of the input) it must initiate error handling just like in the stateless case (which might raise an exception).

reset()
Reset the decoder to the initial state.

getstate()
Return the current state of the decoder. This must be a tuple with two items, the first must be the buffer containing the still undecoded input. The second must be an integer and can be additional state info. (The implementation should make sure that `0` is the most common additional state info.) If this additional state info is `0` it must be possible to set the decoder to the state which has no input buffered and `0` as the additional state info, so that feeding the previously buffered input to the decoder returns it to the previous state without producing any output. (Additional state info that is more complicated than integers can be converted into an integer by marshaling/pickling the info and encoding the bytes of the resulting string into an integer.)

setstate(*state*)
Set the state of the encoder to *state*. *state* must be a decoder state returned by *getstate()*.

Stream Encoding and Decoding

The *StreamWriter* and *StreamReader* classes provide generic working interfaces which can be used to implement new encoding submodules very easily. See `encodings.utf_8` for an example of how this is done.

StreamWriter Objects

The *StreamWriter* class is a subclass of `Codec` and defines the following methods which every stream writer must define in order to be compatible with the Python codec registry.

class codecs.StreamWriter(*stream*, *errors='strict'*)
Constructor for a *StreamWriter* instance.

All stream writers must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

The *stream* argument must be a file-like object open for writing text or binary data, as appropriate for the specific codec.

The *StreamWriter* may implement different error handling schemes by providing the *errors* keyword argument. See *Error Handlers* for the standard error handlers the underlying stream codec may support.

The *errors* argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the *StreamWriter* object.

write(*object*)
Writes the object's contents encoded to the stream.

writelines(*list*)
Writes the concatenated list of strings to the stream (possibly by reusing the *write()* method). The standard bytes-to-bytes codecs do not support this method.

reset()
Flushes and resets the codec buffers used for keeping state.

Calling this method should ensure that the data on the output is put into a clean state that allows appending of new fresh data without having to rescan the whole stream to recover state.

In addition to the above methods, the *StreamWriter* must also inherit all other methods and attributes from the underlying stream.

StreamReader Objects

The *StreamReader* class is a subclass of `Codec` and defines the following methods which every stream reader must define in order to be compatible with the Python codec registry.

class codecs.StreamReader(*stream*, *errors='strict'*)
Constructor for a *StreamReader* instance.

All stream readers must provide this constructor interface. They are free to add additional keyword arguments, but only the ones defined here are used by the Python codec registry.

The *stream* argument must be a file-like object open for reading text or binary data, as appropriate for the specific codec.

The *StreamReader* may implement different error handling schemes by providing the *errors* keyword argument. See *Error Handlers* for the standard error handlers the underlying stream codec may support.

The *errors* argument will be assigned to an attribute of the same name. Assigning to this attribute makes it possible to switch between different error handling strategies during the lifetime of the *StreamReader* object.

The set of allowed values for the *errors* argument can be extended with *register_error()*.

read(*[size[, chars[, firstline]]]*)
Decodes data from the stream and returns the resulting object.

The *chars* argument indicates the number of decoded code points or bytes to return. The *read()* method will never return more data than requested, but it might return less, if there is not enough available.

The *size* argument indicates the approximate maximum number of encoded bytes or code points to read for decoding. The decoder can modify this setting as appropriate. The default value -1 indicates to read and decode as much as possible. This parameter is intended to prevent having to decode huge files in one step.

The *firstline* flag indicates that it would be sufficient to only return the first line, if there are decoding errors on later lines.

The method should use a greedy read strategy meaning that it should read as much data as is allowed within the definition of the encoding and the given size, e.g. if optional encoding endings or state markers are available on the stream, these should be read too.

readline(*[size[, keepends]]*)
Read one line from the input stream and return the decoded data.

size, if given, is passed as size argument to the stream's *read()* method.

If *keepends* is false line-endings will be stripped from the lines returned.

readlines([*sizehint*[, *keepends*]])
Read all lines available on the input stream and return them as a list of lines.

Line-endings are implemented using the codec's decoder method and are included in the list entries if *keepends* is true.

sizehint, if given, is passed as the *size* argument to the stream's *read()* method.

reset()
Resets the codec buffers used for keeping state.

Note that no stream repositioning should take place. This method is primarily intended to be able to recover from decoding errors.

In addition to the above methods, the *StreamReader* must also inherit all other methods and attributes from the underlying stream.

StreamReaderWriter Objects

The *StreamReaderWriter* is a convenience class that allows wrapping streams which work in both read and write modes.

The design is such that one can use the factory functions returned by the *lookup()* function to construct the instance.

class codecs.**StreamReaderWriter**(*stream*, *Reader*, *Writer*, *errors='strict'*)
Creates a *StreamReaderWriter* instance. *stream* must be a file-like object. *Reader* and *Writer* must be factory functions or classes providing the *StreamReader* and *StreamWriter* interface resp. Error handling is done in the same way as defined for the stream readers and writers.

StreamReaderWriter instances define the combined interfaces of *StreamReader* and *StreamWriter* classes. They inherit all other methods and attributes from the underlying stream.

StreamRecoder Objects

The *StreamRecoder* translates data from one encoding to another, which is sometimes useful when dealing with different encoding environments.

The design is such that one can use the factory functions returned by the *lookup()* function to construct the instance.

class codecs.**StreamRecoder**(*stream*, *encode*, *decode*, *Reader*, *Writer*, *errors='strict'*)
Creates a *StreamRecoder* instance which implements a two-way conversion: *encode* and *decode* work on the frontend — the data visible to code calling **read**() and **write**(), while *Reader* and *Writer* work on the backend — the data in *stream*.

You can use these objects to do transparent transcodings from e.g. Latin-1 to UTF-8 and back.

The *stream* argument must be a file-like object.

The *encode* and *decode* arguments must adhere to the **Codec** interface. *Reader* and *Writer* must be factory functions or classes providing objects of the *StreamReader* and *StreamWriter* interface respectively.

Error handling is done in the same way as defined for the stream readers and writers.

StreamRecoder instances define the combined interfaces of *StreamReader* and *StreamWriter* classes. They inherit all other methods and attributes from the underlying stream.

7.2.2 Encodings and Unicode

Strings are stored internally as sequences of code points in range 0x0–0x10FFFF. (See **PEP 393** for more details about the implementation.) Once a string object is used outside of CPU and memory, endianness and how these arrays are stored as bytes become an issue. As with other codecs, serialising a string into a sequence of bytes is known as *encoding*, and recreating the string from the sequence of bytes is known as *decoding*. There are a variety of different text serialisation codecs, which are collectivity referred to as *text encodings*.

The simplest text encoding (called 'latin-1' or 'iso-8859-1') maps the code points 0–255 to the bytes 0x0–0xff, which means that a string object that contains code points above U+00FF can't be encoded with this codec. Doing so will raise a *UnicodeEncodeError* that looks like the following (although the details of the error message may differ): UnicodeEncodeError: 'latin-1' codec can't encode character '\u1234' in position 3: ordinal not in range(256).

There's another group of encodings (the so called charmap encodings) that choose a different subset of all Unicode code points and how these code points are mapped to the bytes 0x0–0xff. To see how this is done simply open e.g. encodings/cp1252.py (which is an encoding that is used primarily on Windows). There's a string constant with 256 characters that shows you which character is mapped to which byte value.

All of these encodings can only encode 256 of the 1114112 code points defined in Unicode. A simple and straightforward way that can store each Unicode code point, is to store each code point as four consecutive bytes. There are two possibilities: store the bytes in big endian or in little endian order. These two encodings are called UTF-32-BE and UTF-32-LE respectively. Their disadvantage is that if e.g. you use UTF-32-BE on a little endian machine you will always have to swap bytes on encoding and decoding. UTF-32 avoids this problem: bytes will always be in natural endianness. When these bytes are read by a CPU with a different endianness, then bytes have to be swapped though. To be able to detect the endianness of a UTF-16 or UTF-32 byte sequence, there's the so called BOM ("Byte Order Mark"). This is the Unicode character U+FEFF. This character can be prepended to every UTF-16 or UTF-32 byte sequence. The byte swapped version of this character (0xFFFE) is an illegal character that may not appear in a Unicode text. So when the first character in an UTF-16 or UTF-32 byte sequence appears to be a U+FFFE the bytes have to be swapped on decoding. Unfortunately the character U+FEFF had a second purpose as a ZERO WIDTH NO-BREAK SPACE: a character that has no width and doesn't allow a word to be split. It can e.g. be used to give hints to a ligature algorithm. With Unicode 4.0 using U+FEFF as a ZERO WIDTH NO-BREAK SPACE has been deprecated (with U+2060 (WORD JOINER) assuming this role). Nevertheless Unicode software still must be able to handle U+FEFF in both roles: as a BOM it's a device to determine the storage layout of the encoded bytes, and vanishes once the byte sequence has been decoded into a string; as a ZERO WIDTH NO-BREAK SPACE it's a normal character that will be decoded like any other.

There's another encoding that is able to encoding the full range of Unicode characters: UTF-8. UTF-8 is an 8-bit encoding, which means there are no issues with byte order in UTF-8. Each byte in a UTF-8 byte sequence consists of two parts: marker bits (the most significant bits) and payload bits. The marker bits are a sequence of zero to four 1 bits followed by a 0 bit. Unicode characters are encoded like this (with x being payload bits, which when concatenated give the Unicode character):

Range	Encoding
U-00000000 … U-0000007F	0xxxxxxx
U-00000080 … U-000007FF	110xxxxx 10xxxxxx
U-00000800 … U-0000FFFF	1110xxxx 10xxxxxx 10xxxxxx
U-00010000 … U-0010FFFF	11110xxx 10xxxxxx 10xxxxxx 10xxxxxx

The least significant bit of the Unicode character is the rightmost x bit.

As UTF-8 is an 8-bit encoding no BOM is required and any U+FEFF character in the decoded string (even if it's the first character) is treated as a ZERO WIDTH NO-BREAK SPACE.

Without external information it's impossible to reliably determine which encoding was used for encoding a

string. Each charmap encoding can decode any random byte sequence. However that's not possible with UTF-8, as UTF-8 byte sequences have a structure that doesn't allow arbitrary byte sequences. To increase the reliability with which a UTF-8 encoding can be detected, Microsoft invented a variant of UTF-8 (that Python 2.5 calls `"utf-8-sig"`) for its Notepad program: Before any of the Unicode characters is written to the file, a UTF-8 encoded BOM (which looks like this as a byte sequence: `0xef`, `0xbb`, `0xbf`) is written. As it's rather improbable that any charmap encoded file starts with these byte values (which would e.g. map to

LATIN SMALL LETTER I WITH DIAERESIS
RIGHT-POINTING DOUBLE ANGLE QUOTATION MARK
INVERTED QUESTION MARK

in iso-8859-1), this increases the probability that a `utf-8-sig` encoding can be correctly guessed from the byte sequence. So here the BOM is not used to be able to determine the byte order used for generating the byte sequence, but as a signature that helps in guessing the encoding. On encoding the utf-8-sig codec will write `0xef`, `0xbb`, `0xbf` as the first three bytes to the file. On decoding `utf-8-sig` will skip those three bytes if they appear as the first three bytes in the file. In UTF-8, the use of the BOM is discouraged and should generally be avoided.

7.2.3 Standard Encodings

Python comes with a number of codecs built-in, either implemented as C functions or with dictionaries as mapping tables. The following table lists the codecs by name, together with a few common aliases, and the languages for which the encoding is likely used. Neither the list of aliases nor the list of languages is meant to be exhaustive. Notice that spelling alternatives that only differ in case or use a hyphen instead of an underscore are also valid aliases; therefore, e.g. `'utf-8'` is a valid alias for the `'utf_8'` codec.

CPython implementation detail: Some common encodings can bypass the codecs lookup machinery to improve performance. These optimization opportunities are only recognized by CPython for a limited set of (case insensitive) aliases: utf-8, utf8, latin-1, latin1, iso-8859-1, iso8859-1, mbcs (Windows only), ascii, us-ascii, utf-16, utf16, utf-32, utf32, and the same using underscores instead of dashes. Using alternative aliases for these encodings may result in slower execution.

Changed in version 3.6: Optimization opportunity recognized for us-ascii.

Many of the character sets support the same languages. They vary in individual characters (e.g. whether the EURO SIGN is supported or not), and in the assignment of characters to code positions. For the European languages in particular, the following variants typically exist:

- an ISO 8859 codeset
- a Microsoft Windows code page, which is typically derived from an 8859 codeset, but replaces control characters with additional graphic characters
- an IBM EBCDIC code page
- an IBM PC code page, which is ASCII compatible

Codec	Aliases	Languages
ascii	646, us-ascii	English
big5	big5-tw, csbig5	Traditional Chinese
big5hkscs	big5-hkscs, hkscs	Traditional Chinese
cp037	IBM037, IBM039	English
cp273	273, IBM273, csIBM273	German New in version 3.4.
cp424	EBCDIC-CP-HE, IBM424	Hebrew
cp437	437, IBM437	English

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Codec	Aliases	Languages
cp500	EBCDIC-CP-BE, EBCDIC-CP-CH, IBM500	Western Europe
cp720		Arabic
cp737		Greek
cp775	IBM775	Baltic languages
cp850	850, IBM850	Western Europe
cp852	852, IBM852	Central and Eastern Europe
cp855	855, IBM855	Bulgarian, Byelorussian, Macedonian, Russian, Serbian
cp856		Hebrew
cp857	857, IBM857	Turkish
cp858	858, IBM858	Western Europe
cp860	860, IBM860	Portuguese
cp861	861, CP-IS, IBM861	Icelandic
cp862	862, IBM862	Hebrew
cp863	863, IBM863	Canadian
cp864	IBM864	Arabic
cp865	865, IBM865	Danish, Norwegian
cp866	866, IBM866	Russian
cp869	869, CP-GR, IBM869	Greek
cp874		Thai
cp875		Greek
cp932	932, ms932, mskanji, ms-kanji	Japanese
cp949	949, ms949, uhc	Korean
cp950	950, ms950	Traditional Chinese
cp1006		Urdu
cp1026	ibm1026	Turkish
cp1125	1125, ibm1125, cp866u, ruscii	Ukrainian New in version 3.4.
cp1140	ibm1140	Western Europe
cp1250	windows-1250	Central and Eastern Europe
cp1251	windows-1251	Bulgarian, Byelorussian, Macedonian, Russian, Serbian
cp1252	windows-1252	Western Europe
cp1253	windows-1253	Greek
cp1254	windows-1254	Turkish
cp1255	windows-1255	Hebrew
cp1256	windows-1256	Arabic
cp1257	windows-1257	Baltic languages
cp1258	windows-1258	Vietnamese
cp65001		Windows only: Windows UTF-8 (`CP_UTF8`) New in version 3.3.
euc_jp	eucjp, ujis, u-jis	Japanese
euc_jis_2004	jisx0213, eucjis2004	Japanese
euc_jisx0213	eucjisx0213	Japanese
euc_kr	euckr, korean, ksc5601, ks_c-5601, ks_c-5601-1987, ksx1001, ks_x-1001	Korean

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Table 1 – continued from previous page

Codec	Aliases	Languages
gb2312	chinese, csiso58gb231280, euc- cn, euccn, eucgb2312-cn, gb2312-1980, gb2312-80, iso-ir-58	Simplified Chinese
gbk	936, cp936, ms936	Unified Chinese
gb18030	gb18030-2000	Unified Chinese
hz	hzgb, hz-gb, hz-gb-2312	Simplified Chinese
iso2022_jp	csiso2022jp, iso2022jp, iso-2022-jp	Japanese
iso2022_jp_1	iso2022jp-1, iso-2022-jp-1	Japanese
iso2022_jp_2	iso2022jp-2, iso-2022-jp-2	Japanese, Korean, Simplified Chinese, Western Europe, Greek
iso2022_jp_2004	iso2022jp-2004, iso-2022-jp-2004	Japanese
iso2022_jp_3	iso2022jp-3, iso-2022-jp-3	Japanese
iso2022_jp_ext	iso2022jp-ext, iso-2022-jp-ext	Japanese
iso2022_kr	csiso2022kr, iso2022kr, iso-2022-kr	Korean
latin_1	iso-8859-1, iso8859-1, 8859, cp819, latin, latin1, L1	West Europe
iso8859_2	iso-8859-2, latin2, L2	Central and Eastern Europe
iso8859_3	iso-8859-3, latin3, L3	Esperanto, Maltese
iso8859_4	iso-8859-4, latin4, L4	Baltic languages
iso8859_5	iso-8859-5, cyrillic	Bulgarian, Byelorussian, Macedonian, Russian, Serbian
iso8859_6	iso-8859-6, arabic	Arabic
iso8859_7	iso-8859-7, greek, greek8	Greek
iso8859_8	iso-8859-8, hebrew	Hebrew
iso8859_9	iso-8859-9, latin5, L5	Turkish
iso8859_10	iso-8859-10, latin6, L6	Nordic languages
iso8859_11	iso-8859-11, thai	Thai languages
iso8859_13	iso-8859-13, latin7, L7	Baltic languages
iso8859_14	iso-8859-14, latin8, L8	Celtic languages
iso8859_15	iso-8859-15, latin9, L9	Western Europe
iso8859_16	iso-8859-16, latin10, L10	South-Eastern Europe
johab	cp1361, ms1361	Korean
koi8_r		Russian
koi8_t		Tajik New in version 3.5.
koi8_u		Ukrainian
kz1048	kz_1048, strk1048_2002, rk1048	Kazakh New in version 3.5.
mac_cyrillic	maccyrillic	Bulgarian, Byelorussian, Macedonian, Russian, Serbian
mac_greek	macgreek	Greek
mac_iceland	maciceland	Icelandic
mac_latin2	maclatin2, maccentraleurope	Central and Eastern Europe
mac_roman	macroman, macintosh	Western Europe
mac_turkish	macturkish	Turkish
ptcp154	csptcp154, pt154, cp154, cyrillic-asian	Kazakh

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Table 1 – continued from previous page

Codec	Aliases	Languages
shift_jis	csshiftjis, shiftjis, sjis, s_jis	Japanese
shift_jis_2004	shiftjis2004, sjis_2004, sjis2004	Japanese
shift_jisx0213	shiftjisx0213, sjisx0213, s_jisx0213	Japanese
utf_32	U32, utf32	all languages
utf_32_be	UTF-32BE	all languages
utf_32_le	UTF-32LE	all languages
utf_16	U16, utf16	all languages
utf_16_be	UTF-16BE	all languages
utf_16_le	UTF-16LE	all languages
utf_7	U7, unicode-1-1-utf-7	all languages
utf_8	U8, UTF, utf8	all languages
utf_8_sig		all languages

Changed in version 3.4: The utf-16* and utf-32* encoders no longer allow surrogate code points (`U+D800`–`U+DFFF`) to be encoded. The utf-32* decoders no longer decode byte sequences that correspond to surrogate code points.

7.2.4 Python Specific Encodings

A number of predefined codecs are specific to Python, so their codec names have no meaning outside Python. These are listed in the tables below based on the expected input and output types (note that while text encodings are the most common use case for codecs, the underlying codec infrastructure supports arbitrary data transforms rather than just text encodings). For asymmetric codecs, the stated purpose describes the encoding direction.

Text Encodings

The following codecs provide *`str`* to *`bytes`* encoding and *bytes-like object* to *`str`* decoding, similar to the Unicode text encodings.

Codec	Aliases	Purpose
idna		Implements **RFC 3490**, see also *encodings.idna*. Only `errors='strict'` is supported.
mbcs	ansi, dbcs	Windows only: Encode operand according to the ANSI codepage (CP_ACP)
oem		Windows only: Encode operand according to the OEM codepage (CP_OEMCP) New in version 3.6.
palmos		Encoding of PalmOS 3.5
punycode		Implements **RFC 3492**. Stateful codecs are not supported.
raw_unicode_escape		Latin-1 encoding with `\uXXXX` and `\UXXXXXXXX` for other code points. Existing backslashes are not escaped in any way. It is used in the Python pickle protocol.
undefined		Raise an exception for all conversions, even empty strings. The error handler is ignored.
unicode_escape		Encoding suitable as the contents of a Unicode literal in ASCII-encoded Python source code, except that quotes are not escaped. Decodes from Latin-1 source code. Beware that Python source code actually uses UTF-8 by default.
unicode_internal		Return the internal representation of the operand. Stateful codecs are not supported. Deprecated since version 3.3: This representation is obsoleted by **PEP 393**.

Binary Transforms

The following codecs provide binary transforms: *bytes-like object* to *bytes* mappings. They are not supported by *bytes.decode()* (which only produces *str* output).

Codec	Aliases	Purpose	Encoder / decoder
base64_codec[1]	base64, base_64	Convert operand to multiline MIME base64 (the result always includes a trailing `'\n'`) Changed in version 3.4: accepts any *bytes-like object* as input for encoding and decoding	*base64.encodebytes()* / *base64.decodebytes()*
bz2_codec	bz2	Compress the operand using bz2	*bz2.compress()* / *bz2.decompress()*
hex_codec	hex	Convert operand to hexadecimal representation, with two digits per byte	*binascii.b2a_hex()* / *binascii.a2b_hex()*
quopri_codec	quopri, quoted-printable, quoted_printable	Convert operand to MIME quoted printable	*quopri.encode()* with `quotetabs=True` / *quopri.decode()*
uu_codec	uu	Convert the operand using uuencode	*uu.encode()* / *uu.decode()*
zlib_codec	zip, zlib	Compress the operand using gzip	*zlib.compress()* / *zlib.decompress()*

New in version 3.2: Restoration of the binary transforms.

Changed in version 3.4: Restoration of the aliases for the binary transforms.

Text Transforms

The following codec provides a text transform: a *str* to *str* mapping. It is not supported by *str.encode()* (which only produces *bytes* output).

Codec	Aliases	Purpose
rot_13	rot13	Returns the Caesar-cypher encryption of the operand

New in version 3.2: Restoration of the `rot_13` text transform.

Changed in version 3.4: Restoration of the `rot13` alias.

7.2.5 `encodings.idna` — Internationalized Domain Names in Applications

This module implements **RFC 3490** (Internationalized Domain Names in Applications) and **RFC 3492** (Nameprep: A Stringprep Profile for Internationalized Domain Names (IDN)). It builds upon the `punycode` encoding and *stringprep*.

These RFCs together define a protocol to support non-ASCII characters in domain names. A domain name containing non-ASCII characters (such as `www.Alliancefrançaise.nu`) is converted into an ASCII-compatible encoding (ACE, such as `www.xn--alliancefranaise-npb.nu`). The ACE form of the domain name is then used in all places where arbitrary characters are not allowed by the protocol, such as DNS queries, HTTP *Host* fields, and so on. This conversion is carried out in the application; if possible invisible

[1] In addition to *bytes-like objects*, `'base64_codec'` also accepts ASCII-only instances of *str* for decoding

to the user: The application should transparently convert Unicode domain labels to IDNA on the wire, and convert back ACE labels to Unicode before presenting them to the user.

Python supports this conversion in several ways: the `idna` codec performs conversion between Unicode and ACE, separating an input string into labels based on the separator characters defined in **section 3.1 of RFC 3490** and converting each label to ACE as required, and conversely separating an input byte string into labels based on the `.` separator and converting any ACE labels found into unicode. Furthermore, the *socket* module transparently converts Unicode host names to ACE, so that applications need not be concerned about converting host names themselves when they pass them to the socket module. On top of that, modules that have host names as function parameters, such as *http.client* and *ftplib*, accept Unicode host names (*http.client* then also transparently sends an IDNA hostname in the *Host* field if it sends that field at all).

When receiving host names from the wire (such as in reverse name lookup), no automatic conversion to Unicode is performed: Applications wishing to present such host names to the user should decode them to Unicode.

The module *encodings.idna* also implements the nameprep procedure, which performs certain normalizations on host names, to achieve case-insensitivity of international domain names, and to unify similar characters. The nameprep functions can be used directly if desired.

`encodings.idna.nameprep`(*label*)
Return the nameprepped version of *label*. The implementation currently assumes query strings, so `AllowUnassigned` is true.

`encodings.idna.ToASCII`(*label*)
Convert a label to ASCII, as specified in **RFC 3490**. `UseSTD3ASCIIRules` is assumed to be false.

`encodings.idna.ToUnicode`(*label*)
Convert a label to Unicode, as specified in **RFC 3490**.

7.2.6 `encodings.mbcs` — Windows ANSI codepage

Encode operand according to the ANSI codepage (CP_ACP).

Availability: Windows only.

Changed in version 3.3: Support any error handler.

Changed in version 3.2: Before 3.2, the *errors* argument was ignored; `'replace'` was always used to encode, and `'ignore'` to decode.

7.2.7 `encodings.utf_8_sig` — UTF-8 codec with BOM signature

This module implements a variant of the UTF-8 codec: On encoding a UTF-8 encoded BOM will be prepended to the UTF-8 encoded bytes. For the stateful encoder this is only done once (on the first write to the byte stream). For decoding an optional UTF-8 encoded BOM at the start of the data will be skipped.

CHAPTER

EIGHT

DATA TYPES

The modules described in this chapter provide a variety of specialized data types such as dates and times, fixed-type arrays, heap queues, synchronized queues, and sets.

Python also provides some built-in data types, in particular, *dict*, *list*, *set* and *frozenset*, and *tuple*. The *str* class is used to hold Unicode strings, and the *bytes* class is used to hold binary data.

The following modules are documented in this chapter:

8.1 datetime — Basic date and time types

Source code: Lib/datetime.py

The *datetime* module supplies classes for manipulating dates and times in both simple and complex ways. While date and time arithmetic is supported, the focus of the implementation is on efficient attribute extraction for output formatting and manipulation. For related functionality, see also the *time* and *calendar* modules.

There are two kinds of date and time objects: "naive" and "aware".

An aware object has sufficient knowledge of applicable algorithmic and political time adjustments, such as time zone and daylight saving time information, to locate itself relative to other aware objects. An aware object is used to represent a specific moment in time that is not open to interpretation[1].

A naive object does not contain enough information to unambiguously locate itself relative to other date/time objects. Whether a naive object represents Coordinated Universal Time (UTC), local time, or time in some other timezone is purely up to the program, just like it is up to the program whether a particular number represents metres, miles, or mass. Naive objects are easy to understand and to work with, at the cost of ignoring some aspects of reality.

For applications requiring aware objects, *datetime* and *time* objects have an optional time zone information attribute, `tzinfo`, that can be set to an instance of a subclass of the abstract *tzinfo* class. These *tzinfo* objects capture information about the offset from UTC time, the time zone name, and whether Daylight Saving Time is in effect. Note that only one concrete *tzinfo* class, the *timezone* class, is supplied by the *datetime* module. The *timezone* class can represent simple timezones with fixed offset from UTC, such as UTC itself or North American EST and EDT timezones. Supporting timezones at deeper levels of detail is up to the application. The rules for time adjustment across the world are more political than rational, change frequently, and there is no standard suitable for every application aside from UTC.

The *datetime* module exports the following constants:

`datetime.MINYEAR`
: The smallest year number allowed in a *date* or *datetime* object. *MINYEAR* is `1`.

[1] If, that is, we ignore the effects of Relativity

datetime.MAXYEAR
The largest year number allowed in a *date* or *datetime* object. *MAXYEAR* is 9999.

See also:

Module *calendar* General calendar related functions.

Module *time* Time access and conversions.

8.1.1 Available Types

class datetime.date
An idealized naive date, assuming the current Gregorian calendar always was, and always will be, in effect. Attributes: *year*, *month*, and *day*.

class datetime.time
An idealized time, independent of any particular day, assuming that every day has exactly 24*60*60 seconds (there is no notion of "leap seconds" here). Attributes: *hour*, *minute*, *second*, *microsecond*, and *tzinfo*.

class datetime.datetime
A combination of a date and a time. Attributes: *year*, *month*, *day*, *hour*, *minute*, *second*, *microsecond*, and *tzinfo*.

class datetime.timedelta
A duration expressing the difference between two *date*, *time*, or *datetime* instances to microsecond resolution.

class datetime.tzinfo
An abstract base class for time zone information objects. These are used by the *datetime* and *time* classes to provide a customizable notion of time adjustment (for example, to account for time zone and/or daylight saving time).

class datetime.timezone
A class that implements the *tzinfo* abstract base class as a fixed offset from the UTC.

New in version 3.2.

Objects of these types are immutable.

Objects of the *date* type are always naive.

An object of type *time* or *datetime* may be naive or aware. A *datetime* object *d* is aware if `d.tzinfo` is not `None` and `d.tzinfo.utcoffset(d)` does not return `None`. If `d.tzinfo` is `None`, or if `d.tzinfo` is not `None` but `d.tzinfo.utcoffset(d)` returns `None`, *d* is naive. A *time* object *t* is aware if `t.tzinfo` is not `None` and `t.tzinfo.utcoffset(None)` does not return `None`. Otherwise, *t* is naive.

The distinction between naive and aware doesn't apply to *timedelta* objects.

Subclass relationships:

```
object
    timedelta
    tzinfo
        timezone
    time
    date
        datetime
```

8.1.2 timedelta Objects

A *timedelta* object represents a duration, the difference between two dates or times.

class datetime.**timedelta**(*days=0*, *seconds=0*, *microseconds=0*, *milliseconds=0*, *minutes=0*, *hours=0*, *weeks=0*)

All arguments are optional and default to `0`. Arguments may be integers or floats, and may be positive or negative.

Only *days*, *seconds* and *microseconds* are stored internally. Arguments are converted to those units:

- A millisecond is converted to 1000 microseconds.
- A minute is converted to 60 seconds.
- An hour is converted to 3600 seconds.
- A week is converted to 7 days.

and days, seconds and microseconds are then normalized so that the representation is unique, with

- `0 <= microseconds < 1000000`
- `0 <= seconds < 3600*24` (the number of seconds in one day)
- `-999999999 <= days <= 999999999`

If any argument is a float and there are fractional microseconds, the fractional microseconds left over from all arguments are combined and their sum is rounded to the nearest microsecond using round-half-to-even tiebreaker. If no argument is a float, the conversion and normalization processes are exact (no information is lost).

If the normalized value of days lies outside the indicated range, *OverflowError* is raised.

Note that normalization of negative values may be surprising at first. For example,

```
>>> from datetime import timedelta
>>> d = timedelta(microseconds=-1)
>>> (d.days, d.seconds, d.microseconds)
(-1, 86399, 999999)
```

Class attributes are:

timedelta.min
The most negative *timedelta* object, `timedelta(-999999999)`.

timedelta.max
The most positive *timedelta* object, `timedelta(days=999999999, hours=23, minutes=59, seconds=59, microseconds=999999)`.

timedelta.resolution
The smallest possible difference between non-equal *timedelta* objects, `timedelta(microseconds=1)`.

Note that, because of normalization, `timedelta.max` > `-timedelta.min`. `-timedelta.max` is not representable as a *timedelta* object.

Instance attributes (read-only):

Attribute	Value
`days`	Between -999999999 and 999999999 inclusive
`seconds`	Between 0 and 86399 inclusive
`microseconds`	Between 0 and 999999 inclusive

Supported operations:

Operation	Result
`t1 = t2 + t3`	Sum of *t2* and *t3*. Afterwards *t1-t2* == *t3* and *t1-t3* == *t2* are true. (1)
`t1 = t2 - t3`	Difference of *t2* and *t3*. Afterwards *t1* == *t2* - *t3* and *t2* == *t1* + *t3* are true. (1)(6)
`t1 = t2 * i or t1 = i * t2`	Delta multiplied by an integer. Afterwards *t1* // i == *t2* is true, provided `i != 0`.
	In general, *t1* * i == *t1* * (i-1) + *t1* is true. (1)
`t1 = t2 * f or t1 = f * t2`	Delta multiplied by a float. The result is rounded to the nearest multiple of timedelta.resolution using round-half-to-even.
`f = t2 / t3`	Division (3) of *t2* by *t3*. Returns a *float* object.
`t1 = t2 / f or t1 = t2 / i`	Delta divided by a float or an int. The result is rounded to the nearest multiple of timedelta.resolution using round-half-to-even.
`t1 = t2 // i` or `t1 = t2 // t3`	The floor is computed and the remainder (if any) is thrown away. In the second case, an integer is returned. (3)
`t1 = t2 % t3`	The remainder is computed as a *timedelta* object. (3)
`q, r = divmod(t1, t2)`	Computes the quotient and the remainder: `q = t1 // t2` (3) and `r = t1 % t2`. q is an integer and r is a *timedelta* object.
`+t1`	Returns a *timedelta* object with the same value. (2)
`-t1`	equivalent to *timedelta*(*-t1.days*, *-t1.seconds*, *-t1.microseconds*), and to *t1** -1. (1)(4)
`abs(t)`	equivalent to +*t* when `t.days >= 0`, and to -*t* when `t.days < 0`. (2)
`str(t)`	Returns a string in the form `[D day[s], ][H]H:MM:SS[.UUUUUU]`, where D is negative for negative `t`. (5)
`repr(t)`	Returns a string representation of the *timedelta* object as a constructor call with canonical attribute values.

Notes:

1. This is exact, but may overflow.
2. This is exact, and cannot overflow.
3. Division by 0 raises *ZeroDivisionError*.
4. -*timedelta.max* is not representable as a *timedelta* object.
5. String representations of *timedelta* objects are normalized similarly to their internal representation. This leads to somewhat unusual results for negative timedeltas. For example:

```
>>> timedelta(hours=-5)
datetime.timedelta(days=-1, seconds=68400)
>>> print(_)
-1 day, 19:00:00
```

6. The expression `t2 - t3` will always be equal to the expression `t2 + (-t3)` except when t3 is equal to `timedelta.max`; in that case the former will produce a result while the latter will overflow.

In addition to the operations listed above *timedelta* objects support certain additions and subtractions with *date* and *datetime* objects (see below).

Changed in version 3.2: Floor division and true division of a *timedelta* object by another *timedelta* object are now supported, as are remainder operations and the *divmod()* function. True division and multiplication of a *timedelta* object by a *float* object are now supported.

Comparisons of *timedelta* objects are supported with the *timedelta* object representing the smaller duration considered to be the smaller timedelta. In order to stop mixed-type comparisons from falling back to the default comparison by object address, when a *timedelta* object is compared to an object of a different type, *TypeError* is raised unless the comparison is `==` or `!=`. The latter cases return *False* or *True*, respectively.

timedelta objects are *hashable* (usable as dictionary keys), support efficient pickling, and in Boolean contexts, a *timedelta* object is considered to be true if and only if it isn't equal to `timedelta(0)`.

Instance methods:

timedelta.total_seconds()
Return the total number of seconds contained in the duration. Equivalent to `td / timedelta(seconds=1)`.

Note that for very large time intervals (greater than 270 years on most platforms) this method will lose microsecond accuracy.

New in version 3.2.

Example usage:

```
>>> from datetime import timedelta
>>> year = timedelta(days=365)
>>> another_year = timedelta(weeks=40, days=84, hours=23,
...                          minutes=50, seconds=600)  # adds up to 365 days
>>> year.total_seconds()
31536000.0
>>> year == another_year
True
>>> ten_years = 10 * year
>>> ten_years, ten_years.days // 365
(datetime.timedelta(days=3650), 10)
>>> nine_years = ten_years - year
>>> nine_years, nine_years.days // 365
(datetime.timedelta(days=3285), 9)
>>> three_years = nine_years // 3
>>> three_years, three_years.days // 365
(datetime.timedelta(days=1095), 3)
>>> abs(three_years - ten_years) == 2 * three_years + year
True
```

8.1.3 `date` Objects

A *date* object represents a date (year, month and day) in an idealized calendar, the current Gregorian calendar indefinitely extended in both directions. January 1 of year 1 is called day number 1, January 2 of year 1 is called day number 2, and so on. This matches the definition of the "proleptic Gregorian" calendar in Dershowitz and Reingold's book Calendrical Calculations, where it's the base calendar for all computations. See the book for algorithms for converting between proleptic Gregorian ordinals and many other calendar systems.

class datetime.date(*year*, *month*, *day*)
All arguments are required. Arguments may be integers, in the following ranges:

- `MINYEAR <= year <= MAXYEAR`
- `1 <= month <= 12`
- `1 <= day <= number of days in the given month and year`

If an argument outside those ranges is given, *ValueError* is raised.

Other constructors, all class methods:

classmethod date.today()
Return the current local date. This is equivalent to `date.fromtimestamp(time.time())`.

classmethod `date.fromtimestamp`(*timestamp*)
Return the local date corresponding to the POSIX timestamp, such as is returned by *time.time()*. This may raise *OverflowError*, if the timestamp is out of the range of values supported by the platform C `localtime()` function, and *OSError* on `localtime()` failure. It's common for this to be restricted to years from 1970 through 2038. Note that on non-POSIX systems that include leap seconds in their notion of a timestamp, leap seconds are ignored by *fromtimestamp()*.

Changed in version 3.3: Raise *OverflowError* instead of *ValueError* if the timestamp is out of the range of values supported by the platform C `localtime()` function. Raise *OSError* instead of *ValueError* on `localtime()` failure.

classmethod `date.fromordinal`(*ordinal*)
Return the date corresponding to the proleptic Gregorian ordinal, where January 1 of year 1 has ordinal 1. *ValueError* is raised unless `1 <= ordinal <= date.max.toordinal()`. For any date *d*, `date.fromordinal(d.toordinal()) == d`.

classmethod `date.fromisoformat`(*date_string*)
Return a *date* corresponding to a *date_string* in the format emitted by *date.isoformat()*. Specifically, this function supports strings in the format(s) `YYYY-MM-DD`.

> **Caution:** This does not support parsing arbitrary ISO 8601 strings - it is only intended as the inverse operation of *date.isoformat()*.

New in version 3.7.

Class attributes:

date.min
The earliest representable date, `date(MINYEAR, 1, 1)`.

date.max
The latest representable date, `date(MAXYEAR, 12, 31)`.

date.resolution
The smallest possible difference between non-equal date objects, `timedelta(days=1)`.

Instance attributes (read-only):

date.year
Between *MINYEAR* and *MAXYEAR* inclusive.

date.month
Between 1 and 12 inclusive.

date.day
Between 1 and the number of days in the given month of the given year.

Supported operations:

Operation	Result
`date2 = date1 + timedelta`	*date2* is `timedelta.days` days removed from *date1*. (1)
`date2 = date1 - timedelta`	Computes *date2* such that `date2 + timedelta == date1`. (2)
`timedelta = date1 - date2`	(3)
`date1 < date2`	*date1* is considered less than *date2* when *date1* precedes *date2* in time. (4)

Notes:

1. *date2* is moved forward in time if `timedelta.days > 0`, or backward if `timedelta.days < 0`. Afterward `date2 - date1 == timedelta.days`. `timedelta.seconds` and `timedelta.microseconds` are ignored. *OverflowError* is raised if `date2.year` would be smaller than *MINYEAR* or larger than *MAXYEAR*.
2. `timedelta.seconds` and `timedelta.microseconds` are ignored.
3. This is exact, and cannot overflow. timedelta.seconds and timedelta.microseconds are 0, and date2 + timedelta == date1 after.
4. In other words, `date1 < date2` if and only if `date1.toordinal() < date2.toordinal()`. In order to stop comparison from falling back to the default scheme of comparing object addresses, date comparison normally raises *TypeError* if the other comparand isn't also a *date* object. However, `NotImplemented` is returned instead if the other comparand has a `timetuple()` attribute. This hook gives other kinds of date objects a chance at implementing mixed-type comparison. If not, when a *date* object is compared to an object of a different type, *TypeError* is raised unless the comparison is `==` or `!=`. The latter cases return *False* or *True*, respectively.

Dates can be used as dictionary keys. In Boolean contexts, all *date* objects are considered to be true.

Instance methods:

date.replace(*year=self.year*, *month=self.month*, *day=self.day*)
Return a date with the same value, except for those parameters given new values by whichever keyword arguments are specified. For example, if `d == date(2002, 12, 31)`, then `d.replace(day=26) == date(2002, 12, 26)`.

date.timetuple()
Return a *time.struct_time* such as returned by *time.localtime()*. The hours, minutes and seconds are 0, and the DST flag is -1. `d.timetuple()` is equivalent to `time.struct_time((d.year, d.month, d.day, 0, 0, 0, d.weekday(), yday, -1))`, where `yday = d.toordinal() - date(d.year, 1, 1).toordinal() + 1` is the day number within the current year starting with `1` for January 1st.

date.toordinal()
Return the proleptic Gregorian ordinal of the date, where January 1 of year 1 has ordinal 1. For any *date* object *d*, `date.fromordinal(d.toordinal()) == d`.

date.weekday()
Return the day of the week as an integer, where Monday is 0 and Sunday is 6. For example, `date(2002, 12, 4).weekday() == 2`, a Wednesday. See also *isoweekday()*.

date.isoweekday()
Return the day of the week as an integer, where Monday is 1 and Sunday is 7. For example, `date(2002, 12, 4).isoweekday() == 3`, a Wednesday. See also *weekday()*, *isocalendar()*.

date.isocalendar()
Return a 3-tuple, (ISO year, ISO week number, ISO weekday).

The ISO calendar is a widely used variant of the Gregorian calendar. See https://www.staff.science.uu.nl/~gent0113/calendar/isocalendar.htm for a good explanation.

The ISO year consists of 52 or 53 full weeks, and where a week starts on a Monday and ends on a Sunday. The first week of an ISO year is the first (Gregorian) calendar week of a year containing a Thursday. This is called week number 1, and the ISO year of that Thursday is the same as its Gregorian year.

For example, 2004 begins on a Thursday, so the first week of ISO year 2004 begins on Monday, 29 Dec 2003 and ends on Sunday, 4 Jan 2004, so that `date(2003, 12, 29).isocalendar() == (2004, 1, 1)` and `date(2004, 1, 4).isocalendar() == (2004, 1, 7)`.

date.isoformat()
Return a string representing the date in ISO 8601 format, 'YYYY-MM-DD'. For example, `date(2002, 12, 4).isoformat() == '2002-12-04'`.

`date.__str__()`
: For a date *d*, `str(d)` is equivalent to `d.isoformat()`.

`date.ctime()`
: Return a string representing the date, for example `date(2002, 12, 4).ctime() == 'Wed Dec 4 00:00:00 2002'`. `d.ctime()` is equivalent to `time.ctime(time.mktime(d.timetuple()))` on platforms where the native C `ctime()` function (which *time.ctime()* invokes, but which *date.ctime()* does not invoke) conforms to the C standard.

`date.strftime(`*format*`)`
: Return a string representing the date, controlled by an explicit format string. Format codes referring to hours, minutes or seconds will see 0 values. For a complete list of formatting directives, see *strftime() and strptime() Behavior*.

`date.__format__(`*format*`)`
: Same as *date.strftime()*. This makes it possible to specify a format string for a *date* object in formatted string literals and when using *str.format()*. For a complete list of formatting directives, see *strftime() and strptime() Behavior*.

Example of counting days to an event:

```
>>> import time
>>> from datetime import date
>>> today = date.today()
>>> today
datetime.date(2007, 12, 5)
>>> today == date.fromtimestamp(time.time())
True
>>> my_birthday = date(today.year, 6, 24)
>>> if my_birthday < today:
...     my_birthday = my_birthday.replace(year=today.year + 1)
>>> my_birthday
datetime.date(2008, 6, 24)
>>> time_to_birthday = abs(my_birthday - today)
>>> time_to_birthday.days
202
```

Example of working with *date*:

```
>>> from datetime import date
>>> d = date.fromordinal(730920) # 730920th day after 1. 1. 0001
>>> d
datetime.date(2002, 3, 11)
>>> t = d.timetuple()
>>> for i in t:
...     print(i)
2002                # year
3                   # month
11                  # day
0
0
0
0                   # weekday (0 = Monday)
70                  # 70th day in the year
-1
>>> ic = d.isocalendar()
>>> for i in ic:
...     print(i)
2002                # ISO year
```

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```
11                  # ISO week number
1                   # ISO day number ( 1 = Monday )
>>> d.isoformat()
'2002-03-11'
>>> d.strftime("%d/%m/%y")
'11/03/02'
>>> d.strftime("%A %d. %B %Y")
'Monday 11. March 2002'
>>> 'The {1} is {0:%d}, the {2} is {0:%B}.'.format(d, "day", "month")
'The day is 11, the month is March.'
```

8.1.4 `datetime` Objects

A *datetime* object is a single object containing all the information from a *date* object and a *time* object. Like a *date* object, *datetime* assumes the current Gregorian calendar extended in both directions; like a time object, *datetime* assumes there are exactly 3600*24 seconds in every day.

Constructor:

class datetime.**datetime**(*year*, *month*, *day*, *hour=0*, *minute=0*, *second=0*, *microsecond=0*, *tzinfo=None*, ***, *fold=0*)

The year, month and day arguments are required. *tzinfo* may be `None`, or an instance of a *tzinfo* subclass. The remaining arguments may be integers, in the following ranges:

- `MINYEAR <= year <= MAXYEAR`,
- `1 <= month <= 12`,
- `1 <= day <= number of days in the given month and year`,
- `0 <= hour < 24`,
- `0 <= minute < 60`,
- `0 <= second < 60`,
- `0 <= microsecond < 1000000`,
- `fold in [0, 1]`.

If an argument outside those ranges is given, *ValueError* is raised.

New in version 3.6: Added the `fold` argument.

Other constructors, all class methods:

classmethod datetime.**today**()

Return the current local datetime, with *tzinfo* `None`. This is equivalent to `datetime.fromtimestamp(time.time())`. See also *now()*, *fromtimestamp()*.

classmethod datetime.**now**(*tz=None*)

Return the current local date and time. If optional argument *tz* is `None` or not specified, this is like *today()*, but, if possible, supplies more precision than can be gotten from going through a *time.time()* timestamp (for example, this may be possible on platforms supplying the C `gettimeofday()` function).

If *tz* is not `None`, it must be an instance of a *tzinfo* subclass, and the current date and time are converted to *tz*'s time zone. In this case the result is equivalent to `tz.fromutc(datetime.utcnow().replace(tzinfo=tz))`. See also *today()*, *utcnow()*.

classmethod datetime.**utcnow**()

Return the current UTC date and time, with *tzinfo* `None`. This is like *now()*, but returns the current

UTC date and time, as a naive *datetime* object. An aware current UTC datetime can be obtained by calling `datetime.now(timezone.utc)`. See also *now()*.

classmethod `datetime.fromtimestamp`(*timestamp*, *tz=None*)

Return the local date and time corresponding to the POSIX timestamp, such as is returned by *time.time()*. If optional argument *tz* is `None` or not specified, the timestamp is converted to the platform's local date and time, and the returned *datetime* object is naive.

If *tz* is not `None`, it must be an instance of a *tzinfo* subclass, and the timestamp is converted to *tz*'s time zone. In this case the result is equivalent to `tz.fromutc(datetime.utcfromtimestamp(timestamp).replace(tzinfo=tz))`.

fromtimestamp() may raise *OverflowError*, if the timestamp is out of the range of values supported by the platform C `localtime()` or `gmtime()` functions, and *OSError* on `localtime()` or `gmtime()` failure. It's common for this to be restricted to years in 1970 through 2038. Note that on non-POSIX systems that include leap seconds in their notion of a timestamp, leap seconds are ignored by *fromtimestamp()*, and then it's possible to have two timestamps differing by a second that yield identical *datetime* objects. See also *utcfromtimestamp()*.

Changed in version 3.3: Raise *OverflowError* instead of *ValueError* if the timestamp is out of the range of values supported by the platform C `localtime()` or `gmtime()` functions. Raise *OSError* instead of *ValueError* on `localtime()` or `gmtime()` failure.

Changed in version 3.6: *fromtimestamp()* may return instances with *fold* set to 1.

classmethod `datetime.utcfromtimestamp`(*timestamp*)

Return the UTC *datetime* corresponding to the POSIX timestamp, with *tzinfo* `None`. This may raise *OverflowError*, if the timestamp is out of the range of values supported by the platform C `gmtime()` function, and *OSError* on `gmtime()` failure. It's common for this to be restricted to years in 1970 through 2038.

To get an aware *datetime* object, call *fromtimestamp()*:

```
datetime.fromtimestamp(timestamp, timezone.utc)
```

On the POSIX compliant platforms, it is equivalent to the following expression:

```
datetime(1970, 1, 1, tzinfo=timezone.utc) + timedelta(seconds=timestamp)
```

except the latter formula always supports the full years range: between *MINYEAR* and *MAXYEAR* inclusive.

Changed in version 3.3: Raise *OverflowError* instead of *ValueError* if the timestamp is out of the range of values supported by the platform C `gmtime()` function. Raise *OSError* instead of *ValueError* on `gmtime()` failure.

classmethod `datetime.fromordinal`(*ordinal*)

Return the *datetime* corresponding to the proleptic Gregorian ordinal, where January 1 of year 1 has ordinal 1. *ValueError* is raised unless `1 <= ordinal <= datetime.max.toordinal()`. The hour, minute, second and microsecond of the result are all 0, and *tzinfo* is `None`.

classmethod `datetime.combine`(*date*, *time*, *tzinfo=self.tzinfo*)

Return a new *datetime* object whose date components are equal to the given *date* object's, and whose time components are equal to the given *time* object's. If the *tzinfo* argument is provided, its value is used to set the *tzinfo* attribute of the result, otherwise the *tzinfo* attribute of the *time* argument is used.

For any *datetime* object *d*, `d == datetime.combine(d.date(), d.time(), d.tzinfo)`. If date is a *datetime* object, its time components and *tzinfo* attributes are ignored.

Changed in version 3.6: Added the *tzinfo* argument.

classmethod datetime.**fromisoformat**(*date_string*)
Return a *datetime* corresponding to a *date_string* in one of the formats emitted by *date.isoformat()* and *datetime.isoformat()*. Specifically, this function supports strings in the format(s) `YYYY-MM-DD[*HH[:MM[:SS[.mmm[mmm]]]][+HH:MM[:SS[.ffffff]]]]`, where `*` can match any single character.

> **Caution:** This does not support parsing arbitrary ISO 8601 strings - it is only intended as the inverse operation of *datetime.isoformat()*.

New in version 3.7.

classmethod datetime.**strptime**(*date_string*, *format*)
Return a *datetime* corresponding to *date_string*, parsed according to *format*. This is equivalent to `datetime(*(time.strptime(date_string, format)[0:6]))`. *ValueError* is raised if the date_string and format can't be parsed by *time.strptime()* or if it returns a value which isn't a time tuple. For a complete list of formatting directives, see *strftime() and strptime() Behavior*.

Class attributes:

datetime.min
The earliest representable *datetime*, `datetime(MINYEAR, 1, 1, tzinfo=None)`.

datetime.max
The latest representable *datetime*, `datetime(MAXYEAR, 12, 31, 23, 59, 59, 999999, tzinfo=None)`.

datetime.resolution
The smallest possible difference between non-equal *datetime* objects, `timedelta(microseconds=1)`.

Instance attributes (read-only):

datetime.year
Between *MINYEAR* and *MAXYEAR* inclusive.

datetime.month
Between 1 and 12 inclusive.

datetime.day
Between 1 and the number of days in the given month of the given year.

datetime.hour
In `range(24)`.

datetime.minute
In `range(60)`.

datetime.second
In `range(60)`.

datetime.microsecond
In `range(1000000)`.

datetime.tzinfo
The object passed as the *tzinfo* argument to the *datetime* constructor, or `None` if none was passed.

datetime.fold
In `[0, 1]`. Used to disambiguate wall times during a repeated interval. (A repeated interval occurs when clocks are rolled back at the end of daylight saving time or when the UTC offset for the current zone is decreased for political reasons.) The value 0 (1) represents the earlier (later) of the two moments with the same wall time representation.

New in version 3.6.

Supported operations:

Operation	Result
`datetime2 = datetime1 + timedelta`	(1)
`datetime2 = datetime1 - timedelta`	(2)
`timedelta = datetime1 - datetime2`	(3)
`datetime1 < datetime2`	Compares *datetime* to *datetime*. (4)

1. datetime2 is a duration of timedelta removed from datetime1, moving forward in time if `timedelta.days` > 0, or backward if `timedelta.days` < 0. The result has the same *tzinfo* attribute as the input datetime, and datetime2 - datetime1 == timedelta after. *OverflowError* is raised if datetime2.year would be smaller than *MINYEAR* or larger than *MAXYEAR*. Note that no time zone adjustments are done even if the input is an aware object.

2. Computes the datetime2 such that datetime2 + timedelta == datetime1. As for addition, the result has the same *tzinfo* attribute as the input datetime, and no time zone adjustments are done even if the input is aware.

3. Subtraction of a *datetime* from a *datetime* is defined only if both operands are naive, or if both are aware. If one is aware and the other is naive, *TypeError* is raised.

   If both are naive, or both are aware and have the same *tzinfo* attribute, the *tzinfo* attributes are ignored, and the result is a *timedelta* object t such that `datetime2 + t == datetime1`. No time zone adjustments are done in this case.

   If both are aware and have different *tzinfo* attributes, `a-b` acts as if a and b were first converted to naive UTC datetimes first. The result is `(a.replace(tzinfo=None) - a.utcoffset()) - (b.replace(tzinfo=None) - b.utcoffset())` except that the implementation never overflows.

4. *datetime1* is considered less than *datetime2* when *datetime1* precedes *datetime2* in time.

   If one comparand is naive and the other is aware, *TypeError* is raised if an order comparison is attempted. For equality comparisons, naive instances are never equal to aware instances.

   If both comparands are aware, and have the same *tzinfo* attribute, the common *tzinfo* attribute is ignored and the base datetimes are compared. If both comparands are aware and have different *tzinfo* attributes, the comparands are first adjusted by subtracting their UTC offsets (obtained from `self.utcoffset()`).

   Changed in version 3.3: Equality comparisons between naive and aware *datetime* instances don't raise *TypeError*.

Note: In order to stop comparison from falling back to the default scheme of comparing object addresses, datetime comparison normally raises *TypeError* if the other comparand isn't also a *datetime* object. However, `NotImplemented` is returned instead if the other comparand has a `timetuple()` attribute. This hook gives other kinds of date objects a chance at implementing mixed-type comparison. If not, when a *datetime* object is compared to an object of a different type, *TypeError* is raised unless the comparison is `==` or `!=`. The latter cases return *False* or *True*, respectively.

---

datetime objects can be used as dictionary keys. In Boolean contexts, all *datetime* objects are considered to be true.

Instance methods:

`datetime.date()`
: Return *date* object with same year, month and day.

`datetime.time()`
: Return *time* object with same hour, minute, second, microsecond and fold. *tzinfo* is `None`. See also method *timetz()*.

Changed in version 3.6: The fold value is copied to the returned *time* object.

datetime.timetz()
Return *time* object with same hour, minute, second, microsecond, fold, and tzinfo attributes. See also method *time()*.

Changed in version 3.6: The fold value is copied to the returned *time* object.

datetime.replace(*year=self.year*, *month=self.month*, *day=self.day*, *hour=self.hour*, *minute=self.minute*, *second=self.second*, *microsecond=self.microsecond*, *tzinfo=self.tzinfo*, ** fold=0*)
Return a datetime with the same attributes, except for those attributes given new values by whichever keyword arguments are specified. Note that `tzinfo=None` can be specified to create a naive datetime from an aware datetime with no conversion of date and time data.

New in version 3.6: Added the `fold` argument.

datetime.astimezone(*tz=None*)
Return a *datetime* object with new *tzinfo* attribute *tz*, adjusting the date and time data so the result is the same UTC time as *self*, but in *tz*'s local time.

If provided, *tz* must be an instance of a *tzinfo* subclass, and its *utcoffset()* and *dst()* methods must not return `None`. If *self* is naive, it is presumed to represent time in the system timezone.

If called without arguments (or with `tz=None`) the system local timezone is assumed for the target timezone. The `.tzinfo` attribute of the converted datetime instance will be set to an instance of *timezone* with the zone name and offset obtained from the OS.

If `self.tzinfo` is *tz*, `self.astimezone(tz)` is equal to *self*: no adjustment of date or time data is performed. Else the result is local time in the timezone *tz*, representing the same UTC time as *self*: after `astz = dt.astimezone(tz)`, `astz - astz.utcoffset()` will have the same date and time data as `dt - dt.utcoffset()`.

If you merely want to attach a time zone object *tz* to a datetime *dt* without adjustment of date and time data, use `dt.replace(tzinfo=tz)`. If you merely want to remove the time zone object from an aware datetime *dt* without conversion of date and time data, use `dt.replace(tzinfo=None)`.

Note that the default *tzinfo.fromutc()* method can be overridden in a *tzinfo* subclass to affect the result returned by *astimezone()*. Ignoring error cases, *astimezone()* acts like:

```
def astimezone(self, tz):
    if self.tzinfo is tz:
        return self
    # Convert self to UTC, and attach the new time zone object.
    utc = (self - self.utcoffset()).replace(tzinfo=tz)
    # Convert from UTC to tz's local time.
    return tz.fromutc(utc)
```

Changed in version 3.3: *tz* now can be omitted.

Changed in version 3.6: The *astimezone()* method can now be called on naive instances that are presumed to represent system local time.

datetime.utcoffset()
If *tzinfo* is `None`, returns `None`, else returns `self.tzinfo.utcoffset(self)`, and raises an exception if the latter doesn't return `None` or a *timedelta* object with magnitude less than one day.

Changed in version 3.7: The UTC offset is not restricted to a whole number of minutes.

datetime.dst()
If *tzinfo* is `None`, returns `None`, else returns `self.tzinfo.dst(self)`, and raises an exception if the latter doesn't return `None` or a *timedelta* object with magnitude less than one day.

Changed in version 3.7: The DST offset is not restricted to a whole number of minutes.

datetime.tzname()
: If *tzinfo* is None, returns None, else returns self.tzinfo.tzname(self), raises an exception if the latter doesn't return None or a string object,

datetime.timetuple()
: Return a *time.struct_time* such as returned by *time.localtime()*. d.timetuple() is equivalent to time.struct_time((d.year, d.month, d.day, d.hour, d.minute, d.second, d.weekday(), yday, dst)), where yday = d.toordinal() - date(d.year, 1, 1).toordinal() + 1 is the day number within the current year starting with 1 for January 1st. The tm_isdst flag of the result is set according to the *dst()* method: *tzinfo* is None or *dst()* returns None, tm_isdst is set to -1; else if *dst()* returns a non-zero value, tm_isdst is set to 1; else tm_isdst is set to 0.

datetime.utctimetuple()
: If *datetime* instance *d* is naive, this is the same as d.timetuple() except that tm_isdst is forced to 0 regardless of what d.dst() returns. DST is never in effect for a UTC time.

  If *d* is aware, *d* is normalized to UTC time, by subtracting d.utcoffset(), and a *time.struct_time* for the normalized time is returned. tm_isdst is forced to 0. Note that an *OverflowError* may be raised if *d*.year was MINYEAR or MAXYEAR and UTC adjustment spills over a year boundary.

datetime.toordinal()
: Return the proleptic Gregorian ordinal of the date. The same as self.date().toordinal().

datetime.timestamp()
: Return POSIX timestamp corresponding to the *datetime* instance. The return value is a *float* similar to that returned by *time.time()*.

  Naive *datetime* instances are assumed to represent local time and this method relies on the platform C mktime() function to perform the conversion. Since *datetime* supports wider range of values than mktime() on many platforms, this method may raise *OverflowError* for times far in the past or far in the future.

  For aware *datetime* instances, the return value is computed as:

```
(dt - datetime(1970, 1, 1, tzinfo=timezone.utc)).total_seconds()
```

  New in version 3.3.

  Changed in version 3.6: The *timestamp()* method uses the *fold* attribute to disambiguate the times during a repeated interval.

  Note: There is no method to obtain the POSIX timestamp directly from a naive *datetime* instance representing UTC time. If your application uses this convention and your system timezone is not set to UTC, you can obtain the POSIX timestamp by supplying tzinfo=timezone.utc:

```
timestamp = dt.replace(tzinfo=timezone.utc).timestamp()
```

  or by calculating the timestamp directly:

```
timestamp = (dt - datetime(1970, 1, 1)) / timedelta(seconds=1)
```

  ---

datetime.weekday()
: Return the day of the week as an integer, where Monday is 0 and Sunday is 6. The same as self.date().weekday(). See also *isoweekday()*.

datetime.isoweekday()
: Return the day of the week as an integer, where Monday is 1 and Sunday is 7. The same as self.date().isoweekday(). See also *weekday()*, *isocalendar()*.

datetime.isocalendar()
Return a 3-tuple, (ISO year, ISO week number, ISO weekday). The same as self.date().isocalendar().

datetime.isoformat(*sep='T', timespec='auto'*)
Return a string representing the date and time in ISO 8601 format, YYYY-MM-DDTHH:MM:SS.mmmmmm or, if *microsecond* is 0, YYYY-MM-DDTHH:MM:SS

If *utcoffset()* does not return None, a 6-character string is appended, giving the UTC offset in (signed) hours and minutes: YYYY-MM-DDTHH:MM:SS.mmmmmm+HH:MM or, if *microsecond* is 0 YYYY-MM-DDTHH:MM:SS+HH:MM

The optional argument *sep* (default 'T') is a one-character separator, placed between the date and time portions of the result. For example,

```
>>> from datetime import tzinfo, timedelta, datetime
>>> class TZ(tzinfo):
...     def utcoffset(self, dt): return timedelta(minutes=-399)
...
>>> datetime(2002, 12, 25, tzinfo=TZ()).isoformat(' ')
'2002-12-25 00:00:00-06:39'
```

The optional argument *timespec* specifies the number of additional components of the time to include (the default is 'auto'). It can be one of the following:

- 'auto': Same as 'seconds' if *microsecond* is 0, same as 'microseconds' otherwise.
- 'hours': Include the *hour* in the two-digit HH format.
- 'minutes': Include *hour* and *minute* in HH:MM format.
- 'seconds': Include *hour*, *minute*, and *second* in HH:MM:SS format.
- 'milliseconds': Include full time, but truncate fractional second part to milliseconds. HH:MM:SS.sss format.
- 'microseconds': Include full time in HH:MM:SS.mmmmmm format.

Note: Excluded time components are truncated, not rounded.

ValueError will be raised on an invalid *timespec* argument.

```
>>> from datetime import datetime
>>> datetime.now().isoformat(timespec='minutes')
'2002-12-25T00:00'
>>> dt = datetime(2015, 1, 1, 12, 30, 59, 0)
>>> dt.isoformat(timespec='microseconds')
'2015-01-01T12:30:59.000000'
```

New in version 3.6: Added the *timespec* argument.

datetime.__str__()
For a *datetime* instance *d*, str(d) is equivalent to d.isoformat(' ').

datetime.ctime()
Return a string representing the date and time, for example datetime(2002, 12, 4, 20, 30, 40).ctime() == 'Wed Dec 4 20:30:40 2002'. d.ctime() is equivalent to time.ctime(time.mktime(d.timetuple())) on platforms where the native C ctime() function (which *time.ctime()* invokes, but which *datetime.ctime()* does not invoke) conforms to the C standard.

datetime.**strftime**(*format*)
: Return a string representing the date and time, controlled by an explicit format string. For a complete list of formatting directives, see *strftime() and strptime() Behavior*.

datetime.**__format__**(*format*)
: Same as *datetime.strftime()*. This makes it possible to specify a format string for a *datetime* object in formatted string literals and when using *str.format()*. For a complete list of formatting directives, see *strftime() and strptime() Behavior*.

Examples of working with datetime objects:

```
>>> from datetime import datetime, date, time
>>> # Using datetime.combine()
>>> d = date(2005, 7, 14)
>>> t = time(12, 30)
>>> datetime.combine(d, t)
datetime.datetime(2005, 7, 14, 12, 30)
>>> # Using datetime.now() or datetime.utcnow()
>>> datetime.now()
datetime.datetime(2007, 12, 6, 16, 29, 43, 79043)   # GMT +1
>>> datetime.utcnow()
datetime.datetime(2007, 12, 6, 15, 29, 43, 79060)
>>> # Using datetime.strptime()
>>> dt = datetime.strptime("21/11/06 16:30", "%d/%m/%y %H:%M")
>>> dt
datetime.datetime(2006, 11, 21, 16, 30)
>>> # Using datetime.timetuple() to get tuple of all attributes
>>> tt = dt.timetuple()
>>> for it in tt:
...     print(it)
...
2006    # year
11      # month
21      # day
16      # hour
30      # minute
0       # second
1       # weekday (0 = Monday)
325     # number of days since 1st January
-1      # dst - method tzinfo.dst() returned None
>>> # Date in ISO format
>>> ic = dt.isocalendar()
>>> for it in ic:
...     print(it)
...
2006    # ISO year
47      # ISO week
2       # ISO weekday
>>> # Formatting datetime
>>> dt.strftime("%A, %d. %B %Y %I:%M%p")
'Tuesday, 21. November 2006 04:30PM'
>>> 'The {1} is {0:%d}, the {2} is {0:%B}, the {3} is {0:%I:%M%p}.'.format(dt, "day", "month",
↪"time")
'The day is 21, the month is November, the time is 04:30PM.'
```

Using datetime with tzinfo:

```
>>> from datetime import timedelta, datetime, tzinfo
```

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```
>>> class GMT1(tzinfo):
...     def utcoffset(self, dt):
...         return timedelta(hours=1) + self.dst(dt)
...     def dst(self, dt):
...         # DST starts last Sunday in March
...         d = datetime(dt.year, 4, 1)   # ends last Sunday in October
...         self.dston = d - timedelta(days=d.weekday() + 1)
...         d = datetime(dt.year, 11, 1)
...         self.dstoff = d - timedelta(days=d.weekday() + 1)
...         if self.dston <=  dt.replace(tzinfo=None) < self.dstoff:
...             return timedelta(hours=1)
...         else:
...             return timedelta(0)
...     def tzname(self,dt):
...          return "GMT +1"
...
>>> class GMT2(tzinfo):
...     def utcoffset(self, dt):
...         return timedelta(hours=2) + self.dst(dt)
...     def dst(self, dt):
...         d = datetime(dt.year, 4, 1)
...         self.dston = d - timedelta(days=d.weekday() + 1)
...         d = datetime(dt.year, 11, 1)
...         self.dstoff = d - timedelta(days=d.weekday() + 1)
...         if self.dston <=  dt.replace(tzinfo=None) < self.dstoff:
...             return timedelta(hours=1)
...         else:
...             return timedelta(0)
...     def tzname(self,dt):
...         return "GMT +2"
...
>>> gmt1 = GMT1()
>>> # Daylight Saving Time
>>> dt1 = datetime(2006, 11, 21, 16, 30, tzinfo=gmt1)
>>> dt1.dst()
datetime.timedelta(0)
>>> dt1.utcoffset()
datetime.timedelta(seconds=3600)
>>> dt2 = datetime(2006, 6, 14, 13, 0, tzinfo=gmt1)
>>> dt2.dst()
datetime.timedelta(seconds=3600)
>>> dt2.utcoffset()
datetime.timedelta(seconds=7200)
>>> # Convert datetime to another time zone
>>> dt3 = dt2.astimezone(GMT2())
>>> dt3
datetime.datetime(2006, 6, 14, 14, 0, tzinfo=<GMT2 object at 0x...>)
>>> dt2
datetime.datetime(2006, 6, 14, 13, 0, tzinfo=<GMT1 object at 0x...>)
>>> dt2.utctimetuple() == dt3.utctimetuple()
True
```

8.1.5 `time` Objects

A time object represents a (local) time of day, independent of any particular day, and subject to adjustment via a *tzinfo* object.

class datetime.time(*hour=0*, *minute=0*, *second=0*, *microsecond=0*, *tzinfo=None*, ***, *fold=0*)

All arguments are optional. *tzinfo* may be `None`, or an instance of a *tzinfo* subclass. The remaining arguments may be integers, in the following ranges:

- `0 <= hour < 24`,
- `0 <= minute < 60`,
- `0 <= second < 60`,
- `0 <= microsecond < 1000000`,
- `fold in [0, 1]`.

If an argument outside those ranges is given, *ValueError* is raised. All default to `0` except *tzinfo*, which defaults to *None*.

Class attributes:

time.min

The earliest representable *time*, `time(0, 0, 0, 0)`.

time.max

The latest representable *time*, `time(23, 59, 59, 999999)`.

time.resolution

The smallest possible difference between non-equal *time* objects, `timedelta(microseconds=1)`, although note that arithmetic on *time* objects is not supported.

Instance attributes (read-only):

time.hour

In `range(24)`.

time.minute

In `range(60)`.

time.second

In `range(60)`.

time.microsecond

In `range(1000000)`.

time.tzinfo

The object passed as the tzinfo argument to the *time* constructor, or `None` if none was passed.

time.fold

In `[0, 1]`. Used to disambiguate wall times during a repeated interval. (A repeated interval occurs when clocks are rolled back at the end of daylight saving time or when the UTC offset for the current zone is decreased for political reasons.) The value 0 (1) represents the earlier (later) of the two moments with the same wall time representation.

New in version 3.6.

Supported operations:

- comparison of *time* to *time*, where *a* is considered less than *b* when *a* precedes *b* in time. If one comparand is naive and the other is aware, *TypeError* is raised if an order comparison is attempted. For equality comparisons, naive instances are never equal to aware instances.

  If both comparands are aware, and have the same *tzinfo* attribute, the common *tzinfo* attribute is ignored and the base times are compared. If both comparands are aware and have different *tzinfo* attributes, the comparands are first adjusted by subtracting their UTC offsets (obtained from `self.utcoffset()`). In order to stop mixed-type comparisons from falling back to the default comparison by object address, when a *time* object is compared to an object of a different type, *TypeError* is raised unless the comparison is `==` or `!=`. The latter cases return *False* or *True*, respectively.

Changed in version 3.3: Equality comparisons between naive and aware *time* instances don't raise *TypeError*.

- hash, use as dict key
- efficient pickling

In boolean contexts, a *time* object is always considered to be true.

Changed in version 3.5: Before Python 3.5, a *time* object was considered to be false if it represented midnight in UTC. This behavior was considered obscure and error-prone and has been removed in Python 3.5. See bpo-13936 for full details.

Other constructor:

classmethod **time.fromisoformat**(*time_string*)

Return a *time* corresponding to a *time_string* in one of the formats emitted by *time.isoformat()*. Specifically, this function supports strings in the format(s) `HH[:MM[:SS[.mmm[mmm]]]][+HH:MM[:SS[.ffffff]]]`.

> **Caution:** This does not support parsing arbitrary ISO 8601 strings - it is only intended as the inverse operation of *time.isoformat()*.

New in version 3.7.

Instance methods:

time.replace(*hour=self.hour*, *minute=self.minute*, *second=self.second*, *microsecond=self.microsecond*, *tzinfo=self.tzinfo*, ** fold=0*)

Return a *time* with the same value, except for those attributes given new values by whichever keyword arguments are specified. Note that `tzinfo=None` can be specified to create a naive *time* from an aware *time*, without conversion of the time data.

New in version 3.6: Added the `fold` argument.

time.isoformat(*timespec='auto'*)

Return a string representing the time in ISO 8601 format, HH:MM:SS.mmmmmm or, if *microsecond* is 0, HH:MM:SS If *utcoffset()* does not return `None`, a 6-character string is appended, giving the UTC offset in (signed) hours and minutes: HH:MM:SS.mmmmmm+HH:MM or, if self.microsecond is 0, HH:MM:SS+HH:MM

The optional argument *timespec* specifies the number of additional components of the time to include (the default is `'auto'`). It can be one of the following:

- `'auto'`: Same as `'seconds'` if *microsecond* is 0, same as `'microseconds'` otherwise.
- `'hours'`: Include the *hour* in the two-digit HH format.
- `'minutes'`: Include *hour* and *minute* in HH:MM format.
- `'seconds'`: Include *hour*, *minute*, and *second* in HH:MM:SS format.
- `'milliseconds'`: Include full time, but truncate fractional second part to milliseconds. HH:MM:SS.sss format.
- `'microseconds'`: Include full time in HH:MM:SS.mmmmmm format.

> **Note:** Excluded time components are truncated, not rounded.

ValueError will be raised on an invalid *timespec* argument.

```
>>> from datetime import time
>>> time(hour=12, minute=34, second=56, microsecond=123456).isoformat(timespec='minutes')
'12:34'
>>> dt = time(hour=12, minute=34, second=56, microsecond=0)
>>> dt.isoformat(timespec='microseconds')
'12:34:56.000000'
>>> dt.isoformat(timespec='auto')
'12:34:56'
```

New in version 3.6: Added the *timespec* argument.

time.__str__()
For a time *t*, `str(t)` is equivalent to `t.isoformat()`.

time.strftime(*format*)
Return a string representing the time, controlled by an explicit format string. For a complete list of formatting directives, see *strftime() and strptime() Behavior*.

time.__format__(*format*)
Same as *time.strftime()*. This makes it possible to specify a format string for a *time* object in formatted string literals and when using *str.format()*. For a complete list of formatting directives, see *strftime() and strptime() Behavior*.

time.utcoffset()
If *tzinfo* is `None`, returns `None`, else returns `self.tzinfo.utcoffset(None)`, and raises an exception if the latter doesn't return `None` or a *timedelta* object with magnitude less than one day.

Changed in version 3.7: The UTC offset is not restricted to a whole number of minutes.

time.dst()
If *tzinfo* is `None`, returns `None`, else returns `self.tzinfo.dst(None)`, and raises an exception if the latter doesn't return `None`, or a *timedelta* object with magnitude less than one day.

Changed in version 3.7: The DST offset is not restricted to a whole number of minutes.

time.tzname()
If *tzinfo* is `None`, returns `None`, else returns `self.tzinfo.tzname(None)`, or raises an exception if the latter doesn't return `None` or a string object.

Example:

```
>>> from datetime import time, tzinfo, timedelta
>>> class GMT1(tzinfo):
...     def utcoffset(self, dt):
...         return timedelta(hours=1)
...     def dst(self, dt):
...         return timedelta(0)
...     def tzname(self,dt):
...         return "Europe/Prague"
...
>>> t = time(12, 10, 30, tzinfo=GMT1())
>>> t
datetime.time(12, 10, 30, tzinfo=<GMT1 object at 0x...>)
>>> gmt = GMT1()
>>> t.isoformat()
'12:10:30+01:00'
>>> t.dst()
datetime.timedelta(0)
>>> t.tzname()
'Europe/Prague'
```

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```
>>> t.strftime("%H:%M:%S %Z")
'12:10:30 Europe/Prague'
>>> 'The {} is {:%H:%M}.'.format("time", t)
'The time is 12:10.'
```

8.1.6 tzinfo Objects

class datetime.tzinfo

This is an abstract base class, meaning that this class should not be instantiated directly. You need to derive a concrete subclass, and (at least) supply implementations of the standard *tzinfo* methods needed by the *datetime* methods you use. The *datetime* module supplies a simple concrete subclass of *tzinfo*, *timezone*, which can represent timezones with fixed offset from UTC such as UTC itself or North American EST and EDT.

An instance of (a concrete subclass of) *tzinfo* can be passed to the constructors for *datetime* and *time* objects. The latter objects view their attributes as being in local time, and the *tzinfo* object supports methods revealing offset of local time from UTC, the name of the time zone, and DST offset, all relative to a date or time object passed to them.

Special requirement for pickling: A *tzinfo* subclass must have an `__init__()` method that can be called with no arguments, else it can be pickled but possibly not unpickled again. This is a technical requirement that may be relaxed in the future.

A concrete subclass of *tzinfo* may need to implement the following methods. Exactly which methods are needed depends on the uses made of aware *datetime* objects. If in doubt, simply implement all of them.

tzinfo.utcoffset(*dt*)

Return offset of local time from UTC, as a *timedelta* object that is positive east of UTC. If local time is west of UTC, this should be negative. Note that this is intended to be the total offset from UTC; for example, if a *tzinfo* object represents both time zone and DST adjustments, *utcoffset()* should return their sum. If the UTC offset isn't known, return `None`. Else the value returned must be a *timedelta* object strictly between `-timedelta(hours=24)` and `timedelta(hours=24)` (the magnitude of the offset must be less than one day). Most implementations of *utcoffset()* will probably look like one of these two:

```
return CONSTANT                 # fixed-offset class
return CONSTANT + self.dst(dt)  # daylight-aware class
```

If *utcoffset()* does not return `None`, *dst()* should not return `None` either.

The default implementation of *utcoffset()* raises *NotImplementedError*.

Changed in version 3.7: The UTC offset is not restricted to a whole number of minutes.

tzinfo.dst(*dt*)

Return the daylight saving time (DST) adjustment, as a *timedelta* object or `None` if DST information isn't known. Return `timedelta(0)` if DST is not in effect. If DST is in effect, return the offset as a *timedelta* object (see *utcoffset()* for details). Note that DST offset, if applicable, has already been added to the UTC offset returned by *utcoffset()*, so there's no need to consult *dst()* unless you're interested in obtaining DST info separately. For example, *datetime.timetuple()* calls its *tzinfo* attribute's *dst()* method to determine how the `tm_isdst` flag should be set, and *tzinfo.fromutc()* calls *dst()* to account for DST changes when crossing time zones.

An instance *tz* of a *tzinfo* subclass that models both standard and daylight times must be consistent in this sense:

`tz.utcoffset(dt) - tz.dst(dt)`

must return the same result for every *datetime* *dt* with `dt.tzinfo == tz` For sane *tzinfo* subclasses, this expression yields the time zone's "standard offset", which should not depend on the date or the time, but only on geographic location. The implementation of *datetime.astimezone()* relies on this, but cannot detect violations; it's the programmer's responsibility to ensure it. If a *tzinfo* subclass cannot guarantee this, it may be able to override the default implementation of *tzinfo.fromutc()* to work correctly with `astimezone()` regardless.

Most implementations of *dst()* will probably look like one of these two:

```
def dst(self, dt):
    # a fixed-offset class:  doesn't account for DST
    return timedelta(0)
```

or

```
def dst(self, dt):
    # Code to set dston and dstoff to the time zone's DST
    # transition times based on the input dt.year, and expressed
    # in standard local time.  Then

    if dston <= dt.replace(tzinfo=None) < dstoff:
        return timedelta(hours=1)
    else:
        return timedelta(0)
```

The default implementation of *dst()* raises *NotImplementedError*.

Changed in version 3.7: The DST offset is not restricted to a whole number of minutes.

`tzinfo.tzname(`*dt*`)`

Return the time zone name corresponding to the *datetime* object *dt*, as a string. Nothing about string names is defined by the *datetime* module, and there's no requirement that it mean anything in particular. For example, "GMT", "UTC", "-500", "-5:00", "EDT", "US/Eastern", "America/New York" are all valid replies. Return `None` if a string name isn't known. Note that this is a method rather than a fixed string primarily because some *tzinfo* subclasses will wish to return different names depending on the specific value of *dt* passed, especially if the *tzinfo* class is accounting for daylight time.

The default implementation of *tzname()* raises *NotImplementedError*.

These methods are called by a *datetime* or *time* object, in response to their methods of the same names. A *datetime* object passes itself as the argument, and a *time* object passes `None` as the argument. A *tzinfo* subclass's methods should therefore be prepared to accept a *dt* argument of `None`, or of class *datetime*.

When `None` is passed, it's up to the class designer to decide the best response. For example, returning `None` is appropriate if the class wishes to say that time objects don't participate in the *tzinfo* protocols. It may be more useful for `utcoffset(None)` to return the standard UTC offset, as there is no other convention for discovering the standard offset.

When a *datetime* object is passed in response to a *datetime* method, `dt.tzinfo` is the same object as *self*. *tzinfo* methods can rely on this, unless user code calls *tzinfo* methods directly. The intent is that the *tzinfo* methods interpret *dt* as being in local time, and not need worry about objects in other timezones.

There is one more *tzinfo* method that a subclass may wish to override:

`tzinfo.fromutc(`*dt*`)`

This is called from the default *datetime.astimezone()* implementation. When called from that, `dt.tzinfo` is *self*, and *dt*'s date and time data are to be viewed as expressing a UTC time. The purpose of *fromutc()* is to adjust the date and time data, returning an equivalent datetime in *self*'s local time.

Most *tzinfo* subclasses should be able to inherit the default *fromutc()* implementation without problems. It's strong enough to handle fixed-offset time zones, and time zones accounting for both standard and daylight time, and the latter even if the DST transition times differ in different years. An example of a time zone the default *fromutc()* implementation may not handle correctly in all cases is one where the standard offset (from UTC) depends on the specific date and time passed, which can happen for political reasons. The default implementations of `astimezone()` and *fromutc()* may not produce the result you want if the result is one of the hours straddling the moment the standard offset changes.

Skipping code for error cases, the default *fromutc()* implementation acts like:

```
def fromutc(self, dt):
    # raise ValueError error if dt.tzinfo is not self
    dtoff = dt.utcoffset()
    dtdst = dt.dst()
    # raise ValueError if dtoff is None or dtdst is None
    delta = dtoff - dtdst  # this is self's standard offset
    if delta:
        dt += delta   # convert to standard local time
        dtdst = dt.dst()
        # raise ValueError if dtdst is None
    if dtdst:
        return dt + dtdst
    else:
        return dt
```

In the following `tzinfo_examples.py` file there are some examples of *tzinfo* classes:

```
from datetime import tzinfo, timedelta, datetime

ZERO = timedelta(0)
HOUR = timedelta(hours=1)
SECOND = timedelta(seconds=1)

# A class capturing the platform's idea of local time.
# (May result in wrong values on historical times in
#  timezones where UTC offset and/or the DST rules had
#  changed in the past.)
import time as _time

STDOFFSET = timedelta(seconds = -_time.timezone)
if _time.daylight:
    DSTOFFSET = timedelta(seconds = -_time.altzone)
else:
    DSTOFFSET = STDOFFSET

DSTDIFF = DSTOFFSET - STDOFFSET

class LocalTimezone(tzinfo):

    def fromutc(self, dt):
        assert dt.tzinfo is self
        stamp = (dt - datetime(1970, 1, 1, tzinfo=self)) // SECOND
        args = _time.localtime(stamp)[:6]
        dst_diff = DSTDIFF // SECOND
        # Detect fold
        fold = (args == _time.localtime(stamp - dst_diff))
        return datetime(*args, microsecond=dt.microsecond,
```

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```
                        tzinfo=self, fold=fold)

    def utcoffset(self, dt):
        if self._isdst(dt):
            return DSTOFFSET
        else:
            return STDOFFSET

    def dst(self, dt):
        if self._isdst(dt):
            return DSTDIFF
        else:
            return ZERO

    def tzname(self, dt):
        return _time.tzname[self._isdst(dt)]

    def _isdst(self, dt):
        tt = (dt.year, dt.month, dt.day,
              dt.hour, dt.minute, dt.second,
              dt.weekday(), 0, 0)
        stamp = _time.mktime(tt)
        tt = _time.localtime(stamp)
        return tt.tm_isdst > 0

Local = LocalTimezone()


# A complete implementation of current DST rules for major US time zones.

def first_sunday_on_or_after(dt):
    days_to_go = 6 - dt.weekday()
    if days_to_go:
        dt += timedelta(days_to_go)
    return dt


# US DST Rules
#
# This is a simplified (i.e., wrong for a few cases) set of rules for US
# DST start and end times. For a complete and up-to-date set of DST rules
# and timezone definitions, visit the Olson Database (or try pytz):
# http://www.twinsun.com/tz/tz-link.htm
# http://sourceforge.net/projects/pytz/ (might not be up-to-date)
#
# In the US, since 2007, DST starts at 2am (standard time) on the second
# Sunday in March, which is the first Sunday on or after Mar 8.
DSTSTART_2007 = datetime(1, 3, 8, 2)
# and ends at 2am (DST time) on the first Sunday of Nov.
DSTEND_2007 = datetime(1, 11, 1, 2)
# From 1987 to 2006, DST used to start at 2am (standard time) on the first
# Sunday in April and to end at 2am (DST time) on the last
# Sunday of October, which is the first Sunday on or after Oct 25.
DSTSTART_1987_2006 = datetime(1, 4, 1, 2)
DSTEND_1987_2006 = datetime(1, 10, 25, 2)
# From 1967 to 1986, DST used to start at 2am (standard time) on the last
```

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```
# Sunday in April (the one on or after April 24) and to end at 2am (DST time)
# on the last Sunday of October, which is the first Sunday
# on or after Oct 25.
DSTSTART_1967_1986 = datetime(1, 4, 24, 2)
DSTEND_1967_1986 = DSTEND_1987_2006

def us_dst_range(year):
    # Find start and end times for US DST. For years before 1967, return
    # start = end for no DST.
    if 2006 < year:
        dststart, dstend = DSTSTART_2007, DSTEND_2007
    elif 1986 < year < 2007:
        dststart, dstend = DSTSTART_1987_2006, DSTEND_1987_2006
    elif 1966 < year < 1987:
        dststart, dstend = DSTSTART_1967_1986, DSTEND_1967_1986
    else:
        return (datetime(year, 1, 1), ) * 2

    start = first_sunday_on_or_after(dststart.replace(year=year))
    end = first_sunday_on_or_after(dstend.replace(year=year))
    return start, end


class USTimeZone(tzinfo):

    def __init__(self, hours, reprname, stdname, dstname):
        self.stdoffset = timedelta(hours=hours)
        self.reprname = reprname
        self.stdname = stdname
        self.dstname = dstname

    def __repr__(self):
        return self.reprname

    def tzname(self, dt):
        if self.dst(dt):
            return self.dstname
        else:
            return self.stdname

    def utcoffset(self, dt):
        return self.stdoffset + self.dst(dt)

    def dst(self, dt):
        if dt is None or dt.tzinfo is None:
            # An exception may be sensible here, in one or both cases.
            # It depends on how you want to treat them.  The default
            # fromutc() implementation (called by the default astimezone()
            # implementation) passes a datetime with dt.tzinfo is self.
            return ZERO
        assert dt.tzinfo is self
        start, end = us_dst_range(dt.year)
        # Can't compare naive to aware objects, so strip the timezone from
        # dt first.
        dt = dt.replace(tzinfo=None)
        if start + HOUR <= dt < end - HOUR:
```

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```
            # DST is in effect.
            return HOUR
        if end - HOUR <= dt < end:
            # Fold (an ambiguous hour): use dt.fold to disambiguate.
            return ZERO if dt.fold else HOUR
        if start <= dt < start + HOUR:
            # Gap (a non-existent hour): reverse the fold rule.
            return HOUR if dt.fold else ZERO
        # DST is off.
        return ZERO

    def fromutc(self, dt):
        assert dt.tzinfo is self
        start, end = us_dst_range(dt.year)
        start = start.replace(tzinfo=self)
        end = end.replace(tzinfo=self)
        std_time = dt + self.stdoffset
        dst_time = std_time + HOUR
        if end <= dst_time < end + HOUR:
            # Repeated hour
            return std_time.replace(fold=1)
        if std_time < start or dst_time >= end:
            # Standard time
            return std_time
        if start <= std_time < end - HOUR:
            # Daylight saving time
            return dst_time


Eastern  = USTimeZone(-5, "Eastern",  "EST", "EDT")
Central  = USTimeZone(-6, "Central",  "CST", "CDT")
Mountain = USTimeZone(-7, "Mountain", "MST", "MDT")
Pacific  = USTimeZone(-8, "Pacific",  "PST", "PDT")
```

Note that there are unavoidable subtleties twice per year in a *tzinfo* subclass accounting for both standard and daylight time, at the DST transition points. For concreteness, consider US Eastern (UTC -0500), where EDT begins the minute after 1:59 (EST) on the second Sunday in March, and ends the minute after 1:59 (EDT) on the first Sunday in November:

```
  UTC   3:MM  4:MM  5:MM  6:MM  7:MM  8:MM
  EST  22:MM 23:MM  0:MM  1:MM  2:MM  3:MM
  EDT  23:MM  0:MM  1:MM  2:MM  3:MM  4:MM

start  22:MM 23:MM  0:MM  1:MM  3:MM  4:MM

  end  23:MM  0:MM  1:MM  1:MM  2:MM  3:MM
```

When DST starts (the "start" line), the local wall clock leaps from 1:59 to 3:00. A wall time of the form 2:MM doesn't really make sense on that day, so `astimezone(Eastern)` won't deliver a result with `hour == 2` on the day DST begins. For example, at the Spring forward transition of 2016, we get

```
>>> from datetime import datetime, timezone
>>> from tzinfo_examples import HOUR, Eastern
>>> u0 = datetime(2016, 3, 13, 5, tzinfo=timezone.utc)
>>> for i in range(4):
...     u = u0 + i*HOUR
```

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```
...     t = u.astimezone(Eastern)
...     print(u.time(), 'UTC =', t.time(), t.tzname())
...
05:00:00 UTC = 00:00:00 EST
06:00:00 UTC = 01:00:00 EST
07:00:00 UTC = 03:00:00 EDT
08:00:00 UTC = 04:00:00 EDT
```

When DST ends (the "end" line), there's a potentially worse problem: there's an hour that can't be spelled unambiguously in local wall time: the last hour of daylight time. In Eastern, that's times of the form 5:MM UTC on the day daylight time ends. The local wall clock leaps from 1:59 (daylight time) back to 1:00 (standard time) again. Local times of the form 1:MM are ambiguous. `astimezone()` mimics the local clock's behavior by mapping two adjacent UTC hours into the same local hour then. In the Eastern example, UTC times of the form 5:MM and 6:MM both map to 1:MM when converted to Eastern, but earlier times have the *fold* attribute set to 0 and the later times have it set to 1. For example, at the Fall back transition of 2016, we get

```
>>> u0 = datetime(2016, 11, 6, 4, tzinfo=timezone.utc)
>>> for i in range(4):
...     u = u0 + i*HOUR
...     t = u.astimezone(Eastern)
...     print(u.time(), 'UTC =', t.time(), t.tzname(), t.fold)
...
04:00:00 UTC = 00:00:00 EDT 0
05:00:00 UTC = 01:00:00 EDT 0
06:00:00 UTC = 01:00:00 EST 1
07:00:00 UTC = 02:00:00 EST 0
```

Note that the *datetime* instances that differ only by the value of the *fold* attribute are considered equal in comparisons.

Applications that can't bear wall-time ambiguities should explicitly check the value of the *fold* attribute or avoid using hybrid *tzinfo* subclasses; there are no ambiguities when using *timezone*, or any other fixed-offset *tzinfo* subclass (such as a class representing only EST (fixed offset -5 hours), or only EDT (fixed offset -4 hours)).

See also:

dateutil.tz The standard library has *timezone* class for handling arbitrary fixed offsets from UTC and *timezone.utc* as UTC timezone instance.

dateutil.tz library brings the *IANA timezone database* (also known as the Olson database) to Python and its usage is recommended.

IANA timezone database The Time Zone Database (often called tz, tzdata or zoneinfo) contains code and data that represent the history of local time for many representative locations around the globe. It is updated periodically to reflect changes made by political bodies to time zone boundaries, UTC offsets, and daylight-saving rules.

8.1.7 `timezone` Objects

The *timezone* class is a subclass of *tzinfo*, each instance of which represents a timezone defined by a fixed offset from UTC. Note that objects of this class cannot be used to represent timezone information in the locations where different offsets are used in different days of the year or where historical changes have been made to civil time.

class datetime.timezone(*offset*, *name=None*)

The *offset* argument must be specified as a *timedelta* object representing the difference between the local time and UTC. It must be strictly between `-timedelta(hours=24)` and `timedelta(hours=24)`, otherwise *ValueError* is raised.

The *name* argument is optional. If specified it must be a string that will be used as the value returned by the *datetime.tzname()* method.

New in version 3.2.

Changed in version 3.7: The UTC offset is not restricted to a whole number of minutes.

timezone.utcoffset(*dt*)

Return the fixed value specified when the *timezone* instance is constructed. The *dt* argument is ignored. The return value is a *timedelta* instance equal to the difference between the local time and UTC.

Changed in version 3.7: The UTC offset is not restricted to a whole number of minutes.

timezone.tzname(*dt*)

Return the fixed value specified when the *timezone* instance is constructed. If *name* is not provided in the constructor, the name returned by `tzname(dt)` is generated from the value of the `offset` as follows. If *offset* is `timedelta(0)`, the name is "UTC", otherwise it is a string 'UTC±HH:MM', where ± is the sign of `offset`, HH and MM are two digits of `offset.hours` and `offset.minutes` respectively.

Changed in version 3.6: Name generated from `offset=timedelta(0)` is now plain 'UTC', not 'UTC+00:00'.

timezone.dst(*dt*)

Always returns `None`.

timezone.fromutc(*dt*)

Return `dt + offset`. The *dt* argument must be an aware *datetime* instance, with `tzinfo` set to `self`.

Class attributes:

timezone.utc

The UTC timezone, `timezone(timedelta(0))`.

8.1.8 strftime() and strptime() Behavior

date, *datetime*, and *time* objects all support a `strftime(format)` method, to create a string representing the time under the control of an explicit format string. Broadly speaking, `d.strftime(fmt)` acts like the *time* module's `time.strftime(fmt, d.timetuple())` although not all objects support a `timetuple()` method.

Conversely, the *datetime.strptime()* class method creates a *datetime* object from a string representing a date and time and a corresponding format string. `datetime.strptime(date_string, format)` is equivalent to `datetime(*(time.strptime(date_string, format)[0:6]))`.

For *time* objects, the format codes for year, month, and day should not be used, as time objects have no such values. If they're used anyway, `1900` is substituted for the year, and `1` for the month and day.

For *date* objects, the format codes for hours, minutes, seconds, and microseconds should not be used, as *date* objects have no such values. If they're used anyway, `0` is substituted for them.

The full set of format codes supported varies across platforms, because Python calls the platform C library's `strftime()` function, and platform variations are common. To see the full set of format codes supported on your platform, consult the *strftime(3)* documentation.

The following is a list of all the format codes that the C standard (1989 version) requires, and these work on all platforms with a standard C implementation. Note that the 1999 version of the C standard added additional format codes.

Directive	Meaning	Example	Notes
%a	Weekday as locale's abbreviated name.	Sun, Mon, …, Sat (en_US); So, Mo, …, Sa (de_DE)	(1)
%A	Weekday as locale's full name.	Sunday, Monday, …, Saturday (en_US); Sonntag, Montag, …, Samstag (de_DE)	(1)
%w	Weekday as a decimal number, where 0 is Sunday and 6 is Saturday.	0, 1, …, 6	
%d	Day of the month as a zero-padded decimal number.	01, 02, …, 31	
%b	Month as locale's abbreviated name.	Jan, Feb, …, Dec (en_US); Jan, Feb, …, Dez (de_DE)	(1)
%B	Month as locale's full name.	January, February, …, December (en_US); Januar, Februar, …, Dezember (de_DE)	(1)
%m	Month as a zero-padded decimal number.	01, 02, …, 12	
%y	Year without century as a zero-padded decimal number.	00, 01, …, 99	
%Y	Year with century as a decimal number.	0001, 0002, …, 2013, 2014, …, 9998, 9999	(2)
%H	Hour (24-hour clock) as a zero-padded decimal number.	00, 01, …, 23	
%I	Hour (12-hour clock) as a zero-padded decimal number.	01, 02, …, 12	
%p	Locale's equivalent of either AM or PM.	AM, PM (en_US); am, pm (de_DE)	(1), (3)
%M	Minute as a zero-padded decimal number.	00, 01, …, 59	
%S	Second as a zero-padded decimal number.	00, 01, …, 59	(4)
%f	Microsecond as a decimal number, zero-padded on the left.	000000, 000001, …, 999999	(5)
%z	UTC offset in the form	(empty), +0000, -0400,	(6)

Several additional directives not required by the C89 standard are included for convenience. These parameters all correspond to ISO 8601 date values. These may not be available on all platforms when used with the `strftime()` method. The ISO 8601 year and ISO 8601 week directives are not interchangeable with the year and week number directives above. Calling `strptime()` with incomplete or ambiguous ISO 8601 directives will raise a *ValueError*.

Directive	Meaning	Example	Notes
`%G`	ISO 8601 year with century representing the year that contains the greater part of the ISO week (`%V`).	0001, 0002, ..., 2013, 2014, ..., 9998, 9999	(8)
`%u`	ISO 8601 weekday as a decimal number where 1 is Monday.	1, 2, ..., 7	
`%V`	ISO 8601 week as a decimal number with Monday as the first day of the week. Week 01 is the week containing Jan 4.	01, 02, ..., 53	(8)

New in version 3.6: `%G`, `%u` and `%V` were added.

Notes:

1. Because the format depends on the current locale, care should be taken when making assumptions about the output value. Field orderings will vary (for example, "month/day/year" versus "day/month/year"), and the output may contain Unicode characters encoded using the locale's default encoding (for example, if the current locale is `ja_JP`, the default encoding could be any one of `eucJP`, `SJIS`, or `utf-8`; use *locale.getlocale()* to determine the current locale's encoding).

2. The `strptime()` method can parse years in the full [1, 9999] range, but years < 1000 must be zero-filled to 4-digit width.

   Changed in version 3.2: In previous versions, `strftime()` method was restricted to years >= 1900.

   Changed in version 3.3: In version 3.2, `strftime()` method was restricted to years >= 1000.

3. When used with the `strptime()` method, the `%p` directive only affects the output hour field if the `%I` directive is used to parse the hour.

4. Unlike the *time* module, the *datetime* module does not support leap seconds.

5. When used with the `strptime()` method, the `%f` directive accepts from one to six digits and zero pads on the right. `%f` is an extension to the set of format characters in the C standard (but implemented separately in datetime objects, and therefore always available).

6. For a naive object, the `%z` and `%Z` format codes are replaced by empty strings.

   For an aware object:

   `%z` `utcoffset()` is transformed into a string of the form ±HHMM[SS[.uuuuuu]], where HH is a 2-digit string giving the number of UTC offset hours, and MM is a 2-digit string giving the number of UTC offset minutes, SS is a 2-digit string giving the number of UTC offset seconds and uuuuuu is a 2-digit string giving the number of UTC offset microseconds. The uuuuuu part is omitted when the offset is a whole number of minutes and both the uuuuuu and the SS parts are omitted when the offset is a whole number of minutes. For example, if `utcoffset()` returns `timedelta(hours=-3, minutes=-30)`, `%z` is replaced with the string `'-0330'`.

   Changed in version 3.7: The UTC offset is not restricted to a whole number of minutes.

   Changed in version 3.7: When the `%z` directive is provided to the `strptime()` method, the UTC offsets can have a colon as a separator between hours, minutes and seconds. For example, `'+01:00:00'` will be parsed as an offset of one hour. In addition, providing `'Z'` is identical to `'+00:00'`.

   `%Z` If `tzname()` returns `None`, `%Z` is replaced by an empty string. Otherwise `%Z` is replaced by the returned value, which must be a string.

Changed in version 3.2: When the `%z` directive is provided to the `strptime()` method, an aware *datetime* object will be produced. The `tzinfo` of the result will be set to a *timezone* instance.

7. When used with the `strptime()` method, `%U` and `%W` are only used in calculations when the day of the week and the calendar year (`%Y`) are specified.
8. Similar to `%U` and `%W`, `%V` is only used in calculations when the day of the week and the ISO year (`%G`) are specified in a `strptime()` format string. Also note that `%G` and `%Y` are not interchangeable.

8.2 `calendar` — General calendar-related functions

Source code: Lib/calendar.py

This module allows you to output calendars like the Unix `cal` program, and provides additional useful functions related to the calendar. By default, these calendars have Monday as the first day of the week, and Sunday as the last (the European convention). Use *setfirstweekday()* to set the first day of the week to Sunday (6) or to any other weekday. Parameters that specify dates are given as integers. For related functionality, see also the *datetime* and *time* modules.

The functions and classes defined in this module use an idealized calendar, the current Gregorian calendar extended indefinitely in both directions. This matches the definition of the "proleptic Gregorian" calendar in Dershowitz and Reingold's book "Calendrical Calculations", where it's the base calendar for all computations. Zero and negative years are interpreted as prescribed by the ISO 8601 standard. Year 0 is 1 BC, year -1 is 2 BC, and so on.

class calendar.Calendar(*firstweekday=0*)

Creates a *Calendar* object. *firstweekday* is an integer specifying the first day of the week. `0` is Monday (the default), `6` is Sunday.

A *Calendar* object provides several methods that can be used for preparing the calendar data for formatting. This class doesn't do any formatting itself. This is the job of subclasses.

Calendar instances have the following methods:

iterweekdays()

Return an iterator for the week day numbers that will be used for one week. The first value from the iterator will be the same as the value of the *firstweekday* property.

itermonthdates(*year*, *month*)

Return an iterator for the month *month* (1–12) in the year *year*. This iterator will return all days (as *datetime.date* objects) for the month and all days before the start of the month or after the end of the month that are required to get a complete week.

itermonthdays(*year*, *month*)

Return an iterator for the month *month* in the year *year* similar to *itermonthdates()*, but not restricted by the *datetime.date* range. Days returned will simply be day of the month numbers. For the days outside of the specified month, the day number is `0`.

itermonthdays2(*year*, *month*)

Return an iterator for the month *month* in the year *year* similar to *itermonthdates()*, but not restricted by the *datetime.date* range. Days returned will be tuples consisting of a day of the month number and a week day number.

itermonthdays3(*year*, *month*)

Return an iterator for the month *month* in the year *year* similar to *itermonthdates()*, but not restricted by the *datetime.date* range. Days returned will be tuples consisting of a year, a month and a day of the month numbers.

New in version 3.7.

itermonthdays4(*year*, *month*)
Return an iterator for the month *month* in the year *year* similar to *itermonthdates()*, but not restricted by the *datetime.date* range. Days returned will be tuples consisting of a year, a month, a day of the month, and a day of the week numbers.

New in version 3.7.

monthdatescalendar(*year*, *month*)
Return a list of the weeks in the month *month* of the *year* as full weeks. Weeks are lists of seven *datetime.date* objects.

monthdays2calendar(*year*, *month*)
Return a list of the weeks in the month *month* of the *year* as full weeks. Weeks are lists of seven tuples of day numbers and weekday numbers.

monthdayscalendar(*year*, *month*)
Return a list of the weeks in the month *month* of the *year* as full weeks. Weeks are lists of seven day numbers.

yeardatescalendar(*year*, *width=3*)
Return the data for the specified year ready for formatting. The return value is a list of month rows. Each month row contains up to *width* months (defaulting to 3). Each month contains between 4 and 6 weeks and each week contains 1–7 days. Days are *datetime.date* objects.

yeardays2calendar(*year*, *width=3*)
Return the data for the specified year ready for formatting (similar to *yeardatescalendar()*). Entries in the week lists are tuples of day numbers and weekday numbers. Day numbers outside this month are zero.

yeardayscalendar(*year*, *width=3*)
Return the data for the specified year ready for formatting (similar to *yeardatescalendar()*). Entries in the week lists are day numbers. Day numbers outside this month are zero.

class calendar.TextCalendar(*firstweekday=0*)
This class can be used to generate plain text calendars.

TextCalendar instances have the following methods:

formatmonth(*theyear*, *themonth*, *w=0*, *l=0*)
Return a month's calendar in a multi-line string. If *w* is provided, it specifies the width of the date columns, which are centered. If *l* is given, it specifies the number of lines that each week will use. Depends on the first weekday as specified in the constructor or set by the *setfirstweekday()* method.

prmonth(*theyear*, *themonth*, *w=0*, *l=0*)
Print a month's calendar as returned by *formatmonth()*.

formatyear(*theyear*, *w=2*, *l=1*, *c=6*, *m=3*)
Return a *m*-column calendar for an entire year as a multi-line string. Optional parameters *w*, *l*, and *c* are for date column width, lines per week, and number of spaces between month columns, respectively. Depends on the first weekday as specified in the constructor or set by the *setfirstweekday()* method. The earliest year for which a calendar can be generated is platform-dependent.

pryear(*theyear*, *w=2*, *l=1*, *c=6*, *m=3*)
Print the calendar for an entire year as returned by *formatyear()*.

class calendar.HTMLCalendar(*firstweekday=0*)
This class can be used to generate HTML calendars.

`HTMLCalendar` instances have the following methods:

formatmonth(*theyear*, *themonth*, *withyear=True*)
Return a month's calendar as an HTML table. If *withyear* is true the year will be included in the header, otherwise just the month name will be used.

formatyear(*theyear*, *width=3*)
Return a year's calendar as an HTML table. *width* (defaulting to 3) specifies the number of months per row.

formatyearpage(*theyear*, *width=3*, *css='calendar.css'*, *encoding=None*)
Return a year's calendar as a complete HTML page. *width* (defaulting to 3) specifies the number of months per row. *css* is the name for the cascading style sheet to be used. *None* can be passed if no style sheet should be used. *encoding* specifies the encoding to be used for the output (defaulting to the system default encoding).

`HTMLCalendar` has the following attributes you can override to customize the CSS classes used by the calendar:

cssclasses
A list of CSS classes used for each weekday. The default class list is:

```
cssclasses = ["mon", "tue", "wed", "thu", "fri", "sat", "sun"]
```

more styles can be added for each day:

```
cssclasses = ["mon text-bold", "tue", "wed", "thu", "fri", "sat", "sun red"]
```

Note that the length of this list must be seven items.

cssclass_noday
The CSS class for a weekday occurring in the previous or coming month.

New in version 3.7.

cssclasses_weekday_head
A list of CSS classes used for weekday names in the header row. The default is the same as *cssclasses*.

New in version 3.7.

cssclass_month_head
The month's head CSS class (used by `formatmonthname()`). The default value is `"month"`.

New in version 3.7.

cssclass_month
The CSS class for the whole month's table (used by *formatmonth()*). The default value is `"month"`.

New in version 3.7.

cssclass_year
The CSS class for the whole year's table of tables (used by *formatyear()*). The default value is `"year"`.

New in version 3.7.

cssclass_year_head
The CSS class for the table head for the whole year (used by *formatyear()*). The default value is `"year"`.

New in version 3.7.

Note that although the naming for the above described class attributes is singular (e.g. `cssclass_month cssclass_noday`), one can replace the single CSS class with a space separated list of CSS classes, for example:

```
"text-bold text-red"
```

Here is an example how `HTMLCalendar` can be customized:

```
class CustomHTMLCal(calendar.HTMLCalendar):
    cssclasses = [style + " text-nowrap" for style in
                  calendar.HTMLCalendar.cssclasses]
    cssclass_month_head = "text-center month-head"
    cssclass_month = "text-center month"
    cssclass_year = "text-italic lead"
```

class calendar.**LocaleTextCalendar**(*firstweekday=0*, *locale=None*)

This subclass of *TextCalendar* can be passed a locale name in the constructor and will return month and weekday names in the specified locale. If this locale includes an encoding all strings containing month and weekday names will be returned as unicode.

class calendar.**LocaleHTMLCalendar**(*firstweekday=0*, *locale=None*)

This subclass of *HTMLCalendar* can be passed a locale name in the constructor and will return month and weekday names in the specified locale. If this locale includes an encoding all strings containing month and weekday names will be returned as unicode.

Note: The `formatweekday()` and `formatmonthname()` methods of these two classes temporarily change the current locale to the given *locale*. Because the current locale is a process-wide setting, they are not thread-safe.

For simple text calendars this module provides the following functions.

calendar.**setfirstweekday**(*weekday*)

Sets the weekday (`0` is Monday, `6` is Sunday) to start each week. The values `MONDAY`, `TUESDAY`, `WEDNESDAY`, `THURSDAY`, `FRIDAY`, `SATURDAY`, and `SUNDAY` are provided for convenience. For example, to set the first weekday to Sunday:

```
import calendar
calendar.setfirstweekday(calendar.SUNDAY)
```

calendar.**firstweekday**()

Returns the current setting for the weekday to start each week.

calendar.**isleap**(*year*)

Returns *True* if *year* is a leap year, otherwise *False*.

calendar.**leapdays**(*y1*, *y2*)

Returns the number of leap years in the range from *y1* to *y2* (exclusive), where *y1* and *y2* are years.

This function works for ranges spanning a century change.

calendar.**weekday**(*year*, *month*, *day*)

Returns the day of the week (`0` is Monday) for *year* (`1970`–…), *month* (`1`–`12`), *day* (`1`–`31`).

calendar.**weekheader**(*n*)

Return a header containing abbreviated weekday names. *n* specifies the width in characters for one weekday.

calendar.**monthrange**(*year*, *month*)

Returns weekday of first day of the month and number of days in month, for the specified *year* and *month*.

calendar.**monthcalendar**(*year*, *month*)

Returns a matrix representing a month's calendar. Each row represents a week; days outside of the

month a represented by zeros. Each week begins with Monday unless set by *setfirstweekday()*.

calendar.prmonth(*theyear*, *themonth*, *w=0*, *l=0*)
Prints a month's calendar as returned by *month()*.

calendar.month(*theyear*, *themonth*, *w=0*, *l=0*)
Returns a month's calendar in a multi-line string using the `formatmonth()` of the *TextCalendar* class.

calendar.prcal(*year*, *w=0*, *l=0*, *c=6*, *m=3*)
Prints the calendar for an entire year as returned by *calendar()*.

calendar.calendar(*year*, *w=2*, *l=1*, *c=6*, *m=3*)
Returns a 3-column calendar for an entire year as a multi-line string using the `formatyear()` of the *TextCalendar* class.

calendar.timegm(*tuple*)
An unrelated but handy function that takes a time tuple such as returned by the *gmtime()* function in the *time* module, and returns the corresponding Unix timestamp value, assuming an epoch of 1970, and the POSIX encoding. In fact, *time.gmtime()* and *timegm()* are each others' inverse.

The *calendar* module exports the following data attributes:

calendar.day_name
An array that represents the days of the week in the current locale.

calendar.day_abbr
An array that represents the abbreviated days of the week in the current locale.

calendar.month_name
An array that represents the months of the year in the current locale. This follows normal convention of January being month number 1, so it has a length of 13 and `month_name[0]` is the empty string.

calendar.month_abbr
An array that represents the abbreviated months of the year in the current locale. This follows normal convention of January being month number 1, so it has a length of 13 and `month_abbr[0]` is the empty string.

See also:

Module *datetime* Object-oriented interface to dates and times with similar functionality to the *time* module.

Module *time* Low-level time related functions.

8.3 `collections` — Container datatypes

Source code: Lib/collections/___init___.py

This module implements specialized container datatypes providing alternatives to Python's general purpose built-in containers, *dict*, *list*, *set*, and *tuple*.

namedtuple()	factory function for creating tuple subclasses with named fields
deque	list-like container with fast appends and pops on either end
ChainMap	dict-like class for creating a single view of multiple mappings
Counter	dict subclass for counting hashable objects
OrderedDict	dict subclass that remembers the order entries were added
defaultdict	dict subclass that calls a factory function to supply missing values
UserDict	wrapper around dictionary objects for easier dict subclassing
UserList	wrapper around list objects for easier list subclassing
UserString	wrapper around string objects for easier string subclassing

Changed in version 3.3: Moved *Collections Abstract Base Classes* to the *collections.abc* module. For backwards compatibility, they continue to be visible in this module through Python 3.7. Subsequently, they will be removed entirely.

8.3.1 ChainMap objects

New in version 3.3.

A *ChainMap* class is provided for quickly linking a number of mappings so they can be treated as a single unit. It is often much faster than creating a new dictionary and running multiple *update()* calls.

The class can be used to simulate nested scopes and is useful in templating.

class collections.ChainMap(**maps*)

A *ChainMap* groups multiple dicts or other mappings together to create a single, updateable view. If no *maps* are specified, a single empty dictionary is provided so that a new chain always has at least one mapping.

The underlying mappings are stored in a list. That list is public and can be accessed or updated using the *maps* attribute. There is no other state.

Lookups search the underlying mappings successively until a key is found. In contrast, writes, updates, and deletions only operate on the first mapping.

A *ChainMap* incorporates the underlying mappings by reference. So, if one of the underlying mappings gets updated, those changes will be reflected in *ChainMap*.

All of the usual dictionary methods are supported. In addition, there is a *maps* attribute, a method for creating new subcontexts, and a property for accessing all but the first mapping:

maps

A user updateable list of mappings. The list is ordered from first-searched to last-searched. It is the only stored state and can be modified to change which mappings are searched. The list should always contain at least one mapping.

new_child(*m=None*)

Returns a new *ChainMap* containing a new map followed by all of the maps in the current instance. If `m` is specified, it becomes the new map at the front of the list of mappings; if not specified, an empty dict is used, so that a call to `d.new_child()` is equivalent to: `ChainMap({}, *d.maps)`. This method is used for creating subcontexts that can be updated without altering values in any of the parent mappings.

Changed in version 3.4: The optional `m` parameter was added.

parents

Property returning a new *ChainMap* containing all of the maps in the current instance except the first one. This is useful for skipping the first map in the search. Use cases are similar to those for the `nonlocal` keyword used in *nested scopes*. The use cases also parallel those for the built-in *super()* function. A reference to `d.parents` is equivalent to: `ChainMap(*d.maps[1:])`.

See also:

- The MultiContext class in the Enthought CodeTools package has options to support writing to any mapping in the chain.
- Django's Context class for templating is a read-only chain of mappings. It also features pushing and popping of contexts similar to the *new_child()* method and the *parents* property.
- The Nested Contexts recipe has options to control whether writes and other mutations apply only to the first mapping or to any mapping in the chain.
- A greatly simplified read-only version of Chainmap.

`ChainMap` Examples and Recipes

This section shows various approaches to working with chained maps.

Example of simulating Python's internal lookup chain:

```
import builtins
pylookup = ChainMap(locals(), globals(), vars(builtins))
```

Example of letting user specified command-line arguments take precedence over environment variables which in turn take precedence over default values:

```
import os, argparse

defaults = {'color': 'red', 'user': 'guest'}

parser = argparse.ArgumentParser()
parser.add_argument('-u', '--user')
parser.add_argument('-c', '--color')
namespace = parser.parse_args()
command_line_args = {k:v for k, v in vars(namespace).items() if v}

combined = ChainMap(command_line_args, os.environ, defaults)
print(combined['color'])
print(combined['user'])
```

Example patterns for using the *ChainMap* class to simulate nested contexts:

```
c = ChainMap()        # Create root context
d = c.new_child()     # Create nested child context
e = c.new_child()     # Child of c, independent from d
e.maps[0]             # Current context dictionary -- like Python's locals()
e.maps[-1]            # Root context -- like Python's globals()
e.parents             # Enclosing context chain -- like Python's nonlocals

d['x']                # Get first key in the chain of contexts
d['x'] = 1            # Set value in current context
del d['x']            # Delete from current context
list(d)               # All nested values
k in d                # Check all nested values
len(d)                # Number of nested values
d.items()             # All nested items
dict(d)               # Flatten into a regular dictionary
```

The *ChainMap* class only makes updates (writes and deletions) to the first mapping in the chain while lookups will search the full chain. However, if deep writes and deletions are desired, it is easy to make a subclass that updates keys found deeper in the chain:

```
class DeepChainMap(ChainMap):
    'Variant of ChainMap that allows direct updates to inner scopes'

    def __setitem__(self, key, value):
        for mapping in self.maps:
            if key in mapping:
                mapping[key] = value
                return
        self.maps[0][key] = value

    def __delitem__(self, key):
        for mapping in self.maps:
            if key in mapping:
                del mapping[key]
                return
        raise KeyError(key)

>>> d = DeepChainMap({'zebra': 'black'}, {'elephant': 'blue'}, {'lion': 'yellow'})
>>> d['lion'] = 'orange'         # update an existing key two levels down
>>> d['snake'] = 'red'           # new keys get added to the topmost dict
>>> del d['elephant']            # remove an existing key one level down
DeepChainMap({'zebra': 'black', 'snake': 'red'}, {}, {'lion': 'orange'})
```

8.3.2 `Counter` objects

A counter tool is provided to support convenient and rapid tallies. For example:

```
>>> # Tally occurrences of words in a list
>>> cnt = Counter()
>>> for word in ['red', 'blue', 'red', 'green', 'blue', 'blue']:
...     cnt[word] += 1
>>> cnt
Counter({'blue': 3, 'red': 2, 'green': 1})

>>> # Find the ten most common words in Hamlet
>>> import re
>>> words = re.findall(r'\w+', open('hamlet.txt').read().lower())
>>> Counter(words).most_common(10)
[('the', 1143), ('and', 966), ('to', 762), ('of', 669), ('i', 631),
 ('you', 554),  ('a', 546), ('my', 514), ('hamlet', 471), ('in', 451)]
```

class collections.Counter([*iterable-or-mapping*])

A *Counter* is a *dict* subclass for counting hashable objects. It is an unordered collection where elements are stored as dictionary keys and their counts are stored as dictionary values. Counts are allowed to be any integer value including zero or negative counts. The *Counter* class is similar to bags or multisets in other languages.

Elements are counted from an *iterable* or initialized from another *mapping* (or counter):

```
>>> c = Counter()                           # a new, empty counter
>>> c = Counter('gallahad')                 # a new counter from an iterable
>>> c = Counter({'red': 4, 'blue': 2})      # a new counter from a mapping
>>> c = Counter(cats=4, dogs=8)             # a new counter from keyword args
```

Counter objects have a dictionary interface except that they return a zero count for missing items instead of raising a *KeyError*:

```
>>> c = Counter(['eggs', 'ham'])
>>> c['bacon']                              # count of a missing element is zero
0
```

Setting a count to zero does not remove an element from a counter. Use `del` to remove it entirely:

```
>>> c['sausage'] = 0                        # counter entry with a zero count
>>> del c['sausage']                        # del actually removes the entry
```

New in version 3.1.

Counter objects support three methods beyond those available for all dictionaries:

elements()
Return an iterator over elements repeating each as many times as its count. Elements are returned in arbitrary order. If an element's count is less than one, *elements()* will ignore it.

```
>>> c = Counter(a=4, b=2, c=0, d=-2)
>>> sorted(c.elements())
['a', 'a', 'a', 'a', 'b', 'b']
```

most_common([*n*]**)**
Return a list of the *n* most common elements and their counts from the most common to the least. If *n* is omitted or `None`, *most_common()* returns *all* elements in the counter. Elements with equal counts are ordered arbitrarily:

```
>>> Counter('abracadabra').most_common(3)
[('a', 5), ('r', 2), ('b', 2)]
```

subtract([*iterable-or-mapping*]**)**
Elements are subtracted from an *iterable* or from another *mapping* (or counter). Like *dict.update()* but subtracts counts instead of replacing them. Both inputs and outputs may be zero or negative.

```
>>> c = Counter(a=4, b=2, c=0, d=-2)
>>> d = Counter(a=1, b=2, c=3, d=4)
>>> c.subtract(d)
>>> c
Counter({'a': 3, 'b': 0, 'c': -3, 'd': -6})
```

New in version 3.2.

The usual dictionary methods are available for *Counter* objects except for two which work differently for counters.

fromkeys(*iterable***)**
This class method is not implemented for *Counter* objects.

update([*iterable-or-mapping*]**)**
Elements are counted from an *iterable* or added-in from another *mapping* (or counter). Like *dict.update()* but adds counts instead of replacing them. Also, the *iterable* is expected to be a sequence of elements, not a sequence of `(key, value)` pairs.

Common patterns for working with *Counter* objects:

```
sum(c.values())                 # total of all counts
c.clear()                       # reset all counts
list(c)                         # list unique elements
set(c)                          # convert to a set
```

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```
dict(c)                         # convert to a regular dictionary
c.items()                       # convert to a list of (elem, cnt) pairs
Counter(dict(list_of_pairs))    # convert from a list of (elem, cnt) pairs
c.most_common()[:-n-1:-1]       # n least common elements
+c                              # remove zero and negative counts
```

Several mathematical operations are provided for combining *Counter* objects to produce multisets (counters that have counts greater than zero). Addition and subtraction combine counters by adding or subtracting the counts of corresponding elements. Intersection and union return the minimum and maximum of corresponding counts. Each operation can accept inputs with signed counts, but the output will exclude results with counts of zero or less.

```
>>> c = Counter(a=3, b=1)
>>> d = Counter(a=1, b=2)
>>> c + d                       # add two counters together:  c[x] + d[x]
Counter({'a': 4, 'b': 3})
>>> c - d                       # subtract (keeping only positive counts)
Counter({'a': 2})
>>> c & d                       # intersection:  min(c[x], d[x])
Counter({'a': 1, 'b': 1})
>>> c | d                       # union:  max(c[x], d[x])
Counter({'a': 3, 'b': 2})
```

Unary addition and subtraction are shortcuts for adding an empty counter or subtracting from an empty counter.

```
>>> c = Counter(a=2, b=-4)
>>> +c
Counter({'a': 2})
>>> -c
Counter({'b': 4})
```

New in version 3.3: Added support for unary plus, unary minus, and in-place multiset operations.

Note: Counters were primarily designed to work with positive integers to represent running counts; however, care was taken to not unnecessarily preclude use cases needing other types or negative values. To help with those use cases, this section documents the minimum range and type restrictions.

- The *Counter* class itself is a dictionary subclass with no restrictions on its keys and values. The values are intended to be numbers representing counts, but you *could* store anything in the value field.
- The *most_common()* method requires only that the values be orderable.
- For in-place operations such as `c[key] += 1`, the value type need only support addition and subtraction. So fractions, floats, and decimals would work and negative values are supported. The same is also true for *update()* and *subtract()* which allow negative and zero values for both inputs and outputs.
- The multiset methods are designed only for use cases with positive values. The inputs may be negative or zero, but only outputs with positive values are created. There are no type restrictions, but the value type needs to support addition, subtraction, and comparison.
- The *elements()* method requires integer counts. It ignores zero and negative counts.

See also:

- Bag class in Smalltalk.
- Wikipedia entry for Multisets.

- C++ multisets tutorial with examples.
- For mathematical operations on multisets and their use cases, see *Knuth, Donald. The Art of Computer Programming Volume II, Section 4.6.3, Exercise 19.*
- To enumerate all distinct multisets of a given size over a given set of elements, see *itertools.combinations_with_replacement()*:

```
map(Counter, combinations_with_replacement('ABC', 2)) # --> AA AB AC BB BC CC
```

8.3.3 deque objects

class collections.deque([*iterable*[, *maxlen*]])

Returns a new deque object initialized left-to-right (using *append()*) with data from *iterable*. If *iterable* is not specified, the new deque is empty.

Deques are a generalization of stacks and queues (the name is pronounced "deck" and is short for "double-ended queue"). Deques support thread-safe, memory efficient appends and pops from either side of the deque with approximately the same O(1) performance in either direction.

Though *list* objects support similar operations, they are optimized for fast fixed-length operations and incur O(n) memory movement costs for `pop(0)` and `insert(0, v)` operations which change both the size and position of the underlying data representation.

If *maxlen* is not specified or is `None`, deques may grow to an arbitrary length. Otherwise, the deque is bounded to the specified maximum length. Once a bounded length deque is full, when new items are added, a corresponding number of items are discarded from the opposite end. Bounded length deques provide functionality similar to the `tail` filter in Unix. They are also useful for tracking transactions and other pools of data where only the most recent activity is of interest.

Deque objects support the following methods:

append(*x*)
Add *x* to the right side of the deque.

appendleft(*x*)
Add *x* to the left side of the deque.

clear()
Remove all elements from the deque leaving it with length 0.

copy()
Create a shallow copy of the deque.

New in version 3.5.

count(*x*)
Count the number of deque elements equal to *x*.

New in version 3.2.

extend(*iterable*)
Extend the right side of the deque by appending elements from the iterable argument.

extendleft(*iterable*)
Extend the left side of the deque by appending elements from *iterable*. Note, the series of left appends results in reversing the order of elements in the iterable argument.

index(*x*[, *start*[, *stop*]])
Return the position of *x* in the deque (at or after index *start* and before index *stop*). Returns the first match or raises *ValueError* if not found.

New in version 3.5.

insert(*i*, *x*)
Insert *x* into the deque at position *i*.

If the insertion would cause a bounded deque to grow beyond *maxlen*, an *IndexError* is raised.

New in version 3.5.

pop()
Remove and return an element from the right side of the deque. If no elements are present, raises an *IndexError*.

popleft()
Remove and return an element from the left side of the deque. If no elements are present, raises an *IndexError*.

remove(*value*)
Remove the first occurrence of *value*. If not found, raises a *ValueError*.

reverse()
Reverse the elements of the deque in-place and then return `None`.

New in version 3.2.

rotate(*n=1*)
Rotate the deque *n* steps to the right. If *n* is negative, rotate to the left.

When the deque is not empty, rotating one step to the right is equivalent to `d.appendleft(d.pop())`, and rotating one step to the left is equivalent to `d.append(d.popleft())`.

Deque objects also provide one read-only attribute:

maxlen
Maximum size of a deque or `None` if unbounded.

New in version 3.1.

In addition to the above, deques support iteration, pickling, `len(d)`, `reversed(d)`, `copy.copy(d)`, `copy.deepcopy(d)`, membership testing with the `in` operator, and subscript references such as `d[-1]`. Indexed access is O(1) at both ends but slows to O(n) in the middle. For fast random access, use lists instead.

Starting in version 3.5, deques support `__add__()`, `__mul__()`, and `__imul__()`.

Example:

```
>>> from collections import deque
>>> d = deque('ghi')                 # make a new deque with three items
>>> for elem in d:                   # iterate over the deque's elements
...     print(elem.upper())
G
H
I

>>> d.append('j')                    # add a new entry to the right side
>>> d.appendleft('f')                # add a new entry to the left side
>>> d                                # show the representation of the deque
deque(['f', 'g', 'h', 'i', 'j'])

>>> d.pop()                          # return and remove the rightmost item
'j'
>>> d.popleft()                      # return and remove the leftmost item
'f'
>>> list(d)                          # list the contents of the deque
```

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```
['g', 'h', 'i']
>>> d[0]                            # peek at leftmost item
'g'
>>> d[-1]                           # peek at rightmost item
'i'

>>> list(reversed(d))               # list the contents of a deque in reverse
['i', 'h', 'g']
>>> 'h' in d                        # search the deque
True
>>> d.extend('jkl')                 # add multiple elements at once
>>> d
deque(['g', 'h', 'i', 'j', 'k', 'l'])
>>> d.rotate(1)                     # right rotation
>>> d
deque(['l', 'g', 'h', 'i', 'j', 'k'])
>>> d.rotate(-1)                    # left rotation
>>> d
deque(['g', 'h', 'i', 'j', 'k', 'l'])

>>> deque(reversed(d))              # make a new deque in reverse order
deque(['l', 'k', 'j', 'i', 'h', 'g'])
>>> d.clear()                       # empty the deque
>>> d.pop()                         # cannot pop from an empty deque
Traceback (most recent call last):
    File "<pyshell#6>", line 1, in -toplevel-
        d.pop()
IndexError: pop from an empty deque

>>> d.extendleft('abc')             # extendleft() reverses the input order
>>> d
deque(['c', 'b', 'a'])
```

deque Recipes

This section shows various approaches to working with deques.

Bounded length deques provide functionality similar to the `tail` filter in Unix:

```
def tail(filename, n=10):
    'Return the last n lines of a file'
    with open(filename) as f:
        return deque(f, n)
```

Another approach to using deques is to maintain a sequence of recently added elements by appending to the right and popping to the left:

```
def moving_average(iterable, n=3):
    # moving_average([40, 30, 50, 46, 39, 44]) --> 40.0 42.0 45.0 43.0
    # http://en.wikipedia.org/wiki/Moving_average
    it = iter(iterable)
    d = deque(itertools.islice(it, n-1))
    d.appendleft(0)
    s = sum(d)
    for elem in it:
        s += elem - d.popleft()
```

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```
        d.append(elem)
        yield s / n
```

A round-robin scheduler can be implemented with input iterators stored in a *deque*. Values are yielded from the active iterator in position zero. If that iterator is exhausted, it can be removed with *popleft()*; otherwise, it can be cycled back to the end with the *rotate()* method:

```
def roundrobin(*iterables):
    "roundrobin('ABC', 'D', 'EF') --> A D E B F C"
    iterators = deque(map(iter, iterables))
    while iterators:
        try:
            while True:
                yield next(iterators[0])
                iterators.rotate(-1)
        except StopIteration:
            # Remove an exhausted iterator.
            iterators.popleft()
```

The *rotate()* method provides a way to implement *deque* slicing and deletion. For example, a pure Python implementation of `del d[n]` relies on the `rotate()` method to position elements to be popped:

```
def delete_nth(d, n):
    d.rotate(-n)
    d.popleft()
    d.rotate(n)
```

To implement *deque* slicing, use a similar approach applying *rotate()* to bring a target element to the left side of the deque. Remove old entries with *popleft()*, add new entries with *extend()*, and then reverse the rotation. With minor variations on that approach, it is easy to implement Forth style stack manipulations such as `dup`, `drop`, `swap`, `over`, `pick`, `rot`, and `roll`.

8.3.4 `defaultdict` objects

class collections.**defaultdict**([*default_factory*[, ...]])

Returns a new dictionary-like object. *defaultdict* is a subclass of the built-in *dict* class. It overrides one method and adds one writable instance variable. The remaining functionality is the same as for the *dict* class and is not documented here.

The first argument provides the initial value for the *default_factory* attribute; it defaults to `None`. All remaining arguments are treated the same as if they were passed to the *dict* constructor, including keyword arguments.

defaultdict objects support the following method in addition to the standard *dict* operations:

__missing__(*key*)

If the *default_factory* attribute is `None`, this raises a *KeyError* exception with the *key* as argument.

If *default_factory* is not `None`, it is called without arguments to provide a default value for the given *key*, this value is inserted in the dictionary for the *key*, and returned.

If calling *default_factory* raises an exception this exception is propagated unchanged.

This method is called by the `__getitem__()` method of the *dict* class when the requested key is not found; whatever it returns or raises is then returned or raised by `__getitem__()`.

Note that *__missing__()* is *not* called for any operations besides `__getitem__()`. This means that `get()` will, like normal dictionaries, return `None` as a default rather than using *default_factory*.

defaultdict objects support the following instance variable:

default_factory
This attribute is used by the *__missing__()* method; it is initialized from the first argument to the constructor, if present, or to `None`, if absent.

defaultdict Examples

Using *list* as the *default_factory*, it is easy to group a sequence of key-value pairs into a dictionary of lists:

```
>>> s = [('yellow', 1), ('blue', 2), ('yellow', 3), ('blue', 4), ('red', 1)]
>>> d = defaultdict(list)
>>> for k, v in s:
...     d[k].append(v)
...
>>> sorted(d.items())
[('blue', [2, 4]), ('red', [1]), ('yellow', [1, 3])]
```

When each key is encountered for the first time, it is not already in the mapping; so an entry is automatically created using the *default_factory* function which returns an empty *list*. The `list.append()` operation then attaches the value to the new list. When keys are encountered again, the look-up proceeds normally (returning the list for that key) and the `list.append()` operation adds another value to the list. This technique is simpler and faster than an equivalent technique using *dict.setdefault()*:

```
>>> d = {}
>>> for k, v in s:
...     d.setdefault(k, []).append(v)
...
>>> sorted(d.items())
[('blue', [2, 4]), ('red', [1]), ('yellow', [1, 3])]
```

Setting the *default_factory* to *int* makes the *defaultdict* useful for counting (like a bag or multiset in other languages):

```
>>> s = 'mississippi'
>>> d = defaultdict(int)
>>> for k in s:
...     d[k] += 1
...
>>> sorted(d.items())
[('i', 4), ('m', 1), ('p', 2), ('s', 4)]
```

When a letter is first encountered, it is missing from the mapping, so the *default_factory* function calls *int()* to supply a default count of zero. The increment operation then builds up the count for each letter.

The function *int()* which always returns zero is just a special case of constant functions. A faster and more flexible way to create constant functions is to use a lambda function which can supply any constant value (not just zero):

```
>>> def constant_factory(value):
...     return lambda: value
>>> d = defaultdict(constant_factory('<missing>'))
```

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```
>>> d.update(name='John', action='ran')
>>> '%(name)s %(action)s to %(object)s' % d
'John ran to <missing>'
```

Setting the *default_factory* to *set* makes the *defaultdict* useful for building a dictionary of sets:

```
>>> s = [('red', 1), ('blue', 2), ('red', 3), ('blue', 4), ('red', 1), ('blue', 4)]
>>> d = defaultdict(set)
>>> for k, v in s:
...     d[k].add(v)
...
>>> sorted(d.items())
[('blue', {2, 4}), ('red', {1, 3})]
```

8.3.5 namedtuple() Factory Function for Tuples with Named Fields

Named tuples assign meaning to each position in a tuple and allow for more readable, self-documenting code. They can be used wherever regular tuples are used, and they add the ability to access fields by name instead of position index.

collections.namedtuple(*typename*, *field_names*, ***, *rename=False*, *defaults=None*, *module=None*)

Returns a new tuple subclass named *typename*. The new subclass is used to create tuple-like objects that have fields accessible by attribute lookup as well as being indexable and iterable. Instances of the subclass also have a helpful docstring (with typename and field_names) and a helpful `__repr__()` method which lists the tuple contents in a `name=value` format.

The *field_names* are a sequence of strings such as `['x', 'y']`. Alternatively, *field_names* can be a single string with each fieldname separated by whitespace and/or commas, for example `'x y'` or `'x, y'`.

Any valid Python identifier may be used for a fieldname except for names starting with an underscore. Valid identifiers consist of letters, digits, and underscores but do not start with a digit or underscore and cannot be a *keyword* such as *class*, *for*, *return*, *global*, *pass*, or *raise*.

If *rename* is true, invalid fieldnames are automatically replaced with positional names. For example, `['abc', 'def', 'ghi', 'abc']` is converted to `['abc', '_1', 'ghi', '_3']`, eliminating the keyword `def` and the duplicate fieldname `abc`.

defaults can be `None` or an *iterable* of default values. Since fields with a default value must come after any fields without a default, the *defaults* are applied to the rightmost parameters. For example, if the fieldnames are `['x', 'y', 'z']` and the defaults are `(1, 2)`, then `x` will be a required argument, `y` will default to `1`, and `z` will default to `2`.

If *module* is defined, the `__module__` attribute of the named tuple is set to that value.

Named tuple instances do not have per-instance dictionaries, so they are lightweight and require no more memory than regular tuples.

Changed in version 3.1: Added support for *rename*.

Changed in version 3.6: The *verbose* and *rename* parameters became *keyword-only arguments*.

Changed in version 3.6: Added the *module* parameter.

Changed in version 3.7: Remove the *verbose* parameter and the `_source` attribute.

Changed in version 3.7: Added the *defaults* parameter and the `_field_defaults` attribute.

```
>>> # Basic example
>>> Point = namedtuple('Point', ['x', 'y'])
>>> p = Point(11, y=22)     # instantiate with positional or keyword arguments
>>> p[0] + p[1]             # indexable like the plain tuple (11, 22)
33
>>> x, y = p                # unpack like a regular tuple
>>> x, y
(11, 22)
>>> p.x + p.y               # fields also accessible by name
33
>>> p                       # readable __repr__ with a name=value style
Point(x=11, y=22)
```

Named tuples are especially useful for assigning field names to result tuples returned by the *csv* or *sqlite3* modules:

```
EmployeeRecord = namedtuple('EmployeeRecord', 'name, age, title, department, paygrade')

import csv
for emp in map(EmployeeRecord._make, csv.reader(open("employees.csv", "rb"))):
    print(emp.name, emp.title)

import sqlite3
conn = sqlite3.connect('/companydata')
cursor = conn.cursor()
cursor.execute('SELECT name, age, title, department, paygrade FROM employees')
for emp in map(EmployeeRecord._make, cursor.fetchall()):
    print(emp.name, emp.title)
```

In addition to the methods inherited from tuples, named tuples support three additional methods and two attributes. To prevent conflicts with field names, the method and attribute names start with an underscore.

classmethod somenamedtuple.**_make**(*iterable*)

Class method that makes a new instance from an existing sequence or iterable.

```
>>> t = [11, 22]
>>> Point._make(t)
Point(x=11, y=22)
```

somenamedtuple.**_asdict**()

Return a new *OrderedDict* which maps field names to their corresponding values:

```
>>> p = Point(x=11, y=22)
>>> p._asdict()
OrderedDict([('x', 11), ('y', 22)])
```

Changed in version 3.1: Returns an *OrderedDict* instead of a regular *dict*.

somenamedtuple.**_replace**(***kwargs*)

Return a new instance of the named tuple replacing specified fields with new values:

```
>>> p = Point(x=11, y=22)
>>> p._replace(x=33)
Point(x=33, y=22)

>>> for partnum, record in inventory.items():
...     inventory[partnum] = record._replace(price=newprices[partnum], timestamp=time.now())
```

somenamedtuple._fields
: Tuple of strings listing the field names. Useful for introspection and for creating new named tuple types from existing named tuples.

```
>>> p._fields            # view the field names
('x', 'y')

>>> Color = namedtuple('Color', 'red green blue')
>>> Pixel = namedtuple('Pixel', Point._fields + Color._fields)
>>> Pixel(11, 22, 128, 255, 0)
Pixel(x=11, y=22, red=128, green=255, blue=0)
```

somenamedtuple._fields_defaults
: Dictionary mapping field names to default values.

```
>>> Account = namedtuple('Account', ['type', 'balance'], defaults=[0])
>>> Account._fields_defaults
{'balance': 0}
>>> Account('premium')
Account(type='premium', balance=0)
```

To retrieve a field whose name is stored in a string, use the *getattr()* function:

```
>>> getattr(p, 'x')
11
```

To convert a dictionary to a named tuple, use the double-star-operator (as described in tut-unpacking-arguments):

```
>>> d = {'x': 11, 'y': 22}
>>> Point(**d)
Point(x=11, y=22)
```

Since a named tuple is a regular Python class, it is easy to add or change functionality with a subclass. Here is how to add a calculated field and a fixed-width print format:

```
>>> class Point(namedtuple('Point', ['x', 'y'])):
...     __slots__ = ()
...     @property
...     def hypot(self):
...         return (self.x ** 2 + self.y ** 2) ** 0.5
...     def __str__(self):
...         return 'Point: x=%6.3f  y=%6.3f  hypot=%6.3f' % (self.x, self.y, self.hypot)

>>> for p in Point(3, 4), Point(14, 5/7):
...     print(p)
Point: x= 3.000  y= 4.000  hypot= 5.000
Point: x=14.000  y= 0.714  hypot=14.018
```

The subclass shown above sets `__slots__` to an empty tuple. This helps keep memory requirements low by preventing the creation of instance dictionaries.

Subclassing is not useful for adding new, stored fields. Instead, simply create a new named tuple type from the *_fields* attribute:

```
>>> Point3D = namedtuple('Point3D', Point._fields + ('z',))
```

Docstrings can be customized by making direct assignments to the `__doc__` fields:

```
>>> Book = namedtuple('Book', ['id', 'title', 'authors'])
>>> Book.__doc__ += ': Hardcover book in active collection'
>>> Book.id.__doc__ = '13-digit ISBN'
>>> Book.title.__doc__ = 'Title of first printing'
>>> Book.authors.__doc__ = 'List of authors sorted by last name'
```

Changed in version 3.5: Property docstrings became writeable.

Default values can be implemented by using *_replace()* to customize a prototype instance:

```
>>> Account = namedtuple('Account', 'owner balance transaction_count')
>>> default_account = Account('<owner name>', 0.0, 0)
>>> johns_account = default_account._replace(owner='John')
>>> janes_account = default_account._replace(owner='Jane')
```

See also:

- Recipe for named tuple abstract base class with a metaclass mix-in by Jan Kaliszewski. Besides providing an *abstract base class* for named tuples, it also supports an alternate *metaclass*-based constructor that is convenient for use cases where named tuples are being subclassed.
- See *types.SimpleNamespace()* for a mutable namespace based on an underlying dictionary instead of a tuple.
- See *typing.NamedTuple()* for a way to add type hints for named tuples.

8.3.6 `OrderedDict` objects

Ordered dictionaries are just like regular dictionaries but they remember the order that items were inserted. When iterating over an ordered dictionary, the items are returned in the order their keys were first added.

class collections.**OrderedDict**([*items*])

Return an instance of a dict subclass, supporting the usual *dict* methods. An *OrderedDict* is a dict that remembers the order that keys were first inserted. If a new entry overwrites an existing entry, the original insertion position is left unchanged. Deleting an entry and reinserting it will move it to the end.

New in version 3.1.

popitem(*last=True*)

The *popitem()* method for ordered dictionaries returns and removes a (key, value) pair. The pairs are returned in LIFO (last-in, first-out) order if *last* is true or FIFO (first-in, first-out) order if false.

move_to_end(*key*, *last=True*)

Move an existing *key* to either end of an ordered dictionary. The item is moved to the right end if *last* is true (the default) or to the beginning if *last* is false. Raises *KeyError* if the *key* does not exist:

```
>>> d = OrderedDict.fromkeys('abcde')
>>> d.move_to_end('b')
>>> ''.join(d.keys())
'acdeb'
>>> d.move_to_end('b', last=False)
>>> ''.join(d.keys())
'bacde'
```

New in version 3.2.

In addition to the usual mapping methods, ordered dictionaries also support reverse iteration using *reversed()*.

Equality tests between *OrderedDict* objects are order-sensitive and are implemented as `list(od1.items())==list(od2.items())`. Equality tests between *OrderedDict* objects and other *Mapping* objects are order-insensitive like regular dictionaries. This allows *OrderedDict* objects to be substituted anywhere a regular dictionary is used.

Changed in version 3.5: The items, keys, and values *views* of *OrderedDict* now support reverse iteration using *reversed()*.

Changed in version 3.6: With the acceptance of **PEP 468**, order is retained for keyword arguments passed to the *OrderedDict* constructor and its `update()` method.

`OrderedDict` Examples and Recipes

Since an ordered dictionary remembers its insertion order, it can be used in conjunction with sorting to make a sorted dictionary:

```
>>> # regular unsorted dictionary
>>> d = {'banana': 3, 'apple': 4, 'pear': 1, 'orange': 2}

>>> # dictionary sorted by key
>>> OrderedDict(sorted(d.items(), key=lambda t: t[0]))
OrderedDict([('apple', 4), ('banana', 3), ('orange', 2), ('pear', 1)])

>>> # dictionary sorted by value
>>> OrderedDict(sorted(d.items(), key=lambda t: t[1]))
OrderedDict([('pear', 1), ('orange', 2), ('banana', 3), ('apple', 4)])

>>> # dictionary sorted by length of the key string
>>> OrderedDict(sorted(d.items(), key=lambda t: len(t[0])))
OrderedDict([('pear', 1), ('apple', 4), ('orange', 2), ('banana', 3)])
```

The new sorted dictionaries maintain their sort order when entries are deleted. But when new keys are added, the keys are appended to the end and the sort is not maintained.

It is also straight-forward to create an ordered dictionary variant that remembers the order the keys were *last* inserted. If a new entry overwrites an existing entry, the original insertion position is changed and moved to the end:

```
class LastUpdatedOrderedDict(OrderedDict):
    'Store items in the order the keys were last added'

    def __setitem__(self, key, value):
        if key in self:
            del self[key]
        OrderedDict.__setitem__(self, key, value)
```

An ordered dictionary can be combined with the *Counter* class so that the counter remembers the order elements are first encountered:

```
class OrderedCounter(Counter, OrderedDict):
    'Counter that remembers the order elements are first encountered'

    def __repr__(self):
        return '%s(%r)' % (self.__class__.__name__, OrderedDict(self))
```

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```
    def __reduce__(self):
        return self.__class__, (OrderedDict(self),)
```

8.3.7 UserDict objects

The class, *UserDict* acts as a wrapper around dictionary objects. The need for this class has been partially supplanted by the ability to subclass directly from *dict*; however, this class can be easier to work with because the underlying dictionary is accessible as an attribute.

class collections.**UserDict**([*initialdata*])

Class that simulates a dictionary. The instance's contents are kept in a regular dictionary, which is accessible via the *data* attribute of *UserDict* instances. If *initialdata* is provided, *data* is initialized with its contents; note that a reference to *initialdata* will not be kept, allowing it be used for other purposes.

In addition to supporting the methods and operations of mappings, *UserDict* instances provide the following attribute:

data

A real dictionary used to store the contents of the *UserDict* class.

8.3.8 UserList objects

This class acts as a wrapper around list objects. It is a useful base class for your own list-like classes which can inherit from them and override existing methods or add new ones. In this way, one can add new behaviors to lists.

The need for this class has been partially supplanted by the ability to subclass directly from *list*; however, this class can be easier to work with because the underlying list is accessible as an attribute.

class collections.**UserList**([*list*])

Class that simulates a list. The instance's contents are kept in a regular list, which is accessible via the *data* attribute of *UserList* instances. The instance's contents are initially set to a copy of *list*, defaulting to the empty list `[]`. *list* can be any iterable, for example a real Python list or a *UserList* object.

In addition to supporting the methods and operations of mutable sequences, *UserList* instances provide the following attribute:

data

A real *list* object used to store the contents of the *UserList* class.

Subclassing requirements: Subclasses of *UserList* are expected to offer a constructor which can be called with either no arguments or one argument. List operations which return a new sequence attempt to create an instance of the actual implementation class. To do so, it assumes that the constructor can be called with a single parameter, which is a sequence object used as a data source.

If a derived class does not wish to comply with this requirement, all of the special methods supported by this class will need to be overridden; please consult the sources for information about the methods which need to be provided in that case.

8.3.9 UserString objects

The class, *UserString* acts as a wrapper around string objects. The need for this class has been partially supplanted by the ability to subclass directly from *str*; however, this class can be easier to work with because

the underlying string is accessible as an attribute.

class collections.**UserString**(*seq*)

Class that simulates a string object. The instance's content is kept in a regular string object, which is accessible via the *data* attribute of *UserString* instances. The instance's contents are initially set to a copy of *seq*. The *seq* argument can be any object which can be converted into a string using the built-in *str()* function.

In addition to supporting the methods and operations of strings, *UserString* instances provide the following attribute:

data

A real *str* object used to store the contents of the *UserString* class.

Changed in version 3.5: New methods `__getnewargs__`, `__rmod__`, `casefold`, `format_map`, `isprintable`, and `maketrans`.

8.4 collections.abc — Abstract Base Classes for Containers

New in version 3.3: Formerly, this module was part of the *collections* module.

Source code: Lib/_collections_abc.py

This module provides *abstract base classes* that can be used to test whether a class provides a particular interface; for example, whether it is hashable or whether it is a mapping.

8.4.1 Collections Abstract Base Classes

The collections module offers the following *ABCs*:

ABC	Inherits from	Abstract Methods	Mixin Methods
Container		`__contains__`	
Hashable		`__hash__`	
Iterable		`__iter__`	
Iterator	*Iterable*	`__next__`	`__iter__`
Reversible	*Iterable*	`__reversed__`	
Generator	*Iterator*	`send`, `throw`	`close`, `__iter__`, `__next__`
Sized		`__len__`	
Callable		`__call__`	
Collection	*Sized*, *Iterable*, *Container*	`__contains__`, `__iter__`, `__len__`	
Sequence	*Reversible*, *Collection*	`__getitem__`, `__len__`	`__contains__`, `__iter__`, `__reversed__`, `index`, and `count`
MutableSequence	*Sequence*	`__getitem__`, `__setitem__`, `__delitem__`, `__len__`, `insert`	Inherited *Sequence* methods and `append`, `reverse`, `extend`, `pop`, `remove`, and `__iadd__`
ByteString	*Sequence*	`__getitem__`, `__len__`	Inherited *Sequence* methods
Set	*Collection*	`__contains__`, `__iter__`, `__len__`	`__le__`, `__lt__`, `__eq__`, `__ne__`, `__gt__`, `__ge__`, `__and__`, `__or__`, `__sub__`, `__xor__`, and `isdisjoint`
MutableSet	*Set*	`__contains__`, `__iter__`, `__len__`, `add`, `discard`	Inherited *Set* methods and `clear`, `pop`, `remove`, `__ior__`, `__iand__`, `__ixor__`, and `__isub__`
Mapping	*Collection*	`__getitem__`, `__iter__`, `__len__`	`__contains__`, `keys`, `items`, `values`, `get`, `__eq__`, and `__ne__`
MutableMapping	*Mapping*	`__getitem__`, `__setitem__`, `__delitem__`, `__iter__`, `__len__`	Inherited *Mapping* methods and `pop`, `popitem`, `clear`, `update`, and `setdefault`
MappingView	*Sized*		`__len__`
ItemsView	*MappingView*, *Set*		`__contains__`, `__iter__`
KeysView	*MappingView*, *Set*		`__contains__`, `__iter__`
ValuesView	*MappingView*, *Collection*		`__contains__`, `__iter__`
Awaitable		`__await__`	
Coroutine	*Awaitable*	`send`, `throw`	`close`
AsyncIterable		`__aiter__`	
AsyncIterator	*AsyncIterable*	`__anext__`	`__aiter__`
AsyncGenerator	*AsyncIterator*	`asend`, `athrow`	`aclose`, `__aiter__`, `__anext__`

class collections.abc.**Container**
class collections.abc.**Hashable**
class collections.abc.**Sized**
class collections.abc.**Callable**

ABCs for classes that provide respectively the methods `__contains__()`, `__hash__()`, `__len__()`, and `__call__()`.

class collections.abc.**Iterable**

ABC for classes that provide the `__iter__()` method.

Checking `isinstance(obj, Iterable)` detects classes that are registered as *Iterable* or that have an `__iter__()` method, but it does not detect classes that iterate with the `__getitem__()` method. The only reliable way to determine whether an object is *iterable* is to call `iter(obj)`.

class collections.abc.Collection
ABC for sized iterable container classes.

New in version 3.6.

class collections.abc.Iterator
ABC for classes that provide the *__iter__()* and *__next__()* methods. See also the definition of *iterator*.

class collections.abc.Reversible
ABC for iterable classes that also provide the `__reversed__()` method.

New in version 3.6.

class collections.abc.Generator
ABC for generator classes that implement the protocol defined in **PEP 342** that extends iterators with the `send()`, `throw()` and `close()` methods. See also the definition of *generator*.

New in version 3.5.

class collections.abc.Sequence
class collections.abc.MutableSequence
class collections.abc.ByteString
ABCs for read-only and mutable *sequences*.

Implementation note: Some of the mixin methods, such as `__iter__()`, `__reversed__()` and `index()`, make repeated calls to the underlying `__getitem__()` method. Consequently, if `__getitem__()` is implemented with constant access speed, the mixin methods will have linear performance; however, if the underlying method is linear (as it would be with a linked list), the mixins will have quadratic performance and will likely need to be overridden.

Changed in version 3.5: The index() method added support for *stop* and *start* arguments.

class collections.abc.Set
class collections.abc.MutableSet
ABCs for read-only and mutable sets.

class collections.abc.Mapping
class collections.abc.MutableMapping
ABCs for read-only and mutable *mappings*.

class collections.abc.MappingView
class collections.abc.ItemsView
class collections.abc.KeysView
class collections.abc.ValuesView
ABCs for mapping, items, keys, and values *views*.

class collections.abc.Awaitable
ABC for *awaitable* objects, which can be used in `await` expressions. Custom implementations must provide the `__await__()` method.

Coroutine objects and instances of the *Coroutine* ABC are all instances of this ABC.

Note: In CPython, generator-based coroutines (generators decorated with *types.coroutine()* or *asyncio.coroutine()*) are *awaitables*, even though they do not have an `__await__()` method. Using

`isinstance(gencoro, Awaitable)` for them will return `False`. Use *inspect.isawaitable()* to detect them.

New in version 3.5.

class collections.abc.**Coroutine**
ABC for coroutine compatible classes. These implement the following methods, defined in coroutine-objects: `send()`, `throw()`, and `close()`. Custom implementations must also implement `__await__()`. All *Coroutine* instances are also instances of *Awaitable*. See also the definition of *coroutine*.

Note: In CPython, generator-based coroutines (generators decorated with *types.coroutine()* or *asyncio.coroutine()*) are *awaitables*, even though they do not have an `__await__()` method. Using `isinstance(gencoro, Coroutine)` for them will return `False`. Use *inspect.isawaitable()* to detect them.

New in version 3.5.

class collections.abc.**AsyncIterable**
ABC for classes that provide `__aiter__` method. See also the definition of *asynchronous iterable*.

New in version 3.5.

class collections.abc.**AsyncIterator**
ABC for classes that provide `__aiter__` and `__anext__` methods. See also the definition of *asynchronous iterator*.

New in version 3.5.

class collections.abc.**AsyncGenerator**
ABC for asynchronous generator classes that implement the protocol defined in **PEP 525** and **PEP 492**.

New in version 3.6.

These ABCs allow us to ask classes or instances if they provide particular functionality, for example:

```
size = None
if isinstance(myvar, collections.abc.Sized):
    size = len(myvar)
```

Several of the ABCs are also useful as mixins that make it easier to develop classes supporting container APIs. For example, to write a class supporting the full *Set* API, it is only necessary to supply the three underlying abstract methods: `__contains__()`, `__iter__()`, and `__len__()`. The ABC supplies the remaining methods such as `__and__()` and `isdisjoint()`:

```
class ListBasedSet(collections.abc.Set):
    ''' Alternate set implementation favoring space over speed
        and not requiring the set elements to be hashable. '''
    def __init__(self, iterable):
        self.elements = lst = []
        for value in iterable:
            if value not in lst:
                lst.append(value)

    def __iter__(self):
        return iter(self.elements)

    def __contains__(self, value):
```

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```
        return value in self.elements

    def __len__(self):
        return len(self.elements)

s1 = ListBasedSet('abcdef')
s2 = ListBasedSet('defghi')
overlap = s1 & s2            # The __and__() method is supported automatically
```

Notes on using *Set* and *MutableSet* as a mixin:

1. Since some set operations create new sets, the default mixin methods need a way to create new instances from an iterable. The class constructor is assumed to have a signature in the form `ClassName(iterable)`. That assumption is factored-out to an internal classmethod called `_from_iterable()` which calls `cls(iterable)` to produce a new set. If the *Set* mixin is being used in a class with a different constructor signature, you will need to override `_from_iterable()` with a classmethod that can construct new instances from an iterable argument.
2. To override the comparisons (presumably for speed, as the semantics are fixed), redefine `__le__()` and `__ge__()`, then the other operations will automatically follow suit.
3. The *Set* mixin provides a `_hash()` method to compute a hash value for the set; however, `__hash__()` is not defined because not all sets are hashable or immutable. To add set hashability using mixins, inherit from both *Set()* and *Hashable()*, then define `__hash__ = Set._hash`.

See also:

- OrderedSet recipe for an example built on *MutableSet*.
- For more about ABCs, see the *abc* module and **PEP 3119**.

8.5 heapq — Heap queue algorithm

Source code: Lib/heapq.py

This module provides an implementation of the heap queue algorithm, also known as the priority queue algorithm.

Heaps are binary trees for which every parent node has a value less than or equal to any of its children. This implementation uses arrays for which `heap[k] <= heap[2*k+1]` and `heap[k] <= heap[2*k+2]` for all *k*, counting elements from zero. For the sake of comparison, non-existing elements are considered to be infinite. The interesting property of a heap is that its smallest element is always the root, `heap[0]`.

The API below differs from textbook heap algorithms in two aspects: (a) We use zero-based indexing. This makes the relationship between the index for a node and the indexes for its children slightly less obvious, but is more suitable since Python uses zero-based indexing. (b) Our pop method returns the smallest item, not the largest (called a "min heap" in textbooks; a "max heap" is more common in texts because of its suitability for in-place sorting).

These two make it possible to view the heap as a regular Python list without surprises: `heap[0]` is the smallest item, and `heap.sort()` maintains the heap invariant!

To create a heap, use a list initialized to `[]`, or you can transform a populated list into a heap via function *heapify()*.

The following functions are provided:

heapq.**heappush**(*heap*, *item*)
Push the value *item* onto the *heap*, maintaining the heap invariant.

heapq.**heappop**(*heap*)
Pop and return the smallest item from the *heap*, maintaining the heap invariant. If the heap is empty, *IndexError* is raised. To access the smallest item without popping it, use `heap[0]`.

heapq.**heappushpop**(*heap*, *item*)
Push *item* on the heap, then pop and return the smallest item from the *heap*. The combined action runs more efficiently than *heappush()* followed by a separate call to *heappop()*.

heapq.**heapify**(*x*)
Transform list *x* into a heap, in-place, in linear time.

heapq.**heapreplace**(*heap*, *item*)
Pop and return the smallest item from the *heap*, and also push the new *item*. The heap size doesn't change. If the heap is empty, *IndexError* is raised.

This one step operation is more efficient than a *heappop()* followed by *heappush()* and can be more appropriate when using a fixed-size heap. The pop/push combination always returns an element from the heap and replaces it with *item*.

The value returned may be larger than the *item* added. If that isn't desired, consider using *heappushpop()* instead. Its push/pop combination returns the smaller of the two values, leaving the larger value on the heap.

The module also offers three general purpose functions based on heaps.

heapq.**merge**(**iterables*, *key=None*, *reverse=False*)
Merge multiple sorted inputs into a single sorted output (for example, merge timestamped entries from multiple log files). Returns an *iterator* over the sorted values.

Similar to `sorted(itertools.chain(*iterables))` but returns an iterable, does not pull the data into memory all at once, and assumes that each of the input streams is already sorted (smallest to largest).

Has two optional arguments which must be specified as keyword arguments.

key specifies a *key function* of one argument that is used to extract a comparison key from each input element. The default value is `None` (compare the elements directly).

reverse is a boolean value. If set to `True`, then the input elements are merged as if each comparison were reversed. To achieve behavior similar to `sorted(itertools.chain(*iterables), reverse=True)`, all iterables must be sorted from largest to smallest.

Changed in version 3.5: Added the optional *key* and *reverse* parameters.

heapq.**nlargest**(*n*, *iterable*, *key=None*)
Return a list with the *n* largest elements from the dataset defined by *iterable*. *key*, if provided, specifies a function of one argument that is used to extract a comparison key from each element in the iterable: `key=str.lower` Equivalent to: `sorted(iterable, key=key, reverse=True)[:n]`

heapq.**nsmallest**(*n*, *iterable*, *key=None*)
Return a list with the *n* smallest elements from the dataset defined by *iterable*. *key*, if provided, specifies a function of one argument that is used to extract a comparison key from each element in the iterable: `key=str.lower` Equivalent to: `sorted(iterable, key=key)[:n]`

The latter two functions perform best for smaller values of *n*. For larger values, it is more efficient to use the *sorted()* function. Also, when `n==1`, it is more efficient to use the built-in *min()* and *max()* functions. If repeated usage of these functions is required, consider turning the iterable into an actual heap.

8.5.1 Basic Examples

A heapsort can be implemented by pushing all values onto a heap and then popping off the smallest values one at a time:

```
>>> def heapsort(iterable):
...     h = []
...     for value in iterable:
...         heappush(h, value)
...     return [heappop(h) for i in range(len(h))]
...
>>> heapsort([1, 3, 5, 7, 9, 2, 4, 6, 8, 0])
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

This is similar to `sorted(iterable)`, but unlike *sorted()*, this implementation is not stable.

Heap elements can be tuples. This is useful for assigning comparison values (such as task priorities) alongside the main record being tracked:

```
>>> h = []
>>> heappush(h, (5, 'write code'))
>>> heappush(h, (7, 'release product'))
>>> heappush(h, (1, 'write spec'))
>>> heappush(h, (3, 'create tests'))
>>> heappop(h)
(1, 'write spec')
```

8.5.2 Priority Queue Implementation Notes

A priority queue is common use for a heap, and it presents several implementation challenges:

- Sort stability: how do you get two tasks with equal priorities to be returned in the order they were originally added?
- Tuple comparison breaks for (priority, task) pairs if the priorities are equal and the tasks do not have a default comparison order.
- If the priority of a task changes, how do you move it to a new position in the heap?
- Or if a pending task needs to be deleted, how do you find it and remove it from the queue?

A solution to the first two challenges is to store entries as 3-element list including the priority, an entry count, and the task. The entry count serves as a tie-breaker so that two tasks with the same priority are returned in the order they were added. And since no two entry counts are the same, the tuple comparison will never attempt to directly compare two tasks.

Another solution to the problem of non-comparable tasks is to create a wrapper class that ignores the task item and only compares the priority field:

```
from dataclasses import dataclass, field
from typing import Any

@dataclass(order=True)
class PrioritizedItem:
    priority: int
    item: Any=field(compare=False)
```

The remaining challenges revolve around finding a pending task and making changes to its priority or removing it entirely. Finding a task can be done with a dictionary pointing to an entry in the queue.

Removing the entry or changing its priority is more difficult because it would break the heap structure invariants. So, a possible solution is to mark the entry as removed and add a new entry with the revised priority:

```
pq = []                         # list of entries arranged in a heap
entry_finder = {}               # mapping of tasks to entries
REMOVED = '<removed-task>'      # placeholder for a removed task
counter = itertools.count()     # unique sequence count

def add_task(task, priority=0):
    'Add a new task or update the priority of an existing task'
    if task in entry_finder:
        remove_task(task)
    count = next(counter)
    entry = [priority, count, task]
    entry_finder[task] = entry
    heappush(pq, entry)

def remove_task(task):
    'Mark an existing task as REMOVED.  Raise KeyError if not found.'
    entry = entry_finder.pop(task)
    entry[-1] = REMOVED

def pop_task():
    'Remove and return the lowest priority task. Raise KeyError if empty.'
    while pq:
        priority, count, task = heappop(pq)
        if task is not REMOVED:
            del entry_finder[task]
            return task
    raise KeyError('pop from an empty priority queue')
```

8.5.3 Theory

Heaps are arrays for which `a[k] <= a[2*k+1]` and `a[k] <= a[2*k+2]` for all k, counting elements from 0. For the sake of comparison, non-existing elements are considered to be infinite. The interesting property of a heap is that `a[0]` is always its smallest element.

The strange invariant above is meant to be an efficient memory representation for a tournament. The numbers below are k, not `a[k]`:

```
                               0

              1                                 2

      3               4                5               6

  7       8       9       10      11      12      13      14

15 16   17 18   19 20   21 22   23 24   25 26   27 28   29 30
```

In the tree above, each cell k is topping `2*k+1` and `2*k+2`. In a usual binary tournament we see in sports, each cell is the winner over the two cells it tops, and we can trace the winner down the tree to see all opponents s/he had. However, in many computer applications of such tournaments, we do not need to trace the history of a winner. To be more memory efficient, when a winner is promoted, we try to replace it by something else at a lower level, and the rule becomes that a cell and the two cells it tops contain three different items, but the top cell "wins" over the two topped cells.

If this heap invariant is protected at all time, index 0 is clearly the overall winner. The simplest algorithmic way to remove it and find the "next" winner is to move some loser (let's say cell 30 in the diagram above) into the 0 position, and then percolate this new 0 down the tree, exchanging values, until the invariant is re-established. This is clearly logarithmic on the total number of items in the tree. By iterating over all items, you get an O(n log n) sort.

A nice feature of this sort is that you can efficiently insert new items while the sort is going on, provided that the inserted items are not "better" than the last 0'th element you extracted. This is especially useful in simulation contexts, where the tree holds all incoming events, and the "win" condition means the smallest scheduled time. When an event schedules other events for execution, they are scheduled into the future, so they can easily go into the heap. So, a heap is a good structure for implementing schedulers (this is what I used for my MIDI sequencer :-).

Various structures for implementing schedulers have been extensively studied, and heaps are good for this, as they are reasonably speedy, the speed is almost constant, and the worst case is not much different than the average case. However, there are other representations which are more efficient overall, yet the worst cases might be terrible.

Heaps are also very useful in big disk sorts. You most probably all know that a big sort implies producing "runs" (which are pre-sorted sequences, whose size is usually related to the amount of CPU memory), followed by a merging passes for these runs, which merging is often very cleverly organised[1]. It is very important that the initial sort produces the longest runs possible. Tournaments are a good way to achieve that. If, using all the memory available to hold a tournament, you replace and percolate items that happen to fit the current run, you'll produce runs which are twice the size of the memory for random input, and much better for input fuzzily ordered.

Moreover, if you output the 0'th item on disk and get an input which may not fit in the current tournament (because the value "wins" over the last output value), it cannot fit in the heap, so the size of the heap decreases. The freed memory could be cleverly reused immediately for progressively building a second heap, which grows at exactly the same rate the first heap is melting. When the first heap completely vanishes, you switch heaps and start a new run. Clever and quite effective!

In a word, heaps are useful memory structures to know. I use them in a few applications, and I think it is good to keep a 'heap' module around. :-)

8.6 `bisect` — Array bisection algorithm

Source code: Lib/bisect.py

This module provides support for maintaining a list in sorted order without having to sort the list after each insertion. For long lists of items with expensive comparison operations, this can be an improvement over the more common approach. The module is called *bisect* because it uses a basic bisection algorithm to do its work. The source code may be most useful as a working example of the algorithm (the boundary conditions are already right!).

The following functions are provided:

bisect.bisect_left(*a*, *x*, *lo=0*, *hi=len(a)*)

Locate the insertion point for *x* in *a* to maintain sorted order. The parameters *lo* and *hi* may be used to specify a subset of the list which should be considered; by default the entire list is used. If *x* is

[1] The disk balancing algorithms which are current, nowadays, are more annoying than clever, and this is a consequence of the seeking capabilities of the disks. On devices which cannot seek, like big tape drives, the story was quite different, and one had to be very clever to ensure (far in advance) that each tape movement will be the most effective possible (that is, will best participate at "progressing" the merge). Some tapes were even able to read backwards, and this was also used to avoid the rewinding time. Believe me, real good tape sorts were quite spectacular to watch! From all times, sorting has always been a Great Art! :-)

already present in *a*, the insertion point will be before (to the left of) any existing entries. The return value is suitable for use as the first parameter to `list.insert()` assuming that *a* is already sorted.

The returned insertion point *i* partitions the array *a* into two halves so that `all(val < x for val in a[lo:i])` for the left side and `all(val >= x for val in a[i:hi])` for the right side.

`bisect.bisect_right`(*a*, *x*, *lo=0*, *hi=len(a)*)
`bisect.bisect`(*a*, *x*, *lo=0*, *hi=len(a)*)

Similar to *bisect_left()*, but returns an insertion point which comes after (to the right of) any existing entries of *x* in *a*.

The returned insertion point *i* partitions the array *a* into two halves so that `all(val <= x for val in a[lo:i])` for the left side and `all(val > x for val in a[i:hi])` for the right side.

`bisect.insort_left`(*a*, *x*, *lo=0*, *hi=len(a)*)

Insert *x* in *a* in sorted order. This is equivalent to `a.insert(bisect.bisect_left(a, x, lo, hi), x)` assuming that *a* is already sorted. Keep in mind that the O(log n) search is dominated by the slow O(n) insertion step.

`bisect.insort_right`(*a*, *x*, *lo=0*, *hi=len(a)*)
`bisect.insort`(*a*, *x*, *lo=0*, *hi=len(a)*)

Similar to *insort_left()*, but inserting *x* in *a* after any existing entries of *x*.

See also:

SortedCollection recipe that uses bisect to build a full-featured collection class with straight-forward search methods and support for a key-function. The keys are precomputed to save unnecessary calls to the key function during searches.

8.6.1 Searching Sorted Lists

The above *bisect()* functions are useful for finding insertion points but can be tricky or awkward to use for common searching tasks. The following five functions show how to transform them into the standard lookups for sorted lists:

```
def index(a, x):
    'Locate the leftmost value exactly equal to x'
    i = bisect_left(a, x)
    if i != len(a) and a[i] == x:
        return i
    raise ValueError

def find_lt(a, x):
    'Find rightmost value less than x'
    i = bisect_left(a, x)
    if i:
        return a[i-1]
    raise ValueError

def find_le(a, x):
    'Find rightmost value less than or equal to x'
    i = bisect_right(a, x)
    if i:
        return a[i-1]
    raise ValueError

def find_gt(a, x):
    'Find leftmost value greater than x'
    i = bisect_right(a, x)
```

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```
    if i != len(a):
        return a[i]
    raise ValueError

def find_ge(a, x):
    'Find leftmost item greater than or equal to x'
    i = bisect_left(a, x)
    if i != len(a):
        return a[i]
    raise ValueError
```

8.6.2 Other Examples

The *bisect()* function can be useful for numeric table lookups. This example uses *bisect()* to look up a letter grade for an exam score (say) based on a set of ordered numeric breakpoints: 90 and up is an 'A', 80 to 89 is a 'B', and so on:

```
>>> def grade(score, breakpoints=[60, 70, 80, 90], grades='FDCBA'):
...     i = bisect(breakpoints, score)
...     return grades[i]
...
>>> [grade(score) for score in [33, 99, 77, 70, 89, 90, 100]]
['F', 'A', 'C', 'C', 'B', 'A', 'A']
```

Unlike the *sorted()* function, it does not make sense for the *bisect()* functions to have *key* or *reversed* arguments because that would lead to an inefficient design (successive calls to bisect functions would not "remember" all of the previous key lookups).

Instead, it is better to search a list of precomputed keys to find the index of the record in question:

```
>>> data = [('red', 5), ('blue', 1), ('yellow', 8), ('black', 0)]
>>> data.sort(key=lambda r: r[1])
>>> keys = [r[1] for r in data]         # precomputed list of keys
>>> data[bisect_left(keys, 0)]
('black', 0)
>>> data[bisect_left(keys, 1)]
('blue', 1)
>>> data[bisect_left(keys, 5)]
('red', 5)
>>> data[bisect_left(keys, 8)]
('yellow', 8)
```

8.7 `array` — Efficient arrays of numeric values

This module defines an object type which can compactly represent an array of basic values: characters, integers, floating point numbers. Arrays are sequence types and behave very much like lists, except that the type of objects stored in them is constrained. The type is specified at object creation time by using a *type code*, which is a single character. The following type codes are defined:

Type code	C Type	Python Type	Minimum size in bytes	Notes
'b'	signed char	int	1	
'B'	unsigned char	int	1	
'u'	Py_UNICODE	Unicode character	2	(1)
'h'	signed short	int	2	
'H'	unsigned short	int	2	
'i'	signed int	int	2	
'I'	unsigned int	int	2	
'l'	signed long	int	4	
'L'	unsigned long	int	4	
'q'	signed long long	int	8	(2)
'Q'	unsigned long long	int	8	(2)
'f'	float	float	4	
'd'	double	float	8	

Notes:

1. The 'u' type code corresponds to Python's obsolete unicode character (Py_UNICODE which is wchar_t). Depending on the platform, it can be 16 bits or 32 bits.

   'u' will be removed together with the rest of the Py_UNICODE API.

   Deprecated since version 3.3, will be removed in version 4.0.

2. The 'q' and 'Q' type codes are available only if the platform C compiler used to build Python supports C long long, or, on Windows, __int64.

   New in version 3.3.

The actual representation of values is determined by the machine architecture (strictly speaking, by the C implementation). The actual size can be accessed through the itemsize attribute.

The module defines the following type:

class array.array(*typecode*[, *initializer*])
A new array whose items are restricted by *typecode*, and initialized from the optional *initializer* value, which must be a list, a *bytes-like object*, or iterable over elements of the appropriate type.

If given a list or string, the initializer is passed to the new array's *fromlist()*, *frombytes()*, or *fromunicode()* method (see below) to add initial items to the array. Otherwise, the iterable initializer is passed to the *extend()* method.

array.typecodes
A string with all available type codes.

Array objects support the ordinary sequence operations of indexing, slicing, concatenation, and multiplication. When using slice assignment, the assigned value must be an array object with the same type code; in all other cases, *TypeError* is raised. Array objects also implement the buffer interface, and may be used wherever *bytes-like objects* are supported.

The following data items and methods are also supported:

array.typecode
The typecode character used to create the array.

array.itemsize
The length in bytes of one array item in the internal representation.

array.append(*x*)
Append a new item with value *x* to the end of the array.

`array.buffer_info()`
Return a tuple `(address, length)` giving the current memory address and the length in elements of the buffer used to hold array's contents. The size of the memory buffer in bytes can be computed as `array.buffer_info()[1] * array.itemsize`. This is occasionally useful when working with low-level (and inherently unsafe) I/O interfaces that require memory addresses, such as certain `ioctl()` operations. The returned numbers are valid as long as the array exists and no length-changing operations are applied to it.

Note: When using array objects from code written in C or C++ (the only way to effectively make use of this information), it makes more sense to use the buffer interface supported by array objects. This method is maintained for backward compatibility and should be avoided in new code. The buffer interface is documented in bufferobjects.

`array.byteswap()`
"Byteswap" all items of the array. This is only supported for values which are 1, 2, 4, or 8 bytes in size; for other types of values, *RuntimeError* is raised. It is useful when reading data from a file written on a machine with a different byte order.

`array.count(`*x*`)`
Return the number of occurrences of *x* in the array.

`array.extend(`*iterable*`)`
Append items from *iterable* to the end of the array. If *iterable* is another array, it must have *exactly* the same type code; if not, *TypeError* will be raised. If *iterable* is not an array, it must be iterable and its elements must be the right type to be appended to the array.

`array.frombytes(`*s*`)`
Appends items from the string, interpreting the string as an array of machine values (as if it had been read from a file using the *fromfile()* method).

New in version 3.2: *fromstring()* is renamed to *frombytes()* for clarity.

`array.fromfile(`*f*, *n*`)`
Read *n* items (as machine values) from the *file object* *f* and append them to the end of the array. If less than *n* items are available, *EOFError* is raised, but the items that were available are still inserted into the array. *f* must be a real built-in file object; something else with a `read()` method won't do.

`array.fromlist(`*list*`)`
Append items from the list. This is equivalent to `for x in list: a.append(x)` except that if there is a type error, the array is unchanged.

`array.fromstring()`
Deprecated alias for *frombytes()*.

`array.fromunicode(`*s*`)`
Extends this array with data from the given unicode string. The array must be a type `'u'` array; otherwise a *ValueError* is raised. Use `array.frombytes(unicodestring.encode(enc))` to append Unicode data to an array of some other type.

`array.index(`*x*`)`
Return the smallest *i* such that *i* is the index of the first occurrence of *x* in the array.

`array.insert(`*i*, *x*`)`
Insert a new item with value *x* in the array before position *i*. Negative values are treated as being relative to the end of the array.

`array.pop(`$\left[i\right]$`)`
Removes the item with the index *i* from the array and returns it. The optional argument defaults to `-1`, so that by default the last item is removed and returned.

`array.remove(x)`
Remove the first occurrence of x from the array.

`array.reverse()`
Reverse the order of the items in the array.

`array.tobytes()`
Convert the array to an array of machine values and return the bytes representation (the same sequence of bytes that would be written to a file by the *tofile()* method.)

New in version 3.2: *tostring()* is renamed to *tobytes()* for clarity.

`array.tofile(f)`
Write all items (as machine values) to the *file object* *f*.

`array.tolist()`
Convert the array to an ordinary list with the same items.

`array.tostring()`
Deprecated alias for *tobytes()*.

`array.tounicode()`
Convert the array to a unicode string. The array must be a type `'u'` array; otherwise a *ValueError* is raised. Use `array.tobytes().decode(enc)` to obtain a unicode string from an array of some other type.

When an array object is printed or converted to a string, it is represented as `array(typecode, initializer)`. The *initializer* is omitted if the array is empty, otherwise it is a string if the *typecode* is `'u'`, otherwise it is a list of numbers. The string is guaranteed to be able to be converted back to an array with the same type and value using *eval()*, so long as the *array* class has been imported using `from array import array`. Examples:

```
array('l')
array('u', 'hello \u2641')
array('l', [1, 2, 3, 4, 5])
array('d', [1.0, 2.0, 3.14])
```

See also:

Module *struct* Packing and unpacking of heterogeneous binary data.

Module *xdrlib* Packing and unpacking of External Data Representation (XDR) data as used in some remote procedure call systems.

The Numerical Python Documentation The Numeric Python extension (NumPy) defines another array type; see http://www.numpy.org/ for further information about Numerical Python.

8.8 `weakref` — Weak references

Source code: Lib/weakref.py

The *weakref* module allows the Python programmer to create *weak references* to objects.

In the following, the term *referent* means the object which is referred to by a weak reference.

A weak reference to an object is not enough to keep the object alive: when the only remaining references to a referent are weak references, *garbage collection* is free to destroy the referent and reuse its memory for something else. However, until the object is actually destroyed the weak reference may return the object even if there are no strong references to it.

A primary use for weak references is to implement caches or mappings holding large objects, where it's desired that a large object not be kept alive solely because it appears in a cache or mapping.

For example, if you have a number of large binary image objects, you may wish to associate a name with each. If you used a Python dictionary to map names to images, or images to names, the image objects would remain alive just because they appeared as values or keys in the dictionaries. The *WeakKeyDictionary* and *WeakValueDictionary* classes supplied by the *weakref* module are an alternative, using weak references to construct mappings that don't keep objects alive solely because they appear in the mapping objects. If, for example, an image object is a value in a *WeakValueDictionary*, then when the last remaining references to that image object are the weak references held by weak mappings, garbage collection can reclaim the object, and its corresponding entries in weak mappings are simply deleted.

WeakKeyDictionary and *WeakValueDictionary* use weak references in their implementation, setting up callback functions on the weak references that notify the weak dictionaries when a key or value has been reclaimed by garbage collection. *WeakSet* implements the *set* interface, but keeps weak references to its elements, just like a *WeakKeyDictionary* does.

finalize provides a straight forward way to register a cleanup function to be called when an object is garbage collected. This is simpler to use than setting up a callback function on a raw weak reference, since the module automatically ensures that the finalizer remains alive until the object is collected.

Most programs should find that using one of these weak container types or *finalize* is all they need – it's not usually necessary to create your own weak references directly. The low-level machinery is exposed by the *weakref* module for the benefit of advanced uses.

Not all objects can be weakly referenced; those objects which can include class instances, functions written in Python (but not in C), instance methods, sets, frozensets, some *file objects*, *generator*s, type objects, sockets, arrays, deques, regular expression pattern objects, and code objects.

Changed in version 3.2: Added support for thread.lock, threading.Lock, and code objects.

Several built-in types such as *list* and *dict* do not directly support weak references but can add support through subclassing:

```
class Dict(dict):
    pass

obj = Dict(red=1, green=2, blue=3)   # this object is weak referenceable
```

Other built-in types such as *tuple* and *int* do not support weak references even when subclassed (This is an implementation detail and may be different across various Python implementations.).

Extension types can easily be made to support weak references; see weakref-support.

class weakref.ref(*object*[, *callback*])

Return a weak reference to *object*. The original object can be retrieved by calling the reference object if the referent is still alive; if the referent is no longer alive, calling the reference object will cause *None* to be returned. If *callback* is provided and not *None*, and the returned weakref object is still alive, the callback will be called when the object is about to be finalized; the weak reference object will be passed as the only parameter to the callback; the referent will no longer be available.

It is allowable for many weak references to be constructed for the same object. Callbacks registered for each weak reference will be called from the most recently registered callback to the oldest registered callback.

Exceptions raised by the callback will be noted on the standard error output, but cannot be propagated; they are handled in exactly the same way as exceptions raised from an object's `__del__()` method.

Weak references are *hashable* if the *object* is hashable. They will maintain their hash value even after the *object* was deleted. If *hash()* is called the first time only after the *object* was deleted, the call will raise *TypeError*.

Weak references support tests for equality, but not ordering. If the referents are still alive, two references have the same equality relationship as their referents (regardless of the *callback*). If either referent has been deleted, the references are equal only if the reference objects are the same object.

This is a subclassable type rather than a factory function.

__callback__
This read-only attribute returns the callback currently associated to the weakref. If there is no callback or if the referent of the weakref is no longer alive then this attribute will have value `None`.

Changed in version 3.4: Added the *__callback__* attribute.

weakref.proxy(*object*[, *callback*])
Return a proxy to *object* which uses a weak reference. This supports use of the proxy in most contexts instead of requiring the explicit dereferencing used with weak reference objects. The returned object will have a type of either `ProxyType` or `CallableProxyType`, depending on whether *object* is callable. Proxy objects are not *hashable* regardless of the referent; this avoids a number of problems related to their fundamentally mutable nature, and prevent their use as dictionary keys. *callback* is the same as the parameter of the same name to the *ref()* function.

weakref.getweakrefcount(*object*)
Return the number of weak references and proxies which refer to *object*.

weakref.getweakrefs(*object*)
Return a list of all weak reference and proxy objects which refer to *object*.

class weakref.WeakKeyDictionary([*dict*])
Mapping class that references keys weakly. Entries in the dictionary will be discarded when there is no longer a strong reference to the key. This can be used to associate additional data with an object owned by other parts of an application without adding attributes to those objects. This can be especially useful with objects that override attribute accesses.

Note: Caution: Because a *WeakKeyDictionary* is built on top of a Python dictionary, it must not change size when iterating over it. This can be difficult to ensure for a *WeakKeyDictionary* because actions performed by the program during iteration may cause items in the dictionary to vanish "by magic" (as a side effect of garbage collection).

WeakKeyDictionary objects have an additional method that exposes the internal references directly. The references are not guaranteed to be "live" at the time they are used, so the result of calling the references needs to be checked before being used. This can be used to avoid creating references that will cause the garbage collector to keep the keys around longer than needed.

WeakKeyDictionary.keyrefs()
Return an iterable of the weak references to the keys.

class weakref.WeakValueDictionary([*dict*])
Mapping class that references values weakly. Entries in the dictionary will be discarded when no strong reference to the value exists any more.

Note: Caution: Because a *WeakValueDictionary* is built on top of a Python dictionary, it must not change size when iterating over it. This can be difficult to ensure for a *WeakValueDictionary* because actions performed by the program during iteration may cause items in the dictionary to vanish "by magic" (as a side effect of garbage collection).

WeakValueDictionary objects have an additional method that has the same issues as the `keyrefs()` method of *WeakKeyDictionary* objects.

WeakValueDictionary.**valuerefs**()
Return an iterable of the weak references to the values.

class weakref.WeakSet([*elements*])
Set class that keeps weak references to its elements. An element will be discarded when no strong reference to it exists any more.

class weakref.WeakMethod(*method*)
A custom *ref* subclass which simulates a weak reference to a bound method (i.e., a method defined on a class and looked up on an instance). Since a bound method is ephemeral, a standard weak reference cannot keep hold of it. *WeakMethod* has special code to recreate the bound method until either the object or the original function dies:

```
>>> class C:
...     def method(self):
...         print("method called!")
...
>>> c = C()
>>> r = weakref.ref(c.method)
>>> r()
>>> r = weakref.WeakMethod(c.method)
>>> r()
<bound method C.method of <__main__.C object at 0x7fc859830220>>
>>> r()()
method called!
>>> del c
>>> gc.collect()
0
>>> r()
>>>
```

New in version 3.4.

class weakref.finalize(*obj*, *func*, **args*, ***kwargs*)
Return a callable finalizer object which will be called when *obj* is garbage collected. Unlike an ordinary weak reference, a finalizer will always survive until the reference object is collected, greatly simplifying lifecycle management.

A finalizer is considered *alive* until it is called (either explicitly or at garbage collection), and after that it is *dead*. Calling a live finalizer returns the result of evaluating `func(*arg, **kwargs)`, whereas calling a dead finalizer returns *None*.

Exceptions raised by finalizer callbacks during garbage collection will be shown on the standard error output, but cannot be propagated. They are handled in the same way as exceptions raised from an object's `__del__()` method or a weak reference's callback.

When the program exits, each remaining live finalizer is called unless its *atexit* attribute has been set to false. They are called in reverse order of creation.

A finalizer will never invoke its callback during the later part of the *interpreter shutdown* when module globals are liable to have been replaced by *None*.

__call__()
If *self* is alive then mark it as dead and return the result of calling `func(*args, **kwargs)`. If *self* is dead then return *None*.

detach()
If *self* is alive then mark it as dead and return the tuple `(obj, func, args, kwargs)`. If *self* is dead then return *None*.

peek()

If *self* is alive then return the tuple `(obj, func, args, kwargs)`. If *self* is dead then return *None*.

alive
Property which is true if the finalizer is alive, false otherwise.

atexit
A writable boolean property which by default is true. When the program exits, it calls all remaining live finalizers for which *atexit* is true. They are called in reverse order of creation.

Note: It is important to ensure that *func*, *args* and *kwargs* do not own any references to *obj*, either directly or indirectly, since otherwise *obj* will never be garbage collected. In particular, *func* should not be a bound method of *obj*.

New in version 3.4.

weakref.ReferenceType
The type object for weak references objects.

weakref.ProxyType
The type object for proxies of objects which are not callable.

weakref.CallableProxyType
The type object for proxies of callable objects.

weakref.ProxyTypes
Sequence containing all the type objects for proxies. This can make it simpler to test if an object is a proxy without being dependent on naming both proxy types.

exception weakref.ReferenceError
Exception raised when a proxy object is used but the underlying object has been collected. This is the same as the standard *ReferenceError* exception.

See also:

PEP 205 - Weak References The proposal and rationale for this feature, including links to earlier implementations and information about similar features in other languages.

8.8.1 Weak Reference Objects

Weak reference objects have no methods and no attributes besides *ref.__callback__*. A weak reference object allows the referent to be obtained, if it still exists, by calling it:

```
>>> import weakref
>>> class Object:
...     pass
...
>>> o = Object()
>>> r = weakref.ref(o)
>>> o2 = r()
>>> o is o2
True
```

If the referent no longer exists, calling the reference object returns *None*:

```
>>> del o, o2
>>> print(r())
None
```

Testing that a weak reference object is still live should be done using the expression `ref() is not None`. Normally, application code that needs to use a reference object should follow this pattern:

```
# r is a weak reference object
o = r()
if o is None:
    # referent has been garbage collected
    print("Object has been deallocated; can't frobnicate.")
else:
    print("Object is still live!")
    o.do_something_useful()
```

Using a separate test for "liveness" creates race conditions in threaded applications; another thread can cause a weak reference to become invalidated before the weak reference is called; the idiom shown above is safe in threaded applications as well as single-threaded applications.

Specialized versions of *ref* objects can be created through subclassing. This is used in the implementation of the *WeakValueDictionary* to reduce the memory overhead for each entry in the mapping. This may be most useful to associate additional information with a reference, but could also be used to insert additional processing on calls to retrieve the referent.

This example shows how a subclass of *ref* can be used to store additional information about an object and affect the value that's returned when the referent is accessed:

```
import weakref

class ExtendedRef(weakref.ref):
    def __init__(self, ob, callback=None, **annotations):
        super(ExtendedRef, self).__init__(ob, callback)
        self.__counter = 0
        for k, v in annotations.items():
            setattr(self, k, v)

    def __call__(self):
        """Return a pair containing the referent and the number of
        times the reference has been called.
        """
        ob = super(ExtendedRef, self).__call__()
        if ob is not None:
            self.__counter += 1
            ob = (ob, self.__counter)
        return ob
```

8.8.2 Example

This simple example shows how an application can use object IDs to retrieve objects that it has seen before. The IDs of the objects can then be used in other data structures without forcing the objects to remain alive, but the objects can still be retrieved by ID if they do.

```
import weakref

_id2obj_dict = weakref.WeakValueDictionary()

def remember(obj):
    oid = id(obj)
    _id2obj_dict[oid] = obj
    return oid
```

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```
def id2obj(oid):
    return _id2obj_dict[oid]
```

8.8.3 Finalizer Objects

The main benefit of using *finalize* is that it makes it simple to register a callback without needing to preserve the returned finalizer object. For instance

```
>>> import weakref
>>> class Object:
...     pass
...
>>> kenny = Object()
>>> weakref.finalize(kenny, print, "You killed Kenny!")
<finalize object at ...; for 'Object' at ...>
>>> del kenny
You killed Kenny!
```

The finalizer can be called directly as well. However the finalizer will invoke the callback at most once.

```
>>> def callback(x, y, z):
...     print("CALLBACK")
...     return x + y + z
...
>>> obj = Object()
>>> f = weakref.finalize(obj, callback, 1, 2, z=3)
>>> assert f.alive
>>> assert f() == 6
CALLBACK
>>> assert not f.alive
>>> f()                     # callback not called because finalizer dead
>>> del obj                 # callback not called because finalizer dead
```

You can unregister a finalizer using its *detach()* method. This kills the finalizer and returns the arguments passed to the constructor when it was created.

```
>>> obj = Object()
>>> f = weakref.finalize(obj, callback, 1, 2, z=3)
>>> f.detach()
(<...Object object ...>, <function callback ...>, (1, 2), {'z': 3})
>>> newobj, func, args, kwargs = _
>>> assert not f.alive
>>> assert newobj is obj
>>> assert func(*args, **kwargs) == 6
CALLBACK
```

Unless you set the *atexit* attribute to *False*, a finalizer will be called when the program exits if it is still alive. For instance

```
>>> obj = Object()
>>> weakref.finalize(obj, print, "obj dead or exiting")
<finalize object at ...; for 'Object' at ...>
>>> exit()
obj dead or exiting
```

8.8.4 Comparing finalizers with `__del__()` methods

Suppose we want to create a class whose instances represent temporary directories. The directories should be deleted with their contents when the first of the following events occurs:

- the object is garbage collected,
- the object's `remove()` method is called, or
- the program exits.

We might try to implement the class using a `__del__()` method as follows:

```
class TempDir:
    def __init__(self):
        self.name = tempfile.mkdtemp()

    def remove(self):
        if self.name is not None:
            shutil.rmtree(self.name)
            self.name = None

    @property
    def removed(self):
        return self.name is None

    def __del__(self):
        self.remove()
```

Starting with Python 3.4, `__del__()` methods no longer prevent reference cycles from being garbage collected, and module globals are no longer forced to *None* during *interpreter shutdown*. So this code should work without any issues on CPython.

However, handling of `__del__()` methods is notoriously implementation specific, since it depends on internal details of the interpreter's garbage collector implementation.

A more robust alternative can be to define a finalizer which only references the specific functions and objects that it needs, rather than having access to the full state of the object:

```
class TempDir:
    def __init__(self):
        self.name = tempfile.mkdtemp()
        self._finalizer = weakref.finalize(self, shutil.rmtree, self.name)

    def remove(self):
        self._finalizer()

    @property
    def removed(self):
        return not self._finalizer.alive
```

Defined like this, our finalizer only receives a reference to the details it needs to clean up the directory appropriately. If the object never gets garbage collected the finalizer will still be called at exit.

The other advantage of weakref based finalizers is that they can be used to register finalizers for classes where the definition is controlled by a third party, such as running code when a module is unloaded:

```
import weakref, sys
def unloading_module():
    # implicit reference to the module globals from the function body
weakref.finalize(sys.modules[__name__], unloading_module)
```

Note: If you create a finalizer object in a daemonic thread just as the program exits then there is the possibility that the finalizer does not get called at exit. However, in a daemonic thread *atexit.register()*, `try: ... finally: ...` and `with: ...` do not guarantee that cleanup occurs either.

8.9 types — Dynamic type creation and names for built-in types

Source code: Lib/types.py

This module defines utility function to assist in dynamic creation of new types.

It also defines names for some object types that are used by the standard Python interpreter, but not exposed as builtins like *int* or *str* are.

Finally, it provides some additional type-related utility classes and functions that are not fundamental enough to be builtins.

8.9.1 Dynamic Type Creation

`types.new_class`(*name*, *bases=()*, *kwds=None*, *exec_body=None*)
Creates a class object dynamically using the appropriate metaclass.

The first three arguments are the components that make up a class definition header: the class name, the base classes (in order), the keyword arguments (such as `metaclass`).

The *exec_body* argument is a callback that is used to populate the freshly created class namespace. It should accept the class namespace as its sole argument and update the namespace directly with the class contents. If no callback is provided, it has the same effect as passing in `lambda ns: ns`.

New in version 3.3.

`types.prepare_class`(*name*, *bases=()*, *kwds=None*)
Calculates the appropriate metaclass and creates the class namespace.

The arguments are the components that make up a class definition header: the class name, the base classes (in order) and the keyword arguments (such as `metaclass`).

The return value is a 3-tuple: `metaclass, namespace, kwds`

metaclass is the appropriate metaclass, *namespace* is the prepared class namespace and *kwds* is an updated copy of the passed in *kwds* argument with any `'metaclass'` entry removed. If no *kwds* argument is passed in, this will be an empty dict.

New in version 3.3.

Changed in version 3.6: The default value for the `namespace` element of the returned tuple has changed. Now an insertion-order-preserving mapping is used when the metaclass does not have a `__prepare__` method.

See also:

metaclasses Full details of the class creation process supported by these functions

PEP 3115 - Metaclasses in Python 3000 Introduced the `__prepare__` namespace hook

types.**resolve_bases**(*bases*)
Resolve MRO entries dynamically as specified by **PEP 560**.

This function looks for items in *bases* that are not instances of *type*, and returns a tuple where each such object that has an `__mro_entries__` method is replaced with an unpacked result of calling this method. If a *bases* item is an instance of *type*, or it doesn't have an `__mro_entries__` method, then it is included in the return tuple unchanged.

New in version 3.7.

See also:

PEP 560 - Core support for typing module and generic types

8.9.2 Standard Interpreter Types

This module provides names for many of the types that are required to implement a Python interpreter. It deliberately avoids including some of the types that arise only incidentally during processing such as the `listiterator` type.

Typical use of these names is for *isinstance()* or *issubclass()* checks.

Standard names are defined for the following types:

types.**FunctionType**
types.**LambdaType**
The type of user-defined functions and functions created by `lambda` expressions.

types.**GeneratorType**
The type of *generator*-iterator objects, created by generator functions.

types.**CoroutineType**
The type of *coroutine* objects, created by `async def` functions.

New in version 3.5.

types.**AsyncGeneratorType**
The type of *asynchronous generator*-iterator objects, created by asynchronous generator functions.

New in version 3.6.

types.**CodeType**
The type for code objects such as returned by *compile()*.

types.**MethodType**
The type of methods of user-defined class instances.

types.**BuiltinFunctionType**
types.**BuiltinMethodType**
The type of built-in functions like *len()* or *sys.exit()*, and methods of built-in classes. (Here, the term "built-in" means "written in C".)

types.**WrapperDescriptorType**
The type of methods of some built-in data types and base classes such as `object.__init__()` or `object.__lt__()`.

New in version 3.7.

types.**MethodWrapperType**
The type of *bound* methods of some built-in data types and base classes. For example it is the type of `object().__str__`.

New in version 3.7.

types.**MethodDescriptorType**
The type of methods of some built-in data types such as *str.join()*.

New in version 3.7.

types.**ClassMethodDescriptorType**
The type of *unbound* class methods of some built-in data types such as `dict.__dict__['fromkeys']`.

New in version 3.7.

class types.**ModuleType**(*name*, *doc=None*)
The type of *modules*. Constructor takes the name of the module to be created and optionally its *docstring*.

Note: Use *importlib.util.module_from_spec()* to create a new module if you wish to set the various import-controlled attributes.

__doc__
The *docstring* of the module. Defaults to `None`.

__loader__
The *loader* which loaded the module. Defaults to `None`.

Changed in version 3.4: Defaults to `None`. Previously the attribute was optional.

__name__
The name of the module.

__package__
Which *package* a module belongs to. If the module is top-level (i.e. not a part of any specific package) then the attribute should be set to `''`, else it should be set to the name of the package (which can be `__name__` if the module is a package itself). Defaults to `None`.

Changed in version 3.4: Defaults to `None`. Previously the attribute was optional.

class types.**TracebackType**(*tb_next*, *tb_frame*, *tb_lasti*, *tb_lineno*)
The type of traceback objects such as found in `sys.exc_info()[2]`.

See the language reference for details of the available attributes and operations, and guidance on creating tracebacks dynamically.

types.**FrameType**
The type of frame objects such as found in `tb.tb_frame` if `tb` is a traceback object.

See the language reference for details of the available attributes and operations.

types.**GetSetDescriptorType**
The type of objects defined in extension modules with `PyGetSetDef`, such as `FrameType.f_locals` or `array.array.typecode`. This type is used as descriptor for object attributes; it has the same purpose as the *property* type, but for classes defined in extension modules.

types.**MemberDescriptorType**
The type of objects defined in extension modules with `PyMemberDef`, such as `datetime.timedelta.days`. This type is used as descriptor for simple C data members which use standard conversion functions; it has the same purpose as the *property* type, but for classes defined in extension modules.

CPython implementation detail: In other implementations of Python, this type may be identical to `GetSetDescriptorType`.

class types.**MappingProxyType**(*mapping*)
Read-only proxy of a mapping. It provides a dynamic view on the mapping's entries, which means that when the mapping changes, the view reflects these changes.

New in version 3.3.

`key in proxy`
: Return `True` if the underlying mapping has a key *key*, else `False`.

`proxy[key]`
: Return the item of the underlying mapping with key *key*. Raises a *KeyError* if *key* is not in the underlying mapping.

`iter(proxy)`
: Return an iterator over the keys of the underlying mapping. This is a shortcut for `iter(proxy.keys())`.

`len(proxy)`
: Return the number of items in the underlying mapping.

`copy()`
: Return a shallow copy of the underlying mapping.

`get(`*key*[, *default*]`)`
: Return the value for *key* if *key* is in the underlying mapping, else *default*. If *default* is not given, it defaults to `None`, so that this method never raises a *KeyError*.

`items()`
: Return a new view of the underlying mapping's items (`(key, value)` pairs).

`keys()`
: Return a new view of the underlying mapping's keys.

`values()`
: Return a new view of the underlying mapping's values.

8.9.3 Additional Utility Classes and Functions

`class types.SimpleNamespace`
: A simple *object* subclass that provides attribute access to its namespace, as well as a meaningful repr.

  Unlike *object*, with `SimpleNamespace` you can add and remove attributes. If a `SimpleNamespace` object is initialized with keyword arguments, those are directly added to the underlying namespace.

  The type is roughly equivalent to the following code:

```
class SimpleNamespace:
    def __init__(self, **kwargs):
        self.__dict__.update(kwargs)

    def __repr__(self):
        keys = sorted(self.__dict__)
        items = ("{}={!r}".format(k, self.__dict__[k]) for k in keys)
        return "{}({})".format(type(self).__name__, ", ".join(items))

    def __eq__(self, other):
        return self.__dict__ == other.__dict__
```

  `SimpleNamespace` may be useful as a replacement for `class NS: pass`. However, for a structured record type use *namedtuple()* instead.

  New in version 3.3.

`types.DynamicClassAttribute(`*fget=None*, *fset=None*, *fdel=None*, *doc=None*`)`
: Route attribute access on a class to __getattr__.

This is a descriptor, used to define attributes that act differently when accessed through an instance and through a class. Instance access remains normal, but access to an attribute through a class will be routed to the class's ___getattr___ method; this is done by raising AttributeError.

This allows one to have properties active on an instance, and have virtual attributes on the class with the same name (see Enum for an example).

New in version 3.4.

8.9.4 Coroutine Utility Functions

`types.coroutine(`*gen_func*`)`
This function transforms a *generator* function into a *coroutine function* which returns a generator-based coroutine. The generator-based coroutine is still a *generator iterator*, but is also considered to be a *coroutine* object and is *awaitable*. However, it may not necessarily implement the `__await__()` method.

If *gen_func* is a generator function, it will be modified in-place.

If *gen_func* is not a generator function, it will be wrapped. If it returns an instance of *collections.abc.Generator*, the instance will be wrapped in an *awaitable* proxy object. All other types of objects will be returned as is.

New in version 3.5.

8.10 copy — Shallow and deep copy operations

Source code: Lib/copy.py

Assignment statements in Python do not copy objects, they create bindings between a target and an object. For collections that are mutable or contain mutable items, a copy is sometimes needed so one can change one copy without changing the other. This module provides generic shallow and deep copy operations (explained below).

Interface summary:

`copy.copy(`*x*`)`
Return a shallow copy of *x*.

`copy.deepcopy(`*x*`)`
Return a deep copy of *x*.

`exception copy.error`
Raised for module specific errors.

The difference between shallow and deep copying is only relevant for compound objects (objects that contain other objects, like lists or class instances):

- A *shallow copy* constructs a new compound object and then (to the extent possible) inserts *references* into it to the objects found in the original.
- A *deep copy* constructs a new compound object and then, recursively, inserts *copies* into it of the objects found in the original.

Two problems often exist with deep copy operations that don't exist with shallow copy operations:

- Recursive objects (compound objects that, directly or indirectly, contain a reference to themselves) may cause a recursive loop.

- Because deep copy copies everything it may copy too much, such as data which is intended to be shared between copies.

The *deepcopy()* function avoids these problems by:

- keeping a "memo" dictionary of objects already copied during the current copying pass; and
- letting user-defined classes override the copying operation or the set of components copied.

This module does not copy types like module, method, stack trace, stack frame, file, socket, window, array, or any similar types. It does "copy" functions and classes (shallow and deeply), by returning the original object unchanged; this is compatible with the way these are treated by the *pickle* module.

Shallow copies of dictionaries can be made using *dict.copy()*, and of lists by assigning a slice of the entire list, for example, `copied_list = original_list[:]`.

Classes can use the same interfaces to control copying that they use to control pickling. See the description of module *pickle* for information on these methods. In fact, the *copy* module uses the registered pickle functions from the *copyreg* module.

In order for a class to define its own copy implementation, it can define special methods `__copy__()` and `__deepcopy__()`. The former is called to implement the shallow copy operation; no additional arguments are passed. The latter is called to implement the deep copy operation; it is passed one argument, the memo dictionary. If the `__deepcopy__()` implementation needs to make a deep copy of a component, it should call the *deepcopy()* function with the component as first argument and the memo dictionary as second argument.

See also:

Module *pickle* Discussion of the special methods used to support object state retrieval and restoration.

8.11 pprint — Data pretty printer

Source code: Lib/pprint.py

The *pprint* module provides a capability to "pretty-print" arbitrary Python data structures in a form which can be used as input to the interpreter. If the formatted structures include objects which are not fundamental Python types, the representation may not be loadable. This may be the case if objects such as files, sockets or classes are included, as well as many other objects which are not representable as Python literals.

The formatted representation keeps objects on a single line if it can, and breaks them onto multiple lines if they don't fit within the allowed width. Construct *PrettyPrinter* objects explicitly if you need to adjust the width constraint.

Dictionaries are sorted by key before the display is computed.

The *pprint* module defines one class:

class pprint.PrettyPrinter(*indent=1*, *width=80*, *depth=None*, *stream=None*, ***, *compact=False*)

Construct a *PrettyPrinter* instance. This constructor understands several keyword parameters. An output stream may be set using the *stream* keyword; the only method used on the stream object is the file protocol's `write()` method. If not specified, the *PrettyPrinter* adopts `sys.stdout`. The amount of indentation added for each recursive level is specified by *indent*; the default is one. Other values can cause output to look a little odd, but can make nesting easier to spot. The number of levels which may be printed is controlled by *depth*; if the data structure being printed is too deep, the next contained level is replaced by `...`. By default, there is no constraint on the depth of the objects being formatted. The desired output width is constrained using the *width* parameter; the default is 80 characters. If a structure cannot be formatted within the constrained width, a best effort will be made. If *compact* is

false (the default) each item of a long sequence will be formatted on a separate line. If *compact* is true, as many items as will fit within the *width* will be formatted on each output line.

Changed in version 3.4: Added the *compact* parameter.

```
>>> import pprint
>>> stuff = ['spam', 'eggs', 'lumberjack', 'knights', 'ni']
>>> stuff.insert(0, stuff[:])
>>> pp = pprint.PrettyPrinter(indent=4)
>>> pp.pprint(stuff)
[   ['spam', 'eggs', 'lumberjack', 'knights', 'ni'],
    'spam',
    'eggs',
    'lumberjack',
    'knights',
    'ni']
>>> pp = pprint.PrettyPrinter(width=41, compact=True)
>>> pp.pprint(stuff)
[['spam', 'eggs', 'lumberjack',
  'knights', 'ni'],
 'spam', 'eggs', 'lumberjack', 'knights',
 'ni']
>>> tup = ('spam', ('eggs', ('lumberjack', ('knights', ('ni', ('dead',
... ('parrot', ('fresh fruit',)))))))
>>> pp = pprint.PrettyPrinter(depth=6)
>>> pp.pprint(tup)
('spam', ('eggs', ('lumberjack', ('knights', ('ni', ('dead', (...)))))))
```

The *pprint* module also provides several shortcut functions:

pprint.pformat(*object*, *indent=1*, *width=80*, *depth=None*, ***, *compact=False*)
Return the formatted representation of *object* as a string. *indent*, *width*, *depth* and *compact* will be passed to the *PrettyPrinter* constructor as formatting parameters.

Changed in version 3.4: Added the *compact* parameter.

pprint.pprint(*object*, *stream=None*, *indent=1*, *width=80*, *depth=None*, ***, *compact=False*)
Prints the formatted representation of *object* on *stream*, followed by a newline. If *stream* is `None`, `sys.stdout` is used. This may be used in the interactive interpreter instead of the *print()* function for inspecting values (you can even reassign `print = pprint.pprint` for use within a scope). *indent*, *width*, *depth* and *compact* will be passed to the *PrettyPrinter* constructor as formatting parameters.

Changed in version 3.4: Added the *compact* parameter.

```
>>> import pprint
>>> stuff = ['spam', 'eggs', 'lumberjack', 'knights', 'ni']
>>> stuff.insert(0, stuff)
>>> pprint.pprint(stuff)
[<Recursion on list with id=...>,
 'spam',
 'eggs',
 'lumberjack',
 'knights',
 'ni']
```

pprint.isreadable(*object*)
Determine if the formatted representation of *object* is "readable," or can be used to reconstruct the value using *eval()*. This always returns `False` for recursive objects.

```
>>> pprint.isreadable(stuff)
False
```

pprint.isrecursive(*object*)
Determine if *object* requires a recursive representation.

One more support function is also defined:

pprint.saferepr(*object*)
Return a string representation of *object*, protected against recursive data structures. If the representation of *object* exposes a recursive entry, the recursive reference will be represented as `<Recursion on typename with id=number>`. The representation is not otherwise formatted.

```
>>> pprint.saferepr(stuff)
"[<Recursion on list with id=...>, 'spam', 'eggs', 'lumberjack', 'knights', 'ni']"
```

8.11.1 PrettyPrinter Objects

PrettyPrinter instances have the following methods:

PrettyPrinter.pformat(*object*)
Return the formatted representation of *object*. This takes into account the options passed to the *PrettyPrinter* constructor.

PrettyPrinter.pprint(*object*)
Print the formatted representation of *object* on the configured stream, followed by a newline.

The following methods provide the implementations for the corresponding functions of the same names. Using these methods on an instance is slightly more efficient since new *PrettyPrinter* objects don't need to be created.

PrettyPrinter.isreadable(*object*)
Determine if the formatted representation of the object is "readable," or can be used to reconstruct the value using *eval()*. Note that this returns `False` for recursive objects. If the *depth* parameter of the *PrettyPrinter* is set and the object is deeper than allowed, this returns `False`.

PrettyPrinter.isrecursive(*object*)
Determine if the object requires a recursive representation.

This method is provided as a hook to allow subclasses to modify the way objects are converted to strings. The default implementation uses the internals of the *saferepr()* implementation.

PrettyPrinter.format(*object*, *context*, *maxlevels*, *level*)
Returns three values: the formatted version of *object* as a string, a flag indicating whether the result is readable, and a flag indicating whether recursion was detected. The first argument is the object to be presented. The second is a dictionary which contains the *id()* of objects that are part of the current presentation context (direct and indirect containers for *object* that are affecting the presentation) as the keys; if an object needs to be presented which is already represented in *context*, the third return value should be `True`. Recursive calls to the *format()* method should add additional entries for containers to this dictionary. The third argument, *maxlevels*, gives the requested limit to recursion; this will be `0` if there is no requested limit. This argument should be passed unmodified to recursive calls. The fourth argument, *level*, gives the current level; recursive calls should be passed a value less than that of the current call.

8.11.2 Example

To demonstrate several uses of the *pprint()* function and its parameters, let's fetch information about a project from PyPI:

```
>>> import json
>>> import pprint
>>> from urllib.request import urlopen
>>> with urlopen('http://pypi.org/project/Twisted/json') as url:
...     http_info = url.info()
...     raw_data = url.read().decode(http_info.get_content_charset())
>>> project_info = json.loads(raw_data)
```

In its basic form, *pprint()* shows the whole object:

```
>>> pprint.pprint(project_info)
{'info': {'_pypi_hidden': False,
          '_pypi_ordering': 125,
          'author': 'Glyph Lefkowitz',
          'author_email': 'glyph@twistedmatrix.com',
          'bugtrack_url': '',
          'cheesecake_code_kwalitee_id': None,
          'cheesecake_documentation_id': None,
          'cheesecake_installability_id': None,
          'classifiers': ['Programming Language :: Python :: 2.6',
                          'Programming Language :: Python :: 2.7',
                          'Programming Language :: Python :: 2 :: Only'],
          'description': 'An extensible framework for Python programming, with '
                         'special focus\r\n'
                         'on event-based network programming and multiprotocol '
                         'integration.',
          'docs_url': '',
          'download_url': 'UNKNOWN',
          'home_page': 'http://twistedmatrix.com/',
          'keywords': '',
          'license': 'MIT',
          'maintainer': '',
          'maintainer_email': '',
          'name': 'Twisted',
          'package_url': 'http://pypi.org/project/Twisted',
          'platform': 'UNKNOWN',
          'release_url': 'http://pypi.org/project/Twisted/12.3.0',
          'requires_python': None,
          'stable_version': None,
          'summary': 'An asynchronous networking framework written in Python',
          'version': '12.3.0'},
 'urls': [{'comment_text': '',
           'downloads': 71844,
           'filename': 'Twisted-12.3.0.tar.bz2',
           'has_sig': False,
           'md5_digest': '6e289825f3bf5591cfd670874cc0862d',
           'packagetype': 'sdist',
           'python_version': 'source',
           'size': 2615733,
           'upload_time': '2012-12-26T12:47:03',
           'url': 'https://pypi.org/packages/source/T/Twisted/Twisted-12.3.0.tar.bz2'},
          {'comment_text': '',
           'downloads': 5224,
```

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```
           'filename': 'Twisted-12.3.0.win32-py2.7.msi',
           'has_sig': False,
           'md5_digest': '6b778f5201b622a5519a2aca1a2fe512',
           'packagetype': 'bdist_msi',
           'python_version': '2.7',
           'size': 2916352,
           'upload_time': '2012-12-26T12:48:15',
           'url': 'https://pypi.org/packages/2.7/T/Twisted/Twisted-12.3.0.win32-py2.7.msi'}]}
```

The result can be limited to a certain *depth* (ellipsis is used for deeper contents):

```
>>> pprint.pprint(project_info, depth=2)
{'info': {'_pypi_hidden': False,
          '_pypi_ordering': 125,
          'author': 'Glyph Lefkowitz',
          'author_email': 'glyph@twistedmatrix.com',
          'bugtrack_url': '',
          'cheesecake_code_kwalitee_id': None,
          'cheesecake_documentation_id': None,
          'cheesecake_installability_id': None,
          'classifiers': [...],
          'description': 'An extensible framework for Python programming, with '
                         'special focus\r\n'
                         'on event-based network programming and multiprotocol '
                         'integration.',
          'docs_url': '',
          'download_url': 'UNKNOWN',
          'home_page': 'http://twistedmatrix.com/',
          'keywords': '',
          'license': 'MIT',
          'maintainer': '',
          'maintainer_email': '',
          'name': 'Twisted',
          'package_url': 'http://pypi.org/project/Twisted',
          'platform': 'UNKNOWN',
          'release_url': 'http://pypi.org/project/Twisted/12.3.0',
          'requires_python': None,
          'stable_version': None,
          'summary': 'An asynchronous networking framework written in Python',
          'version': '12.3.0'},
 'urls': [{...}, {...}]}
```

Additionally, maximum character *width* can be suggested. If a long object cannot be split, the specified width will be exceeded:

```
>>> pprint.pprint(project_info, depth=2, width=50)
{'info': {'_pypi_hidden': False,
          '_pypi_ordering': 125,
          'author': 'Glyph Lefkowitz',
          'author_email': 'glyph@twistedmatrix.com',
          'bugtrack_url': '',
          'cheesecake_code_kwalitee_id': None,
          'cheesecake_documentation_id': None,
          'cheesecake_installability_id': None,
          'classifiers': [...],
          'description': 'An extensible '
```

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```
                        'framework for Python '
                        'programming, with '
                        'special focus\r\n'
                        'on event-based network '
                        'programming and '
                        'multiprotocol '
                        'integration.',
          'docs_url': '',
          'download_url': 'UNKNOWN',
          'home_page': 'http://twistedmatrix.com/',
          'keywords': '',
          'license': 'MIT',
          'maintainer': '',
          'maintainer_email': '',
          'name': 'Twisted',
          'package_url': 'http://pypi.org/project/Twisted',
          'platform': 'UNKNOWN',
          'release_url': 'http://pypi.org/project/Twisted/12.3.0',
          'requires_python': None,
          'stable_version': None,
          'summary': 'An asynchronous networking '
                     'framework written in '
                     'Python',
          'version': '12.3.0'},
 'urls': [{...}, {...}]}
```

8.12 reprlib — Alternate repr() implementation

Source code: Lib/reprlib.py

The *reprlib* module provides a means for producing object representations with limits on the size of the resulting strings. This is used in the Python debugger and may be useful in other contexts as well.

This module provides a class, an instance, and a function:

class reprlib.Repr
Class which provides formatting services useful in implementing functions similar to the built-in *repr()*; size limits for different object types are added to avoid the generation of representations which are excessively long.

reprlib.aRepr
This is an instance of *Repr* which is used to provide the *repr()* function described below. Changing the attributes of this object will affect the size limits used by *repr()* and the Python debugger.

reprlib.repr(*obj*)
This is the *repr()* method of `aRepr`. It returns a string similar to that returned by the built-in function of the same name, but with limits on most sizes.

In addition to size-limiting tools, the module also provides a decorator for detecting recursive calls to `__repr__()` and substituting a placeholder string instead.

@reprlib.recursive_repr(*fillvalue="..."*)
Decorator for `__repr__()` methods to detect recursive calls within the same thread. If a recursive call is made, the *fillvalue* is returned, otherwise, the usual `__repr__()` call is made. For example:

```
>>> from reprlib import recursive_repr
>>> class MyList(list):
...     @recursive_repr()
...     def __repr__(self):
...         return '<' + '|'.join(map(repr, self)) + '>'
...
>>> m = MyList('abc')
>>> m.append(m)
>>> m.append('x')
>>> print(m)
<'a'|'b'|'c'|...|'x'>
```

New in version 3.2.

8.12.1 Repr Objects

Repr instances provide several attributes which can be used to provide size limits for the representations of different object types, and methods which format specific object types.

Repr.maxlevel
Depth limit on the creation of recursive representations. The default is `6`.

Repr.maxdict
Repr.maxlist
Repr.maxtuple
Repr.maxset
Repr.maxfrozenset
Repr.maxdeque
Repr.maxarray
Limits on the number of entries represented for the named object type. The default is `4` for *maxdict*, `5` for *maxarray*, and `6` for the others.

Repr.maxlong
Maximum number of characters in the representation for an integer. Digits are dropped from the middle. The default is `40`.

Repr.maxstring
Limit on the number of characters in the representation of the string. Note that the "normal" representation of the string is used as the character source: if escape sequences are needed in the representation, these may be mangled when the representation is shortened. The default is `30`.

Repr.maxother
This limit is used to control the size of object types for which no specific formatting method is available on the *Repr* object. It is applied in a similar manner as *maxstring*. The default is `20`.

Repr.repr(*obj*)
The equivalent to the built-in *repr()* that uses the formatting imposed by the instance.

Repr.repr1(*obj*, *level*)
Recursive implementation used by *repr()*. This uses the type of *obj* to determine which formatting method to call, passing it *obj* and *level*. The type-specific methods should call *repr1()* to perform recursive formatting, with `level - 1` for the value of *level* in the recursive call.

Repr.repr_TYPE(*obj*, *level*)
Formatting methods for specific types are implemented as methods with a name based on the type name. In the method name, **TYPE** is replaced by `'_'.join(type(obj).__name__.split())`. Dispatch to these methods is handled by *repr1()*. Type-specific methods which need to recursively format a value should call `self.repr1(subobj, level - 1)`.

8.12.2 Subclassing Repr Objects

The use of dynamic dispatching by *Repr.repr1()* allows subclasses of *Repr* to add support for additional built-in object types or to modify the handling of types already supported. This example shows how special support for file objects could be added:

```
import reprlib
import sys

class MyRepr(reprlib.Repr):

    def repr_TextIOWrapper(self, obj, level):
        if obj.name in {'<stdin>', '<stdout>', '<stderr>'}:
            return obj.name
        return repr(obj)

aRepr = MyRepr()
print(aRepr.repr(sys.stdin))         # prints '<stdin>'
```

8.13 enum — Support for enumerations

New in version 3.4.

Source code: Lib/enum.py

An enumeration is a set of symbolic names (members) bound to unique, constant values. Within an enumeration, the members can be compared by identity, and the enumeration itself can be iterated over.

8.13.1 Module Contents

This module defines four enumeration classes that can be used to define unique sets of names and values: *Enum*, *IntEnum*, *Flag*, and *IntFlag*. It also defines one decorator, *unique()*, and one helper, *auto*.

class enum.Enum
Base class for creating enumerated constants. See section *Functional API* for an alternate construction syntax.

class enum.IntEnum
Base class for creating enumerated constants that are also subclasses of *int*.

class enum.IntFlag
Base class for creating enumerated constants that can be combined using the bitwise operators without losing their *IntFlag* membership. *IntFlag* members are also subclasses of *int*.

class enum.Flag
Base class for creating enumerated constants that can be combined using the bitwise operations without losing their *Flag* membership.

enum.unique()
Enum class decorator that ensures only one name is bound to any one value.

class enum.auto
Instances are replaced with an appropriate value for Enum members.

New in version 3.6: `Flag`, `IntFlag`, `auto`

8.13.2 Creating an Enum

Enumerations are created using the `class` syntax, which makes them easy to read and write. An alternative creation method is described in *Functional API*. To define an enumeration, subclass *Enum* as follows:

```
>>> from enum import Enum
>>> class Color(Enum):
...     RED = 1
...     GREEN = 2
...     BLUE = 3
...
```

Note: Enum member values

Member values can be anything: *int*, *str*, etc.. If the exact value is unimportant you may use *auto* instances and an appropriate value will be chosen for you. Care must be taken if you mix *auto* with other values.

Note: Nomenclature

- The class `Color` is an *enumeration* (or *enum*)
- The attributes `Color.RED`, `Color.GREEN`, etc., are *enumeration members* (or *enum members*) and are functionally constants.
- The enum members have *names* and *values* (the name of `Color.RED` is `RED`, the value of `Color.BLUE` is `3`, etc.)

Note: Even though we use the `class` syntax to create Enums, Enums are not normal Python classes. See *How are Enums different?* for more details.

Enumeration members have human readable string representations:

```
>>> print(Color.RED)
Color.RED
```

...while their `repr` has more information:

```
>>> print(repr(Color.RED))
<Color.RED: 1>
```

The *type* of an enumeration member is the enumeration it belongs to:

```
>>> type(Color.RED)
<enum 'Color'>
>>> isinstance(Color.GREEN, Color)
True
>>>
```

Enum members also have a property that contains just their item name:

```
>>> print(Color.RED.name)
RED
```

Enumerations support iteration, in definition order:

```
>>> class Shake(Enum):
...     VANILLA = 7
...     CHOCOLATE = 4
...     COOKIES = 9
...     MINT = 3
...
>>> for shake in Shake:
...     print(shake)
...
Shake.VANILLA
Shake.CHOCOLATE
Shake.COOKIES
Shake.MINT
```

Enumeration members are hashable, so they can be used in dictionaries and sets:

```
>>> apples = {}
>>> apples[Color.RED] = 'red delicious'
>>> apples[Color.GREEN] = 'granny smith'
>>> apples == {Color.RED: 'red delicious', Color.GREEN: 'granny smith'}
True
```

8.13.3 Programmatic access to enumeration members and their attributes

Sometimes it's useful to access members in enumerations programmatically (i.e. situations where `Color.RED` won't do because the exact color is not known at program-writing time). `Enum` allows such access:

```
>>> Color(1)
<Color.RED: 1>
>>> Color(3)
<Color.BLUE: 3>
```

If you want to access enum members by *name*, use item access:

```
>>> Color['RED']
<Color.RED: 1>
>>> Color['GREEN']
<Color.GREEN: 2>
```

If you have an enum member and need its `name` or `value`:

```
>>> member = Color.RED
>>> member.name
'RED'
>>> member.value
1
```

8.13.4 Duplicating enum members and values

Having two enum members with the same name is invalid:

```
>>> class Shape(Enum):
...     SQUARE = 2
...     SQUARE = 3
```

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```
...
Traceback (most recent call last):
...
TypeError: Attempted to reuse key: 'SQUARE'
```

However, two enum members are allowed to have the same value. Given two members A and B with the same value (and A defined first), B is an alias to A. By-value lookup of the value of A and B will return A. By-name lookup of B will also return A:

```
>>> class Shape(Enum):
...     SQUARE = 2
...     DIAMOND = 1
...     CIRCLE = 3
...     ALIAS_FOR_SQUARE = 2
...
>>> Shape.SQUARE
<Shape.SQUARE: 2>
>>> Shape.ALIAS_FOR_SQUARE
<Shape.SQUARE: 2>
>>> Shape(2)
<Shape.SQUARE: 2>
```

Note: Attempting to create a member with the same name as an already defined attribute (another member, a method, etc.) or attempting to create an attribute with the same name as a member is not allowed.

8.13.5 Ensuring unique enumeration values

By default, enumerations allow multiple names as aliases for the same value. When this behavior isn't desired, the following decorator can be used to ensure each value is used only once in the enumeration:

@enum.unique

A `class` decorator specifically for enumerations. It searches an enumeration's `__members__` gathering any aliases it finds; if any are found *ValueError* is raised with the details:

```
>>> from enum import Enum, unique
>>> @unique
... class Mistake(Enum):
...     ONE = 1
...     TWO = 2
...     THREE = 3
...     FOUR = 3
...
Traceback (most recent call last):
...
ValueError: duplicate values found in <enum 'Mistake'>: FOUR -> THREE
```

8.13.6 Using automatic values

If the exact value is unimportant you can use *auto*:

```
>>> from enum import Enum, auto
>>> class Color(Enum):
...     RED = auto()
...     BLUE = auto()
...     GREEN = auto()
...
>>> list(Color)
[<Color.RED: 1>, <Color.BLUE: 2>, <Color.GREEN: 3>]
```

The values are chosen by `_generate_next_value_()`, which can be overridden:

```
>>> class AutoName(Enum):
...     def _generate_next_value_(name, start, count, last_values):
...         return name
...
>>> class Ordinal(AutoName):
...     NORTH = auto()
...     SOUTH = auto()
...     EAST = auto()
...     WEST = auto()
...
>>> list(Ordinal)
[<Ordinal.NORTH: 'NORTH'>, <Ordinal.SOUTH: 'SOUTH'>, <Ordinal.EAST: 'EAST'>, <Ordinal.WEST: 'WEST'>
↪]
```

Note: The goal of the default `_generate_next_value_()` methods is to provide the next *int* in sequence with the last *int* provided, but the way it does this is an implementation detail and may change.

8.13.7 Iteration

Iterating over the members of an enum does not provide the aliases:

```
>>> list(Shape)
[<Shape.SQUARE: 2>, <Shape.DIAMOND: 1>, <Shape.CIRCLE: 3>]
```

The special attribute `__members__` is an ordered dictionary mapping names to members. It includes all names defined in the enumeration, including the aliases:

```
>>> for name, member in Shape.__members__.items():
...     name, member
...
('SQUARE', <Shape.SQUARE: 2>)
('DIAMOND', <Shape.DIAMOND: 1>)
('CIRCLE', <Shape.CIRCLE: 3>)
('ALIAS_FOR_SQUARE', <Shape.SQUARE: 2>)
```

The `__members__` attribute can be used for detailed programmatic access to the enumeration members. For example, finding all the aliases:

```
>>> [name for name, member in Shape.__members__.items() if member.name != name]
['ALIAS_FOR_SQUARE']
```

8.13.8 Comparisons

Enumeration members are compared by identity:

```
>>> Color.RED is Color.RED
True
>>> Color.RED is Color.BLUE
False
>>> Color.RED is not Color.BLUE
True
```

Ordered comparisons between enumeration values are *not* supported. Enum members are not integers (but see *IntEnum* below):

```
>>> Color.RED < Color.BLUE
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: '<' not supported between instances of 'Color' and 'Color'
```

Equality comparisons are defined though:

```
>>> Color.BLUE == Color.RED
False
>>> Color.BLUE != Color.RED
True
>>> Color.BLUE == Color.BLUE
True
```

Comparisons against non-enumeration values will always compare not equal (again, *IntEnum* was explicitly designed to behave differently, see below):

```
>>> Color.BLUE == 2
False
```

8.13.9 Allowed members and attributes of enumerations

The examples above use integers for enumeration values. Using integers is short and handy (and provided by default by the *Functional API*), but not strictly enforced. In the vast majority of use-cases, one doesn't care what the actual value of an enumeration is. But if the value *is* important, enumerations can have arbitrary values.

Enumerations are Python classes, and can have methods and special methods as usual. If we have this enumeration:

```
>>> class Mood(Enum):
...     FUNKY = 1
...     HAPPY = 3
...
...     def describe(self):
...         # self is the member here
...         return self.name, self.value
...
...     def __str__(self):
...         return 'my custom str! {0}'.format(self.value)
...
...     @classmethod
```

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```
...     def favorite_mood(cls):
...         # cls here is the enumeration
...         return cls.HAPPY
...
```

Then:

```
>>> Mood.favorite_mood()
<Mood.HAPPY: 3>
>>> Mood.HAPPY.describe()
('HAPPY', 3)
>>> str(Mood.FUNKY)
'my custom str! 1'
```

The rules for what is allowed are as follows: names that start and end with a single underscore are reserved by enum and cannot be used; all other attributes defined within an enumeration will become members of this enumeration, with the exception of special methods (`__str__()`, `__add__()`, etc.), descriptors (methods are also descriptors), and variable names listed in `_ignore_`.

Note: if your enumeration defines `__new__()` and/or `__init__()` then whatever value(s) were given to the enum member will be passed into those methods. See *Planet* for an example.

8.13.10 Restricted subclassing of enumerations

Subclassing an enumeration is allowed only if the enumeration does not define any members. So this is forbidden:

```
>>> class MoreColor(Color):
...     PINK = 17
...
Traceback (most recent call last):
...
TypeError: Cannot extend enumerations
```

But this is allowed:

```
>>> class Foo(Enum):
...     def some_behavior(self):
...         pass
...
>>> class Bar(Foo):
...     HAPPY = 1
...     SAD = 2
...
```

Allowing subclassing of enums that define members would lead to a violation of some important invariants of types and instances. On the other hand, it makes sense to allow sharing some common behavior between a group of enumerations. (See *OrderedEnum* for an example.)

8.13.11 Pickling

Enumerations can be pickled and unpickled:

```
>>> from test.test_enum import Fruit
>>> from pickle import dumps, loads
>>> Fruit.TOMATO is loads(dumps(Fruit.TOMATO))
True
```

The usual restrictions for pickling apply: picklable enums must be defined in the top level of a module, since unpickling requires them to be importable from that module.

Note: With pickle protocol version 4 it is possible to easily pickle enums nested in other classes.

It is possible to modify how Enum members are pickled/unpickled by defining *__reduce_ex__()* in the enumeration class.

8.13.12 Functional API

The *Enum* class is callable, providing the following functional API:

```
>>> Animal = Enum('Animal', 'ANT BEE CAT DOG')
>>> Animal
<enum 'Animal'>
>>> Animal.ANT
<Animal.ANT: 1>
>>> Animal.ANT.value
1
>>> list(Animal)
[<Animal.ANT: 1>, <Animal.BEE: 2>, <Animal.CAT: 3>, <Animal.DOG: 4>]
```

The semantics of this API resemble *namedtuple*. The first argument of the call to *Enum* is the name of the enumeration.

The second argument is the *source* of enumeration member names. It can be a whitespace-separated string of names, a sequence of names, a sequence of 2-tuples with key/value pairs, or a mapping (e.g. dictionary) of names to values. The last two options enable assigning arbitrary values to enumerations; the others auto-assign increasing integers starting with 1 (use the `start` parameter to specify a different starting value). A new class derived from *Enum* is returned. In other words, the above assignment to `Animal` is equivalent to:

```
>>> class Animal(Enum):
...     ANT = 1
...     BEE = 2
...     CAT = 3
...     DOG = 4
...
```

The reason for defaulting to `1` as the starting number and not `0` is that `0` is `False` in a boolean sense, but enum members all evaluate to `True`.

Pickling enums created with the functional API can be tricky as frame stack implementation details are used to try and figure out which module the enumeration is being created in (e.g. it will fail if you use a utility function in separate module, and also may not work on IronPython or Jython). The solution is to specify the module name explicitly as follows:

```
>>> Animal = Enum('Animal', 'ANT BEE CAT DOG', module=__name__)
```

Warning: If `module` is not supplied, and Enum cannot determine what it is, the new Enum members will not be unpicklable; to keep errors closer to the source, pickling will be disabled.

The new pickle protocol 4 also, in some circumstances, relies on *__qualname__* being set to the location where pickle will be able to find the class. For example, if the class was made available in class SomeData in the global scope:

```
>>> Animal = Enum('Animal', 'ANT BEE CAT DOG', qualname='SomeData.Animal')
```

The complete signature is:

```
Enum(value='NewEnumName', names=<...>, *, module='...', qualname='...', type=<mixed-in class>,␣
↪start=1)
```

value What the new Enum class will record as its name.

names The Enum members. This can be a whitespace or comma separated string (values will start at 1 unless otherwise specified):

```
'RED GREEN BLUE' | 'RED,GREEN,BLUE' | 'RED, GREEN, BLUE'
```

or an iterator of names:

```
['RED', 'GREEN', 'BLUE']
```

or an iterator of (name, value) pairs:

```
[('CYAN', 4), ('MAGENTA', 5), ('YELLOW', 6)]
```

or a mapping:

```
{'CHARTREUSE': 7, 'SEA_GREEN': 11, 'ROSEMARY': 42}
```

module name of module where new Enum class can be found.

qualname where in module new Enum class can be found.

type type to mix in to new Enum class.

start number to start counting at if only names are passed in.

Changed in version 3.5: The *start* parameter was added.

8.13.13 Derived Enumerations

IntEnum

The first variation of *Enum* that is provided is also a subclass of *int*. Members of an *IntEnum* can be compared to integers; by extension, integer enumerations of different types can also be compared to each other:

```
>>> from enum import IntEnum
>>> class Shape(IntEnum):
...     CIRCLE = 1
...     SQUARE = 2
...
>>> class Request(IntEnum):
...     POST = 1
```

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```
...     GET = 2
...
>>> Shape == 1
False
>>> Shape.CIRCLE == 1
True
>>> Shape.CIRCLE == Request.POST
True
```

However, they still can't be compared to standard *Enum* enumerations:

```
>>> class Shape(IntEnum):
...     CIRCLE = 1
...     SQUARE = 2
...
>>> class Color(Enum):
...     RED = 1
...     GREEN = 2
...
>>> Shape.CIRCLE == Color.RED
False
```

IntEnum values behave like integers in other ways you'd expect:

```
>>> int(Shape.CIRCLE)
1
>>> ['a', 'b', 'c'][Shape.CIRCLE]
'b'
>>> [i for i in range(Shape.SQUARE)]
[0, 1]
```

IntFlag

The next variation of *Enum* provided, *IntFlag*, is also based on *int*. The difference being *IntFlag* members can be combined using the bitwise operators (&, |, ^, ~) and the result is still an *IntFlag* member. However, as the name implies, *IntFlag* members also subclass *int* and can be used wherever an *int* is used. Any operation on an *IntFlag* member besides the bit-wise operations will lose the *IntFlag* membership.

New in version 3.6.

Sample *IntFlag* class:

```
>>> from enum import IntFlag
>>> class Perm(IntFlag):
...     R = 4
...     W = 2
...     X = 1
...
>>> Perm.R | Perm.W
<Perm.R|W: 6>
>>> Perm.R + Perm.W
6
>>> RW = Perm.R | Perm.W
>>> Perm.R in RW
True
```

It is also possible to name the combinations:

```
>>> class Perm(IntFlag):
...     R = 4
...     W = 2
...     X = 1
...     RWX = 7
>>> Perm.RWX
<Perm.RWX: 7>
>>> ~Perm.RWX
<Perm.-8: -8>
```

Another important difference between *IntFlag* and *Enum* is that if no flags are set (the value is 0), its boolean evaluation is *False*:

```
>>> Perm.R & Perm.X
<Perm.0: 0>
>>> bool(Perm.R & Perm.X)
False
```

Because *IntFlag* members are also subclasses of *int* they can be combined with them:

```
>>> Perm.X | 8
<Perm.8|X: 9>
```

Flag

The last variation is *Flag*. Like *IntFlag*, *Flag* members can be combined using the bitwise operators (&, |, ^, ~). Unlike *IntFlag*, they cannot be combined with, nor compared against, any other *Flag* enumeration, nor *int*. While it is possible to specify the values directly it is recommended to use *auto* as the value and let *Flag* select an appropriate value.

New in version 3.6.

Like *IntFlag*, if a combination of *Flag* members results in no flags being set, the boolean evaluation is *False*:

```
>>> from enum import Flag, auto
>>> class Color(Flag):
...     RED = auto()
...     BLUE = auto()
...     GREEN = auto()
...
>>> Color.RED & Color.GREEN
<Color.0: 0>
>>> bool(Color.RED & Color.GREEN)
False
```

Individual flags should have values that are powers of two (1, 2, 4, 8, ...), while combinations of flags won't:

```
>>> class Color(Flag):
...     RED = auto()
...     BLUE = auto()
...     GREEN = auto()
...     WHITE = RED | BLUE | GREEN
...
>>> Color.WHITE
<Color.WHITE: 7>
```

Giving a name to the "no flags set" condition does not change its boolean value:

```
>>> class Color(Flag):
...     BLACK = 0
...     RED = auto()
...     BLUE = auto()
...     GREEN = auto()
...
>>> Color.BLACK
<Color.BLACK: 0>
>>> bool(Color.BLACK)
False
```

Note: For the majority of new code, *Enum* and *Flag* are strongly recommended, since *IntEnum* and *IntFlag* break some semantic promises of an enumeration (by being comparable to integers, and thus by transitivity to other unrelated enumerations). *IntEnum* and *IntFlag* should be used only in cases where *Enum* and *Flag* will not do; for example, when integer constants are replaced with enumerations, or for interoperability with other systems.

Others

While *IntEnum* is part of the *enum* module, it would be very simple to implement independently:

```
class IntEnum(int, Enum):
    pass
```

This demonstrates how similar derived enumerations can be defined; for example a `StrEnum` that mixes in *str* instead of *int*.

Some rules:

1. When subclassing *Enum*, mix-in types must appear before *Enum* itself in the sequence of bases, as in the *IntEnum* example above.
2. While *Enum* can have members of any type, once you mix in an additional type, all the members must have values of that type, e.g. *int* above. This restriction does not apply to mix-ins which only add methods and don't specify another data type such as *int* or *str*.
3. When another data type is mixed in, the `value` attribute is *not the same* as the enum member itself, although it is equivalent and will compare equal.
4. %-style formatting: *%s* and *%r* call the *Enum* class's `__str__()` and `__repr__()` respectively; other codes (such as *%i* or *%h* for IntEnum) treat the enum member as its mixed-in type.
5. Formatted string literals, *str.format()*, and *format()* will use the mixed-in type's `__format__()`. If the *Enum* class's *str()* or *repr()* is desired, use the *!s* or *!r* format codes.

8.13.14 Interesting examples

While *Enum*, *IntEnum*, *IntFlag*, and *Flag* are expected to cover the majority of use-cases, they cannot cover them all. Here are recipes for some different types of enumerations that can be used directly, or as examples for creating one's own.

Omitting values

In many use-cases one doesn't care what the actual value of an enumeration is. There are several ways to define this type of simple enumeration:

- use instances of *auto* for the value
- use instances of *object* as the value
- use a descriptive string as the value
- use a tuple as the value and a custom `__new__()` to replace the tuple with an *int* value

Using any of these methods signifies to the user that these values are not important, and also enables one to add, remove, or reorder members without having to renumber the remaining members.

Whichever method you choose, you should provide a *repr()* that also hides the (unimportant) value:

```
>>> class NoValue(Enum):
...     def __repr__(self):
...         return '<%s.%s>' % (self.__class__.__name__, self.name)
...
```

Using `auto`

Using *auto* would look like:

```
>>> class Color(NoValue):
...     RED = auto()
...     BLUE = auto()
...     GREEN = auto()
...
>>> Color.GREEN
<Color.GREEN>
```

Using `object`

Using *object* would look like:

```
>>> class Color(NoValue):
...     RED = object()
...     GREEN = object()
...     BLUE = object()
...
>>> Color.GREEN
<Color.GREEN>
```

Using a descriptive string

Using a string as the value would look like:

```
>>> class Color(NoValue):
...     RED = 'stop'
...     GREEN = 'go'
...     BLUE = 'too fast!'
```

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```
...
>>> Color.GREEN
<Color.GREEN>
>>> Color.GREEN.value
'go'
```

Using a custom `__new__()`

Using an auto-numbering `__new__()` would look like:

```
>>> class AutoNumber(NoValue):
...     def __new__(cls):
...         value = len(cls.__members__) + 1
...         obj = object.__new__(cls)
...         obj._value_ = value
...         return obj
...
>>> class Color(AutoNumber):
...     RED = ()
...     GREEN = ()
...     BLUE = ()
...
>>> Color.GREEN
<Color.GREEN>
>>> Color.GREEN.value
2
```

Note: The `__new__()` method, if defined, is used during creation of the Enum members; it is then replaced by Enum's `__new__()` which is used after class creation for lookup of existing members.

OrderedEnum

An ordered enumeration that is not based on *IntEnum* and so maintains the normal *Enum* invariants (such as not being comparable to other enumerations):

```
>>> class OrderedEnum(Enum):
...     def __ge__(self, other):
...         if self.__class__ is other.__class__:
...             return self.value >= other.value
...         return NotImplemented
...     def __gt__(self, other):
...         if self.__class__ is other.__class__:
...             return self.value > other.value
...         return NotImplemented
...     def __le__(self, other):
...         if self.__class__ is other.__class__:
...             return self.value <= other.value
...         return NotImplemented
...     def __lt__(self, other):
...         if self.__class__ is other.__class__:
...             return self.value < other.value
...         return NotImplemented
```

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```
...
>>> class Grade(OrderedEnum):
...     A = 5
...     B = 4
...     C = 3
...     D = 2
...     F = 1
...
>>> Grade.C < Grade.A
True
```

DuplicateFreeEnum

Raises an error if a duplicate member name is found instead of creating an alias:

```
>>> class DuplicateFreeEnum(Enum):
...     def __init__(self, *args):
...         cls = self.__class__
...         if any(self.value == e.value for e in cls):
...             a = self.name
...             e = cls(self.value).name
...             raise ValueError(
...                 "aliases not allowed in DuplicateFreeEnum:  %r --> %r"
...                 % (a, e))
...
>>> class Color(DuplicateFreeEnum):
...     RED = 1
...     GREEN = 2
...     BLUE = 3
...     GRENE = 2
...
Traceback (most recent call last):
...
ValueError: aliases not allowed in DuplicateFreeEnum:  'GRENE' --> 'GREEN'
```

Note: This is a useful example for subclassing Enum to add or change other behaviors as well as disallowing aliases. If the only desired change is disallowing aliases, the *unique()* decorator can be used instead.

Planet

If `__new__()` or `__init__()` is defined the value of the enum member will be passed to those methods:

```
>>> class Planet(Enum):
...     MERCURY = (3.303e+23, 2.4397e6)
...     VENUS   = (4.869e+24, 6.0518e6)
...     EARTH   = (5.976e+24, 6.37814e6)
...     MARS    = (6.421e+23, 3.3972e6)
...     JUPITER = (1.9e+27,   7.1492e7)
...     SATURN  = (5.688e+26, 6.0268e7)
...     URANUS  = (8.686e+25, 2.5559e7)
...     NEPTUNE = (1.024e+26, 2.4746e7)
...     def __init__(self, mass, radius):
```

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```
...         self.mass = mass       # in kilograms
...         self.radius = radius   # in meters
...     @property
...     def surface_gravity(self):
...         # universal gravitational constant  (m3 kg-1 s-2)
...         G = 6.67300E-11
...         return G * self.mass / (self.radius * self.radius)
...
>>> Planet.EARTH.value
(5.976e+24, 6378140.0)
>>> Planet.EARTH.surface_gravity
9.802652743337129
```

TimePeriod

An example to show the `_ignore_` attribute in use:

```
>>> from datetime import timedelta
>>> class Period(timedelta, Enum):
...     "different lengths of time"
...     _ignore_ = 'Period i'
...     Period = vars()
...     for i in range(367):
...         Period['day_%d' % i] = i
...
>>> list(Period)[:2]
[<Period.day_0: datetime.timedelta(0)>, <Period.day_1: datetime.timedelta(days=1)>]
>>> list(Period)[-2:]
[<Period.day_365: datetime.timedelta(days=365)>, <Period.day_366: datetime.timedelta(days=366)>]
```

8.13.15 How are Enums different?

Enums have a custom metaclass that affects many aspects of both derived Enum classes and their instances (members).

Enum Classes

The `EnumMeta` metaclass is responsible for providing the `__contains__()`, `__dir__()`, `__iter__()` and other methods that allow one to do things with an *Enum* class that fail on a typical class, such as *list(Color)* or *some_enum_var in Color*. `EnumMeta` is responsible for ensuring that various other methods on the final *Enum* class are correct (such as `__new__()`, *__getnewargs__()*, `__str__()` and `__repr__()`).

Enum Members (aka instances)

The most interesting thing about Enum members is that they are singletons. `EnumMeta` creates them all while it is creating the *Enum* class itself, and then puts a custom `__new__()` in place to ensure that no new ones are ever instantiated by returning only the existing member instances.

Finer Points

Supported __dunder__ names

__members__ is an OrderedDict of member_name:member items. It is only available on the class.

__new__(), if specified, must create and return the enum members; it is also a very good idea to set the member's _value_ appropriately. Once all the members are created it is no longer used.

Supported _sunder_ names

- _name_ – name of the member
- _value_ – value of the member; can be set / modified in __new__
- _missing_ – a lookup function used when a value is not found; may be overridden
- _ignore_ – a list of names, either as a *list()* or a *str()*, that will not be transformed into members, and will be removed from the final class
- _order_ – used in Python 2/3 code to ensure member order is consistent (class attribute, removed during class creation)
- _generate_next_value_ – used by the *Functional API* and by *auto* to get an appropriate value for an enum member; may be overridden

New in version 3.6: _missing_, _order_, _generate_next_value_

New in version 3.7: _ignore_

To help keep Python 2 / Python 3 code in sync an _order_ attribute can be provided. It will be checked against the actual order of the enumeration and raise an error if the two do not match:

```
>>> class Color(Enum):
...     _order_ = 'RED GREEN BLUE'
...     RED = 1
...     BLUE = 3
...     GREEN = 2
...
Traceback (most recent call last):
...
TypeError: member order does not match _order_
```

Note: In Python 2 code the _order_ attribute is necessary as definition order is lost before it can be recorded.

Enum member type

Enum members are instances of their *Enum* class, and are normally accessed as EnumClass.member. Under certain circumstances they can also be accessed as EnumClass.member.member, but you should never do this as that lookup may fail or, worse, return something besides the *Enum* member you are looking for (this is another good reason to use all-uppercase names for members):

```
>>> class FieldTypes(Enum):
...     name = 0
...     value = 1
```

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```
...     size = 2
...
>>> FieldTypes.value.size
<FieldTypes.size: 2>
>>> FieldTypes.size.value
2
```

Changed in version 3.5.

Boolean value of `Enum` classes and members

Enum members that are mixed with non-*Enum* types (such as *int*, *str*, etc.) are evaluated according to the mixed-in type's rules; otherwise, all members evaluate as *True*. To make your own Enum's boolean evaluation depend on the member's value add the following to your class:

```
def __bool__(self):
    return bool(self.value)
```

Enum classes always evaluate as *True*.

`Enum` classes with methods

If you give your *Enum* subclass extra methods, like the *Planet* class above, those methods will show up in a *dir()* of the member, but not of the class:

```
>>> dir(Planet)
['EARTH', 'JUPITER', 'MARS', 'MERCURY', 'NEPTUNE', 'SATURN', 'URANUS', 'VENUS', '__class__', '__
↪doc__', '__members__', '__module__']
>>> dir(Planet.EARTH)
['__class__', '__doc__', '__module__', 'name', 'surface_gravity', 'value']
```

Combining members of `Flag`

If a combination of Flag members is not named, the *repr()* will include all named flags and all named combinations of flags that are in the value:

```
>>> class Color(Flag):
...     RED = auto()
...     GREEN = auto()
...     BLUE = auto()
...     MAGENTA = RED | BLUE
...     YELLOW = RED | GREEN
...     CYAN = GREEN | BLUE
...
>>> Color(3)  # named combination
<Color.YELLOW: 3>
>>> Color(7)      # not named combination
<Color.CYAN|MAGENTA|BLUE|YELLOW|GREEN|RED: 7>
```

CHAPTER

NINE

NUMERIC AND MATHEMATICAL MODULES

The modules described in this chapter provide numeric and math-related functions and data types. The *numbers* module defines an abstract hierarchy of numeric types. The *math* and *cmath* modules contain various mathematical functions for floating-point and complex numbers. The *decimal* module supports exact representations of decimal numbers, using arbitrary precision arithmetic.

The following modules are documented in this chapter:

9.1 numbers — Numeric abstract base classes

Source code: Lib/numbers.py

The *numbers* module (**PEP 3141**) defines a hierarchy of numeric *abstract base classes* which progressively define more operations. None of the types defined in this module can be instantiated.

class numbers.Number
The root of the numeric hierarchy. If you just want to check if an argument x is a number, without caring what kind, use `isinstance(x, Number)`.

9.1.1 The numeric tower

class numbers.Complex
Subclasses of this type describe complex numbers and include the operations that work on the built-in *complex* type. These are: conversions to *complex* and *bool*, *real*, *imag*, `+`, `-`, `*`, `/`, *abs()*, *conjugate()*, `==`, and `!=`. All except `-` and `!=` are abstract.

real
Abstract. Retrieves the real component of this number.

imag
Abstract. Retrieves the imaginary component of this number.

abstractmethod conjugate()
Abstract. Returns the complex conjugate. For example, `(1+3j).conjugate() == (1-3j)`.

class numbers.Real
To *Complex*, *Real* adds the operations that work on real numbers.

In short, those are: a conversion to *float*, *math.trunc()*, *round()*, *math.floor()*, *math.ceil()*, *divmod()*, `//`, `%`, `<`, `<=`, `>`, and `>=`.

Real also provides defaults for *complex()*, *real*, *imag*, and *conjugate()*.

class numbers.Rational
Subtypes *Real* and adds *numerator* and *denominator* properties, which should be in lowest terms. With these, it provides a default for *float()*.

numerator
Abstract.

denominator
Abstract.

class numbers.Integral
Subtypes *Rational* and adds a conversion to *int*. Provides defaults for *float()*, *numerator*, and *denominator*. Adds abstract methods for `**` and bit-string operations: `<<`, `>>`, `&`, `^`, `|`, `~`.

9.1.2 Notes for type implementors

Implementors should be careful to make equal numbers equal and hash them to the same values. This may be subtle if there are two different extensions of the real numbers. For example, *fractions.Fraction* implements *hash()* as follows:

```
def __hash__(self):
    if self.denominator == 1:
        # Get integers right.
        return hash(self.numerator)
    # Expensive check, but definitely correct.
    if self == float(self):
        return hash(float(self))
    else:
        # Use tuple's hash to avoid a high collision rate on
        # simple fractions.
        return hash((self.numerator, self.denominator))
```

Adding More Numeric ABCs

There are, of course, more possible ABCs for numbers, and this would be a poor hierarchy if it precluded the possibility of adding those. You can add `MyFoo` between *Complex* and *Real* with:

```
class MyFoo(Complex): ...
MyFoo.register(Real)
```

Implementing the arithmetic operations

We want to implement the arithmetic operations so that mixed-mode operations either call an implementation whose author knew about the types of both arguments, or convert both to the nearest built in type and do the operation there. For subtypes of *Integral*, this means that `__add__()` and `__radd__()` should be defined as:

```
class MyIntegral(Integral):

    def __add__(self, other):
        if isinstance(other, MyIntegral):
            return do_my_adding_stuff(self, other)
        elif isinstance(other, OtherTypeIKnowAbout):
            return do_my_other_adding_stuff(self, other)
```

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```
        else:
            return NotImplemented

    def __radd__(self, other):
        if isinstance(other, MyIntegral):
            return do_my_adding_stuff(other, self)
        elif isinstance(other, OtherTypeIKnowAbout):
            return do_my_other_adding_stuff(other, self)
        elif isinstance(other, Integral):
            return int(other) + int(self)
        elif isinstance(other, Real):
            return float(other) + float(self)
        elif isinstance(other, Complex):
            return complex(other) + complex(self)
        else:
            return NotImplemented
```

There are 5 different cases for a mixed-type operation on subclasses of *Complex*. I'll refer to all of the above code that doesn't refer to `MyIntegral` and `OtherTypeIKnowAbout` as "boilerplate". `a` will be an instance of `A`, which is a subtype of *Complex* (`a : A <: Complex`), and `b : B <: Complex`. I'll consider `a + b`:

1. If `A` defines an `__add__()` which accepts `b`, all is well.
2. If `A` falls back to the boilerplate code, and it were to return a value from `__add__()`, we'd miss the possibility that `B` defines a more intelligent `__radd__()`, so the boilerplate should return *NotImplemented* from `__add__()`. (Or `A` may not implement `__add__()` at all.)
3. Then `B`'s `__radd__()` gets a chance. If it accepts `a`, all is well.
4. If it falls back to the boilerplate, there are no more possible methods to try, so this is where the default implementation should live.
5. If `B <: A`, Python tries `B.__radd__` before `A.__add__`. This is ok, because it was implemented with knowledge of `A`, so it can handle those instances before delegating to *Complex*.

If `A <: Complex` and `B <: Real` without sharing any other knowledge, then the appropriate shared operation is the one involving the built in *complex*, and both `__radd__()` s land there, so `a+b == b+a`.

Because most of the operations on any given type will be very similar, it can be useful to define a helper function which generates the forward and reverse instances of any given operator. For example, *fractions.Fraction* uses:

```
def _operator_fallbacks(monomorphic_operator, fallback_operator):
    def forward(a, b):
        if isinstance(b, (int, Fraction)):
            return monomorphic_operator(a, b)
        elif isinstance(b, float):
            return fallback_operator(float(a), b)
        elif isinstance(b, complex):
            return fallback_operator(complex(a), b)
        else:
            return NotImplemented
    forward.__name__ = '__' + fallback_operator.__name__ + '__'
    forward.__doc__ = monomorphic_operator.__doc__

    def reverse(b, a):
        if isinstance(a, Rational):
            # Includes ints.
            return monomorphic_operator(a, b)
```

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```
        elif isinstance(a, numbers.Real):
            return fallback_operator(float(a), float(b))
        elif isinstance(a, numbers.Complex):
            return fallback_operator(complex(a), complex(b))
        else:
            return NotImplemented
    reverse.__name__ = '__r' + fallback_operator.__name__ + '__'
    reverse.__doc__ = monomorphic_operator.__doc__

    return forward, reverse

def _add(a, b):
    """a + b"""
    return Fraction(a.numerator * b.denominator +
                    b.numerator * a.denominator,
                    a.denominator * b.denominator)

__add__, __radd__ = _operator_fallbacks(_add, operator.add)

# ...
```

9.2 `math` — Mathematical functions

This module is always available. It provides access to the mathematical functions defined by the C standard.

These functions cannot be used with complex numbers; use the functions of the same name from the *cmath* module if you require support for complex numbers. The distinction between functions which support complex numbers and those which don't is made since most users do not want to learn quite as much mathematics as required to understand complex numbers. Receiving an exception instead of a complex result allows earlier detection of the unexpected complex number used as a parameter, so that the programmer can determine how and why it was generated in the first place.

The following functions are provided by this module. Except when explicitly noted otherwise, all return values are floats.

9.2.1 Number-theoretic and representation functions

math.ceil(*x*)
: Return the ceiling of *x*, the smallest integer greater than or equal to *x*. If *x* is not a float, delegates to `x.__ceil__()`, which should return an *Integral* value.

math.copysign(*x*, *y*)
: Return a float with the magnitude (absolute value) of *x* but the sign of *y*. On platforms that support signed zeros, `copysign(1.0, -0.0)` returns *-1.0*.

math.fabs(*x*)
: Return the absolute value of *x*.

math.factorial(*x*)
: Return *x* factorial. Raises *ValueError* if *x* is not integral or is negative.

math.floor(*x*)
: Return the floor of *x*, the largest integer less than or equal to *x*. If *x* is not a float, delegates to `x.__floor__()`, which should return an *Integral* value.

math.fmod(*x*, *y*)
Return `fmod(x, y)`, as defined by the platform C library. Note that the Python expression `x % y` may not return the same result. The intent of the C standard is that `fmod(x, y)` be exactly (mathematically; to infinite precision) equal to `x - n*y` for some integer *n* such that the result has the same sign as *x* and magnitude less than `abs(y)`. Python's `x % y` returns a result with the sign of *y* instead, and may not be exactly computable for float arguments. For example, `fmod(-1e-100, 1e100)` is `-1e-100`, but the result of Python's `-1e-100 % 1e100` is `1e100-1e-100`, which cannot be represented exactly as a float, and rounds to the surprising `1e100`. For this reason, function *fmod()* is generally preferred when working with floats, while Python's `x % y` is preferred when working with integers.

math.frexp(*x*)
Return the mantissa and exponent of *x* as the pair `(m, e)`. *m* is a float and *e* is an integer such that `x == m * 2**e` exactly. If *x* is zero, returns `(0.0, 0)`, otherwise `0.5 <= abs(m) < 1`. This is used to "pick apart" the internal representation of a float in a portable way.

math.fsum(*iterable*)
Return an accurate floating point sum of values in the iterable. Avoids loss of precision by tracking multiple intermediate partial sums:

```
>>> sum([.1, .1, .1, .1, .1, .1, .1, .1, .1, .1])
0.9999999999999999
>>> fsum([.1, .1, .1, .1, .1, .1, .1, .1, .1, .1])
1.0
```

The algorithm's accuracy depends on IEEE-754 arithmetic guarantees and the typical case where the rounding mode is half-even. On some non-Windows builds, the underlying C library uses extended precision addition and may occasionally double-round an intermediate sum causing it to be off in its least significant bit.

For further discussion and two alternative approaches, see the ASPN cookbook recipes for accurate floating point summation.

math.gcd(*a*, *b*)
Return the greatest common divisor of the integers *a* and *b*. If either *a* or *b* is nonzero, then the value of `gcd(a, b)` is the largest positive integer that divides both *a* and *b*. `gcd(0, 0)` returns `0`.

New in version 3.5.

math.isclose(*a*, *b*, ***, *rel_tol=1e-09*, *abs_tol=0.0*)
Return `True` if the values *a* and *b* are close to each other and `False` otherwise.

Whether or not two values are considered close is determined according to given absolute and relative tolerances.

rel_tol is the relative tolerance – it is the maximum allowed difference between *a* and *b*, relative to the larger absolute value of *a* or *b*. For example, to set a tolerance of 5%, pass `rel_tol=0.05`. The default tolerance is `1e-09`, which assures that the two values are the same within about 9 decimal digits. *rel_tol* must be greater than zero.

abs_tol is the minimum absolute tolerance – useful for comparisons near zero. *abs_tol* must be at least zero.

If no errors occur, the result will be: `abs(a-b) <= max(rel_tol * max(abs(a), abs(b)), abs_tol)`.

The IEEE 754 special values of `NaN`, `inf`, and `-inf` will be handled according to IEEE rules. Specifically, `NaN` is not considered close to any other value, including `NaN`. `inf` and `-inf` are only considered close to themselves.

New in version 3.5.

See also:

PEP 485 – A function for testing approximate equality

`math.isfinite(x)`
Return `True` if x is neither an infinity nor a NaN, and `False` otherwise. (Note that `0.0` *is* considered finite.)

New in version 3.2.

`math.isinf(x)`
Return `True` if x is a positive or negative infinity, and `False` otherwise.

`math.isnan(x)`
Return `True` if x is a NaN (not a number), and `False` otherwise.

`math.ldexp(x, i)`
Return `x * (2**i)`. This is essentially the inverse of function *frexp()*.

`math.modf(x)`
Return the fractional and integer parts of x. Both results carry the sign of x and are floats.

`math.remainder(x, y)`
Return the IEEE 754-style remainder of x with respect to y. For finite x and finite nonzero y, this is the difference `x - n*y`, where `n` is the closest integer to the exact value of the quotient `x / y`. If `x / y` is exactly halfway between two consecutive integers, the nearest *even* integer is used for `n`. The remainder `r = remainder(x, y)` thus always satisfies `abs(r) <= 0.5 * abs(y)`.

Special cases follow IEEE 754: in particular, `remainder(x, math.inf)` is x for any finite x, and `remainder(x, 0)` and `remainder(math.inf, x)` raise *ValueError* for any non-NaN x. If the result of the remainder operation is zero, that zero will have the same sign as x.

On platforms using IEEE 754 binary floating-point, the result of this operation is always exactly representable: no rounding error is introduced.

New in version 3.7.

`math.trunc(x)`
Return the *Real* value x truncated to an *Integral* (usually an integer). Delegates to `x.__trunc__()`.

Note that *frexp()* and *modf()* have a different call/return pattern than their C equivalents: they take a single argument and return a pair of values, rather than returning their second return value through an 'output parameter' (there is no such thing in Python).

For the *ceil()*, *floor()*, and *modf()* functions, note that *all* floating-point numbers of sufficiently large magnitude are exact integers. Python floats typically carry no more than 53 bits of precision (the same as the platform C double type), in which case any float x with `abs(x) >= 2**52` necessarily has no fractional bits.

9.2.2 Power and logarithmic functions

`math.exp(x)`
Return e raised to the power x, where $e = 2.718281\ldots$ is the base of natural logarithms. This is usually more accurate than `math.e ** x` or `pow(math.e, x)`.

`math.expm1(x)`
Return e raised to the power x, minus 1. Here e is the base of natural logarithms. For small floats x, the subtraction in `exp(x) - 1` can result in a significant loss of precision; the *expm1()* function provides a way to compute this quantity to full precision:

```
>>> from math import exp, expm1
>>> exp(1e-5) - 1  # gives result accurate to 11 places
1.0000050000069649e-05
```

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```
>>> expm1(1e-5)    # result accurate to full precision
1.0000050000166668e-05
```

New in version 3.2.

`math.log`(*x*[, *base*])
With one argument, return the natural logarithm of *x* (to base *e*).

With two arguments, return the logarithm of *x* to the given *base*, calculated as `log(x)/log(base)`.

`math.log1p`(*x*)
Return the natural logarithm of *1+x* (base *e*). The result is calculated in a way which is accurate for *x* near zero.

`math.log2`(*x*)
Return the base-2 logarithm of *x*. This is usually more accurate than `log(x, 2)`.

New in version 3.3.

See also:

`int.bit_length()` returns the number of bits necessary to represent an integer in binary, excluding the sign and leading zeros.

`math.log10`(*x*)
Return the base-10 logarithm of *x*. This is usually more accurate than `log(x, 10)`.

`math.pow`(*x*, *y*)
Return `x` raised to the power `y`. Exceptional cases follow Annex 'F' of the C99 standard as far as possible. In particular, `pow(1.0, x)` and `pow(x, 0.0)` always return `1.0`, even when `x` is a zero or a NaN. If both `x` and `y` are finite, `x` is negative, and `y` is not an integer then `pow(x, y)` is undefined, and raises *`ValueError`*.

Unlike the built-in `**` operator, *`math.pow()`* converts both its arguments to type *`float`*. Use `**` or the built-in *`pow()`* function for computing exact integer powers.

`math.sqrt`(*x*)
Return the square root of *x*.

9.2.3 Trigonometric functions

`math.acos`(*x*)
Return the arc cosine of *x*, in radians.

`math.asin`(*x*)
Return the arc sine of *x*, in radians.

`math.atan`(*x*)
Return the arc tangent of *x*, in radians.

`math.atan2`(*y*, *x*)
Return `atan(y / x)`, in radians. The result is between `-pi` and `pi`. The vector in the plane from the origin to point `(x, y)` makes this angle with the positive X axis. The point of *`atan2()`* is that the signs of both inputs are known to it, so it can compute the correct quadrant for the angle. For example, `atan(1)` and `atan2(1, 1)` are both `pi/4`, but `atan2(-1, -1)` is `-3*pi/4`.

`math.cos`(*x*)
Return the cosine of *x* radians.

math.**hypot**(*x*, *y*)
Return the Euclidean norm, `sqrt(x*x + y*y)`. This is the length of the vector from the origin to point `(x, y)`.

math.**sin**(*x*)
Return the sine of *x* radians.

math.**tan**(*x*)
Return the tangent of *x* radians.

9.2.4 Angular conversion

math.**degrees**(*x*)
Convert angle *x* from radians to degrees.

math.**radians**(*x*)
Convert angle *x* from degrees to radians.

9.2.5 Hyperbolic functions

Hyperbolic functions are analogs of trigonometric functions that are based on hyperbolas instead of circles.

math.**acosh**(*x*)
Return the inverse hyperbolic cosine of *x*.

math.**asinh**(*x*)
Return the inverse hyperbolic sine of *x*.

math.**atanh**(*x*)
Return the inverse hyperbolic tangent of *x*.

math.**cosh**(*x*)
Return the hyperbolic cosine of *x*.

math.**sinh**(*x*)
Return the hyperbolic sine of *x*.

math.**tanh**(*x*)
Return the hyperbolic tangent of *x*.

9.2.6 Special functions

math.**erf**(*x*)
Return the error function at *x*.

The *erf()* function can be used to compute traditional statistical functions such as the cumulative standard normal distribution:

```
def phi(x):
    'Cumulative distribution function for the standard normal distribution'
    return (1.0 + erf(x / sqrt(2.0))) / 2.0
```

New in version 3.2.

math.**erfc**(*x*)
Return the complementary error function at *x*. The complementary error function is defined as `1.0 - erf(x)`. It is used for large values of *x* where a subtraction from one would cause a loss of significance.

New in version 3.2.

`math.gamma(`*x*`)`
Return the Gamma function at *x*.

New in version 3.2.

`math.lgamma(`*x*`)`
Return the natural logarithm of the absolute value of the Gamma function at *x*.

New in version 3.2.

9.2.7 Constants

`math.pi`
The mathematical constant $\pi = 3.141592\ldots$, to available precision.

`math.e`
The mathematical constant $e = 2.718281\ldots$, to available precision.

`math.tau`
The mathematical constant $\tau = 6.283185\ldots$, to available precision. Tau is a circle constant equal to 2π, the ratio of a circle's circumference to its radius. To learn more about Tau, check out Vi Hart's video Pi is (still) Wrong, and start celebrating Tau day by eating twice as much pie!

New in version 3.6.

`math.inf`
A floating-point positive infinity. (For negative infinity, use `-math.inf`.) Equivalent to the output of `float('inf')`.

New in version 3.5.

`math.nan`
A floating-point "not a number" (NaN) value. Equivalent to the output of `float('nan')`.

New in version 3.5.

CPython implementation detail: The *math* module consists mostly of thin wrappers around the platform C math library functions. Behavior in exceptional cases follows Annex F of the C99 standard where appropriate. The current implementation will raise *ValueError* for invalid operations like `sqrt(-1.0)` or `log(0.0)` (where C99 Annex F recommends signaling invalid operation or divide-by-zero), and *OverflowError* for results that overflow (for example, `exp(1000.0)`). A NaN will not be returned from any of the functions above unless one or more of the input arguments was a NaN; in that case, most functions will return a NaN, but (again following C99 Annex F) there are some exceptions to this rule, for example `pow(float('nan'), 0.0)` or `hypot(float('nan'), float('inf'))`.

Note that Python makes no effort to distinguish signaling NaNs from quiet NaNs, and behavior for signaling NaNs remains unspecified. Typical behavior is to treat all NaNs as though they were quiet.

See also:

Module *cmath* Complex number versions of many of these functions.

9.3 `cmath` — Mathematical functions for complex numbers

This module is always available. It provides access to mathematical functions for complex numbers. The functions in this module accept integers, floating-point numbers or complex numbers as arguments. They will also accept any Python object that has either a `__complex__()` or a `__float__()` method: these methods

are used to convert the object to a complex or floating-point number, respectively, and the function is then applied to the result of the conversion.

Note: On platforms with hardware and system-level support for signed zeros, functions involving branch cuts are continuous on *both* sides of the branch cut: the sign of the zero distinguishes one side of the branch cut from the other. On platforms that do not support signed zeros the continuity is as specified below.

9.3.1 Conversions to and from polar coordinates

A Python complex number `z` is stored internally using *rectangular* or *Cartesian* coordinates. It is completely determined by its *real part* `z.real` and its *imaginary part* `z.imag`. In other words:

```
z == z.real + z.imag*1j
```

Polar coordinates give an alternative way to represent a complex number. In polar coordinates, a complex number z is defined by the modulus r and the phase angle *phi*. The modulus r is the distance from z to the origin, while the phase *phi* is the counterclockwise angle, measured in radians, from the positive x-axis to the line segment that joins the origin to z.

The following functions can be used to convert from the native rectangular coordinates to polar coordinates and back.

`cmath.phase(`x`)`
: Return the phase of x (also known as the *argument* of x), as a float. `phase(x)` is equivalent to `math.atan2(x.imag, x.real)`. The result lies in the range [$-\pi$, π], and the branch cut for this operation lies along the negative real axis, continuous from above. On systems with support for signed zeros (which includes most systems in current use), this means that the sign of the result is the same as the sign of `x.imag`, even when `x.imag` is zero:

```
>>> phase(complex(-1.0, 0.0))
3.141592653589793
>>> phase(complex(-1.0, -0.0))
-3.141592653589793
```

Note: The modulus (absolute value) of a complex number x can be computed using the built-in *abs()* function. There is no separate *cmath* module function for this operation.

`cmath.polar(`x`)`
: Return the representation of x in polar coordinates. Returns a pair `(r, phi)` where r is the modulus of x and phi is the phase of x. `polar(x)` is equivalent to `(abs(x), phase(x))`.

`cmath.rect(`r, *phi*`)`
: Return the complex number x with polar coordinates r and *phi*. Equivalent to `r * (math.cos(phi) + math.sin(phi)*1j)`.

9.3.2 Power and logarithmic functions

`cmath.exp(`x`)`
: Return e raised to the power x, where e is the base of natural logarithms.

`cmath.log(`x[, *base*]`)`
: Returns the logarithm of x to the given *base*. If the *base* is not specified, returns the natural logarithm of x. There is one branch cut, from 0 along the negative real axis to $-\infty$, continuous from above.

cmath.log10(*x*)
Return the base-10 logarithm of *x*. This has the same branch cut as *log()*.

cmath.sqrt(*x*)
Return the square root of *x*. This has the same branch cut as *log()*.

9.3.3 Trigonometric functions

cmath.acos(*x*)
Return the arc cosine of *x*. There are two branch cuts: One extends right from 1 along the real axis to ∞, continuous from below. The other extends left from -1 along the real axis to -∞, continuous from above.

cmath.asin(*x*)
Return the arc sine of *x*. This has the same branch cuts as *acos()*.

cmath.atan(*x*)
Return the arc tangent of *x*. There are two branch cuts: One extends from `1j` along the imaginary axis to ∞`j`, continuous from the right. The other extends from `-1j` along the imaginary axis to -∞`j`, continuous from the left.

cmath.cos(*x*)
Return the cosine of *x*.

cmath.sin(*x*)
Return the sine of *x*.

cmath.tan(*x*)
Return the tangent of *x*.

9.3.4 Hyperbolic functions

cmath.acosh(*x*)
Return the inverse hyperbolic cosine of *x*. There is one branch cut, extending left from 1 along the real axis to -∞, continuous from above.

cmath.asinh(*x*)
Return the inverse hyperbolic sine of *x*. There are two branch cuts: One extends from `1j` along the imaginary axis to ∞`j`, continuous from the right. The other extends from `-1j` along the imaginary axis to -∞`j`, continuous from the left.

cmath.atanh(*x*)
Return the inverse hyperbolic tangent of *x*. There are two branch cuts: One extends from `1` along the real axis to ∞, continuous from below. The other extends from `-1` along the real axis to -∞, continuous from above.

cmath.cosh(*x*)
Return the hyperbolic cosine of *x*.

cmath.sinh(*x*)
Return the hyperbolic sine of *x*.

cmath.tanh(*x*)
Return the hyperbolic tangent of *x*.

9.3.5 Classification functions

`cmath.isfinite(x)`
Return `True` if both the real and imaginary parts of x are finite, and `False` otherwise.

New in version 3.2.

`cmath.isinf(x)`
Return `True` if either the real or the imaginary part of x is an infinity, and `False` otherwise.

`cmath.isnan(x)`
Return `True` if either the real or the imaginary part of x is a NaN, and `False` otherwise.

`cmath.isclose(a, b, *, rel_tol=1e-09, abs_tol=0.0)`
Return `True` if the values a and b are close to each other and `False` otherwise.

Whether or not two values are considered close is determined according to given absolute and relative tolerances.

rel_tol is the relative tolerance – it is the maximum allowed difference between a and b, relative to the larger absolute value of a or b. For example, to set a tolerance of 5%, pass `rel_tol=0.05`. The default tolerance is `1e-09`, which assures that the two values are the same within about 9 decimal digits. *rel_tol* must be greater than zero.

abs_tol is the minimum absolute tolerance – useful for comparisons near zero. *abs_tol* must be at least zero.

If no errors occur, the result will be: `abs(a-b) <= max(rel_tol * max(abs(a), abs(b)), abs_tol)`.

The IEEE 754 special values of `NaN`, `inf`, and `-inf` will be handled according to IEEE rules. Specifically, `NaN` is not considered close to any other value, including `NaN`. `inf` and `-inf` are only considered close to themselves.

New in version 3.5.

See also:

PEP 485 – A function for testing approximate equality

9.3.6 Constants

`cmath.pi`
The mathematical constant π, as a float.

`cmath.e`
The mathematical constant e, as a float.

`cmath.tau`
The mathematical constant τ, as a float.

New in version 3.6.

`cmath.inf`
Floating-point positive infinity. Equivalent to `float('inf')`.

New in version 3.6.

`cmath.infj`
Complex number with zero real part and positive infinity imaginary part. Equivalent to `complex(0.0, float('inf'))`.

New in version 3.6.

`cmath.nan`
A floating-point "not a number" (NaN) value. Equivalent to `float('nan')`.

New in version 3.6.

`cmath.nanj`
Complex number with zero real part and NaN imaginary part. Equivalent to `complex(0.0, float('nan'))`.

New in version 3.6.

Note that the selection of functions is similar, but not identical, to that in module *math*. The reason for having two modules is that some users aren't interested in complex numbers, and perhaps don't even know what they are. They would rather have `math.sqrt(-1)` raise an exception than return a complex number. Also note that the functions defined in *cmath* always return a complex number, even if the answer can be expressed as a real number (in which case the complex number has an imaginary part of zero).

A note on branch cuts: They are curves along which the given function fails to be continuous. They are a necessary feature of many complex functions. It is assumed that if you need to compute with complex functions, you will understand about branch cuts. Consult almost any (not too elementary) book on complex variables for enlightenment. For information of the proper choice of branch cuts for numerical purposes, a good reference should be the following:

See also:

Kahan, W: Branch cuts for complex elementary functions; or, Much ado about nothing's sign bit. In Iserles, A., and Powell, M. (eds.), The state of the art in numerical analysis. Clarendon Press (1987) pp165–211.

9.4 `decimal` — Decimal fixed point and floating point arithmetic

Source code: Lib/decimal.py

The *decimal* module provides support for fast correctly-rounded decimal floating point arithmetic. It offers several advantages over the *float* datatype:

- Decimal "is based on a floating-point model which was designed with people in mind, and necessarily has a paramount guiding principle – computers must provide an arithmetic that works in the same way as the arithmetic that people learn at school." – excerpt from the decimal arithmetic specification.
- Decimal numbers can be represented exactly. In contrast, numbers like `1.1` and `2.2` do not have exact representations in binary floating point. End users typically would not expect `1.1 + 2.2` to display as `3.3000000000000003` as it does with binary floating point.
- The exactness carries over into arithmetic. In decimal floating point, `0.1 + 0.1 + 0.1 - 0.3` is exactly equal to zero. In binary floating point, the result is `5.5511151231257827e-017`. While near to zero, the differences prevent reliable equality testing and differences can accumulate. For this reason, decimal is preferred in accounting applications which have strict equality invariants.
- The decimal module incorporates a notion of significant places so that `1.30 + 1.20` is `2.50`. The trailing zero is kept to indicate significance. This is the customary presentation for monetary applications. For multiplication, the "schoolbook" approach uses all the figures in the multiplicands. For instance, `1.3 * 1.2` gives `1.56` while `1.30 * 1.20` gives `1.5600`.
- Unlike hardware based binary floating point, the decimal module has a user alterable precision (defaulting to 28 places) which can be as large as needed for a given problem:

```
>>> from decimal import *
>>> getcontext().prec = 6
>>> Decimal(1) / Decimal(7)
Decimal('0.142857')
>>> getcontext().prec = 28
>>> Decimal(1) / Decimal(7)
Decimal('0.1428571428571428571428571429')
```

- Both binary and decimal floating point are implemented in terms of published standards. While the built-in float type exposes only a modest portion of its capabilities, the decimal module exposes all required parts of the standard. When needed, the programmer has full control over rounding and signal handling. This includes an option to enforce exact arithmetic by using exceptions to block any inexact operations.
- The decimal module was designed to support "without prejudice, both exact unrounded decimal arithmetic (sometimes called fixed-point arithmetic) and rounded floating-point arithmetic." – excerpt from the decimal arithmetic specification.

The module design is centered around three concepts: the decimal number, the context for arithmetic, and signals.

A decimal number is immutable. It has a sign, coefficient digits, and an exponent. To preserve significance, the coefficient digits do not truncate trailing zeros. Decimals also include special values such as `Infinity`, `-Infinity`, and `NaN`. The standard also differentiates `-0` from `+0`.

The context for arithmetic is an environment specifying precision, rounding rules, limits on exponents, flags indicating the results of operations, and trap enablers which determine whether signals are treated as exceptions. Rounding options include *ROUND_CEILING*, *ROUND_DOWN*, *ROUND_FLOOR*, *ROUND_HALF_DOWN*, *ROUND_HALF_EVEN*, *ROUND_HALF_UP*, *ROUND_UP*, and *ROUND_05UP*.

Signals are groups of exceptional conditions arising during the course of computation. Depending on the needs of the application, signals may be ignored, considered as informational, or treated as exceptions. The signals in the decimal module are: *Clamped*, *InvalidOperation*, *DivisionByZero*, *Inexact*, *Rounded*, *Subnormal*, *Overflow*, *Underflow* and *FloatOperation*.

For each signal there is a flag and a trap enabler. When a signal is encountered, its flag is set to one, then, if the trap enabler is set to one, an exception is raised. Flags are sticky, so the user needs to reset them before monitoring a calculation.

See also:

- IBM's General Decimal Arithmetic Specification, The General Decimal Arithmetic Specification.

9.4.1 Quick-start Tutorial

The usual start to using decimals is importing the module, viewing the current context with *getcontext()* and, if necessary, setting new values for precision, rounding, or enabled traps:

```
>>> from decimal import *
>>> getcontext()
Context(prec=28, rounding=ROUND_HALF_EVEN, Emin=-999999, Emax=999999,
        capitals=1, clamp=0, flags=[], traps=[Overflow, DivisionByZero,
        InvalidOperation])

>>> getcontext().prec = 7       # Set a new precision
```

Decimal instances can be constructed from integers, strings, floats, or tuples. Construction from an integer or a float performs an exact conversion of the value of that integer or float. Decimal numbers include special values such as `NaN` which stands for "Not a number", positive and negative `Infinity`, and `-0`:

```
>>> getcontext().prec = 28
>>> Decimal(10)
Decimal('10')
>>> Decimal('3.14')
Decimal('3.14')
>>> Decimal(3.14)
Decimal('3.140000000000000124344978758017532527446746826171875')
>>> Decimal((0, (3, 1, 4), -2))
Decimal('3.14')
>>> Decimal(str(2.0 ** 0.5))
Decimal('1.4142135623730951')
>>> Decimal(2) ** Decimal('0.5')
Decimal('1.4142135623730950488016887242')
>>> Decimal('NaN')
Decimal('NaN')
>>> Decimal('-Infinity')
Decimal('-Infinity')
```

If the *FloatOperation* signal is trapped, accidental mixing of decimals and floats in constructors or ordering comparisons raises an exception:

```
>>> c = getcontext()
>>> c.traps[FloatOperation] = True
>>> Decimal(3.14)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
decimal.FloatOperation: [<class 'decimal.FloatOperation'>]
>>> Decimal('3.5') < 3.7
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
decimal.FloatOperation: [<class 'decimal.FloatOperation'>]
>>> Decimal('3.5') == 3.5
True
```

New in version 3.3.

The significance of a new Decimal is determined solely by the number of digits input. Context precision and rounding only come into play during arithmetic operations.

```
>>> getcontext().prec = 6
>>> Decimal('3.0')
Decimal('3.0')
>>> Decimal('3.1415926535')
Decimal('3.1415926535')
>>> Decimal('3.1415926535') + Decimal('2.7182818285')
Decimal('5.85987')
>>> getcontext().rounding = ROUND_UP
>>> Decimal('3.1415926535') + Decimal('2.7182818285')
Decimal('5.85988')
```

If the internal limits of the C version are exceeded, constructing a decimal raises *InvalidOperation*:

```
>>> Decimal("1e9999999999999999999")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
decimal.InvalidOperation: [<class 'decimal.InvalidOperation'>]
```

Changed in version 3.3.

Decimals interact well with much of the rest of Python. Here is a small decimal floating point flying circus:

```
>>> data = list(map(Decimal, '1.34 1.87 3.45 2.35 1.00 0.03 9.25'.split()))
>>> max(data)
Decimal('9.25')
>>> min(data)
Decimal('0.03')
>>> sorted(data)
[Decimal('0.03'), Decimal('1.00'), Decimal('1.34'), Decimal('1.87'),
 Decimal('2.35'), Decimal('3.45'), Decimal('9.25')]
>>> sum(data)
Decimal('19.29')
>>> a,b,c = data[:3]
>>> str(a)
'1.34'
>>> float(a)
1.34
>>> round(a, 1)
Decimal('1.3')
>>> int(a)
1
>>> a * 5
Decimal('6.70')
>>> a * b
Decimal('2.5058')
>>> c % a
Decimal('0.77')
```

And some mathematical functions are also available to Decimal:

```
>>> getcontext().prec = 28
>>> Decimal(2).sqrt()
Decimal('1.4142135623730950488016887242')
>>> Decimal(1).exp()
Decimal('2.7182818284590452353602874713')
>>> Decimal('10').ln()
Decimal('2.3025850929940456840179914547')
>>> Decimal('10').log10()
Decimal('1')
```

The `quantize()` method rounds a number to a fixed exponent. This method is useful for monetary applications that often round results to a fixed number of places:

```
>>> Decimal('7.325').quantize(Decimal('.01'), rounding=ROUND_DOWN)
Decimal('7.32')
>>> Decimal('7.325').quantize(Decimal('1.'), rounding=ROUND_UP)
Decimal('8')
```

As shown above, the *getcontext()* function accesses the current context and allows the settings to be changed. This approach meets the needs of most applications.

For more advanced work, it may be useful to create alternate contexts using the Context() constructor. To make an alternate active, use the *setcontext()* function.

In accordance with the standard, the *decimal* module provides two ready to use standard contexts, *BasicContext* and *ExtendedContext*. The former is especially useful for debugging because many of the traps are enabled:

```
>>> myothercontext = Context(prec=60, rounding=ROUND_HALF_DOWN)
>>> setcontext(myothercontext)
>>> Decimal(1) / Decimal(7)
Decimal('0.142857142857142857142857142857142857142857142857142857142857')

>>> ExtendedContext
Context(prec=9, rounding=ROUND_HALF_EVEN, Emin=-999999, Emax=999999,
        capitals=1, clamp=0, flags=[], traps=[])
>>> setcontext(ExtendedContext)
>>> Decimal(1) / Decimal(7)
Decimal('0.142857143')
>>> Decimal(42) / Decimal(0)
Decimal('Infinity')

>>> setcontext(BasicContext)
>>> Decimal(42) / Decimal(0)
Traceback (most recent call last):
  File "<pyshell#143>", line 1, in -toplevel-
    Decimal(42) / Decimal(0)
DivisionByZero: x / 0
```

Contexts also have signal flags for monitoring exceptional conditions encountered during computations. The flags remain set until explicitly cleared, so it is best to clear the flags before each set of monitored computations by using the `clear_flags()` method.

```
>>> setcontext(ExtendedContext)
>>> getcontext().clear_flags()
>>> Decimal(355) / Decimal(113)
Decimal('3.14159292')
>>> getcontext()
Context(prec=9, rounding=ROUND_HALF_EVEN, Emin=-999999, Emax=999999,
        capitals=1, clamp=0, flags=[Inexact, Rounded], traps=[])
```

The *flags* entry shows that the rational approximation to `Pi` was rounded (digits beyond the context precision were thrown away) and that the result is inexact (some of the discarded digits were non-zero).

Individual traps are set using the dictionary in the `traps` field of a context:

```
>>> setcontext(ExtendedContext)
>>> Decimal(1) / Decimal(0)
Decimal('Infinity')
>>> getcontext().traps[DivisionByZero] = 1
>>> Decimal(1) / Decimal(0)
Traceback (most recent call last):
  File "<pyshell#112>", line 1, in -toplevel-
    Decimal(1) / Decimal(0)
DivisionByZero: x / 0
```

Most programs adjust the current context only once, at the beginning of the program. And, in many applications, data is converted to *Decimal* with a single cast inside a loop. With context set and decimals created, the bulk of the program manipulates the data no differently than with other Python numeric types.

9.4.2 Decimal objects

class decimal.**Decimal**(*value="0"*, *context=None*)

Construct a new *Decimal* object based from *value*.

value can be an integer, string, tuple, *float*, or another *Decimal* object. If no *value* is given, returns `Decimal('0')`. If *value* is a string, it should conform to the decimal numeric string syntax after leading and trailing whitespace characters, as well as underscores throughout, are removed:

```
sign           ::=  '+' | '-'
digit          ::=  '0' | '1' | '2' | '3' | '4' | '5' | '6' | '7' | '8' | '9'
indicator      ::=  'e' | 'E'
digits         ::=  digit [digit]...
decimal-part   ::=  digits '.' [digits] | ['.'] digits
exponent-part  ::=  indicator [sign] digits
infinity       ::=  'Infinity' | 'Inf'
nan            ::=  'NaN' [digits] | 'sNaN' [digits]
numeric-value  ::=  decimal-part [exponent-part] | infinity
numeric-string ::=  [sign] numeric-value | [sign] nan
```

Other Unicode decimal digits are also permitted where `digit` appears above. These include decimal digits from various other alphabets (for example, Arabic-Indic and Devanāgarī digits) along with the fullwidth digits `'\uff10'` through `'\uff19'`.

If *value* is a *tuple*, it should have three components, a sign (`0` for positive or `1` for negative), a *tuple* of digits, and an integer exponent. For example, `Decimal((0, (1, 4, 1, 4), -3))` returns `Decimal('1.414')`.

If *value* is a *float*, the binary floating point value is losslessly converted to its exact decimal equivalent. This conversion can often require 53 or more digits of precision. For example, `Decimal(float('1.1'))` converts to `Decimal('1.100000000000000088817841970012523233890533447265625')`.

The *context* precision does not affect how many digits are stored. That is determined exclusively by the number of digits in *value*. For example, `Decimal('3.00000')` records all five zeros even if the context precision is only three.

The purpose of the *context* argument is determining what to do if *value* is a malformed string. If the context traps *InvalidOperation*, an exception is raised; otherwise, the constructor returns a new Decimal with the value of `NaN`.

Once constructed, *Decimal* objects are immutable.

Changed in version 3.2: The argument to the constructor is now permitted to be a *float* instance.

Changed in version 3.3: *float* arguments raise an exception if the *FloatOperation* trap is set. By default the trap is off.

Changed in version 3.6: Underscores are allowed for grouping, as with integral and floating-point literals in code.

Decimal floating point objects share many properties with the other built-in numeric types such as *float* and *int*. All of the usual math operations and special methods apply. Likewise, decimal objects can be copied, pickled, printed, used as dictionary keys, used as set elements, compared, sorted, and coerced to another type (such as *float* or *int*).

There are some small differences between arithmetic on Decimal objects and arithmetic on integers and floats. When the remainder operator `%` is applied to Decimal objects, the sign of the result is the sign of the *dividend* rather than the sign of the divisor:

```
>>> (-7) % 4
1
>>> Decimal(-7) % Decimal(4)
Decimal('-3')
```

The integer division operator `//` behaves analogously, returning the integer part of the true quotient (truncating towards zero) rather than its floor, so as to preserve the usual identity `x == (x // y) * y + x % y`:

```
>>> -7 // 4
-2
>>> Decimal(-7) // Decimal(4)
Decimal('-1')
```

The `%` and `//` operators implement the `remainder` and `divide-integer` operations (respectively) as described in the specification.

Decimal objects cannot generally be combined with floats or instances of *fractions.Fraction* in arithmetic operations: an attempt to add a *Decimal* to a *float*, for example, will raise a *TypeError*. However, it is possible to use Python's comparison operators to compare a *Decimal* instance `x` with another number `y`. This avoids confusing results when doing equality comparisons between numbers of different types.

Changed in version 3.2: Mixed-type comparisons between *Decimal* instances and other numeric types are now fully supported.

In addition to the standard numeric properties, decimal floating point objects also have a number of specialized methods:

adjusted()
Return the adjusted exponent after shifting out the coefficient's rightmost digits until only the lead digit remains: `Decimal('321e+5').adjusted()` returns seven. Used for determining the position of the most significant digit with respect to the decimal point.

as_integer_ratio()
Return a pair `(n, d)` of integers that represent the given *Decimal* instance as a fraction, in lowest terms and with a positive denominator:

```
>>> Decimal('-3.14').as_integer_ratio()
(-157, 50)
```

The conversion is exact. Raise OverflowError on infinities and ValueError on NaNs.

New in version 3.6.

as_tuple()
Return a *named tuple* representation of the number: `DecimalTuple(sign, digits, exponent)`.

canonical()
Return the canonical encoding of the argument. Currently, the encoding of a *Decimal* instance is always canonical, so this operation returns its argument unchanged.

compare(*other*, *context=None*)
Compare the values of two Decimal instances. *compare()* returns a Decimal instance, and if either operand is a NaN then the result is a NaN:

```
a or b is a NaN  ==> Decimal('NaN')
a < b            ==> Decimal('-1')
a == b           ==> Decimal('0')
a > b            ==> Decimal('1')
```

compare_signal(*other*, *context=None*)
This operation is identical to the *compare()* method, except that all NaNs signal. That is, if neither operand is a signaling NaN then any quiet NaN operand is treated as though it were a signaling NaN.

compare_total(*other*, *context=None*)
Compare two operands using their abstract representation rather than their numerical value. Similar to the *compare()* method, but the result gives a total ordering on *Decimal* instances. Two

Decimal instances with the same numeric value but different representations compare unequal in this ordering:

```
>>> Decimal('12.0').compare_total(Decimal('12'))
Decimal('-1')
```

Quiet and signaling NaNs are also included in the total ordering. The result of this function is `Decimal('0')` if both operands have the same representation, `Decimal('-1')` if the first operand is lower in the total order than the second, and `Decimal('1')` if the first operand is higher in the total order than the second operand. See the specification for details of the total order.

This operation is unaffected by context and is quiet: no flags are changed and no rounding is performed. As an exception, the C version may raise InvalidOperation if the second operand cannot be converted exactly.

compare_total_mag(*other*, *context=None*)
Compare two operands using their abstract representation rather than their value as in *compare_total()*, but ignoring the sign of each operand. `x.compare_total_mag(y)` is equivalent to `x.copy_abs().compare_total(y.copy_abs())`.

This operation is unaffected by context and is quiet: no flags are changed and no rounding is performed. As an exception, the C version may raise InvalidOperation if the second operand cannot be converted exactly.

conjugate()
Just returns self, this method is only to comply with the Decimal Specification.

copy_abs()
Return the absolute value of the argument. This operation is unaffected by the context and is quiet: no flags are changed and no rounding is performed.

copy_negate()
Return the negation of the argument. This operation is unaffected by the context and is quiet: no flags are changed and no rounding is performed.

copy_sign(*other*, *context=None*)
Return a copy of the first operand with the sign set to be the same as the sign of the second operand. For example:

```
>>> Decimal('2.3').copy_sign(Decimal('-1.5'))
Decimal('-2.3')
```

This operation is unaffected by context and is quiet: no flags are changed and no rounding is performed. As an exception, the C version may raise InvalidOperation if the second operand cannot be converted exactly.

exp(*context=None*)
Return the value of the (natural) exponential function `e**x` at the given number. The result is correctly rounded using the *ROUND_HALF_EVEN* rounding mode.

```
>>> Decimal(1).exp()
Decimal('2.718281828459045235360287471')
>>> Decimal(321).exp()
Decimal('2.561702493119680037517373933E+139')
```

from_float(*f*)
Classmethod that converts a float to a decimal number, exactly.

Note *Decimal.from_float(0.1)* is not the same as *Decimal('0.1')*. Since 0.1 is not exactly representable in binary floating point, the value is stored as the nearest rep-

resentable value which is *0x1.999999999999ap-4*. That equivalent value in decimal is *0.1000000000000000055511151231257827021181583404541015625*.

Note: From Python 3.2 onwards, a `Decimal` instance can also be constructed directly from a `float`.

```
>>> Decimal.from_float(0.1)
Decimal('0.1000000000000000055511151231257827021181583404541015625')
>>> Decimal.from_float(float('nan'))
Decimal('NaN')
>>> Decimal.from_float(float('inf'))
Decimal('Infinity')
>>> Decimal.from_float(float('-inf'))
Decimal('-Infinity')
```

New in version 3.1.

fma(*other*, *third*, *context=None*)
Fused multiply-add. Return self*other+third with no rounding of the intermediate product self*other.

```
>>> Decimal(2).fma(3, 5)
Decimal('11')
```

is_canonical()
Return `True` if the argument is canonical and `False` otherwise. Currently, a `Decimal` instance is always canonical, so this operation always returns `True`.

is_finite()
Return `True` if the argument is a finite number, and `False` if the argument is an infinity or a NaN.

is_infinite()
Return `True` if the argument is either positive or negative infinity and `False` otherwise.

is_nan()
Return `True` if the argument is a (quiet or signaling) NaN and `False` otherwise.

is_normal(*context=None*)
Return `True` if the argument is a *normal* finite number. Return `False` if the argument is zero, subnormal, infinite or a NaN.

is_qnan()
Return `True` if the argument is a quiet NaN, and `False` otherwise.

is_signed()
Return `True` if the argument has a negative sign and `False` otherwise. Note that zeros and NaNs can both carry signs.

is_snan()
Return `True` if the argument is a signaling NaN and `False` otherwise.

is_subnormal(*context=None*)
Return `True` if the argument is subnormal, and `False` otherwise.

is_zero()
Return `True` if the argument is a (positive or negative) zero and `False` otherwise.

ln(*context=None*)
Return the natural (base e) logarithm of the operand. The result is correctly rounded using the *ROUND_HALF_EVEN* rounding mode.

log10(*context=None*)
Return the base ten logarithm of the operand. The result is correctly rounded using the *ROUND_HALF_EVEN* rounding mode.

logb(*context=None*)
For a nonzero number, return the adjusted exponent of its operand as a *Decimal* instance. If the operand is a zero then `Decimal('-Infinity')` is returned and the *DivisionByZero* flag is raised. If the operand is an infinity then `Decimal('Infinity')` is returned.

logical_and(*other*, *context=None*)
logical_and() is a logical operation which takes two *logical operands* (see *Logical operands*). The result is the digit-wise `and` of the two operands.

logical_invert(*context=None*)
logical_invert() is a logical operation. The result is the digit-wise inversion of the operand.

logical_or(*other*, *context=None*)
logical_or() is a logical operation which takes two *logical operands* (see *Logical operands*). The result is the digit-wise `or` of the two operands.

logical_xor(*other*, *context=None*)
logical_xor() is a logical operation which takes two *logical operands* (see *Logical operands*). The result is the digit-wise exclusive or of the two operands.

max(*other*, *context=None*)
Like `max(self, other)` except that the context rounding rule is applied before returning and that `NaN` values are either signaled or ignored (depending on the context and whether they are signaling or quiet).

max_mag(*other*, *context=None*)
Similar to the *max()* method, but the comparison is done using the absolute values of the operands.

min(*other*, *context=None*)
Like `min(self, other)` except that the context rounding rule is applied before returning and that `NaN` values are either signaled or ignored (depending on the context and whether they are signaling or quiet).

min_mag(*other*, *context=None*)
Similar to the *min()* method, but the comparison is done using the absolute values of the operands.

next_minus(*context=None*)
Return the largest number representable in the given context (or in the current thread's context if no context is given) that is smaller than the given operand.

next_plus(*context=None*)
Return the smallest number representable in the given context (or in the current thread's context if no context is given) that is larger than the given operand.

next_toward(*other*, *context=None*)
If the two operands are unequal, return the number closest to the first operand in the direction of the second operand. If both operands are numerically equal, return a copy of the first operand with the sign set to be the same as the sign of the second operand.

normalize(*context=None*)
Normalize the number by stripping the rightmost trailing zeros and converting any result equal to `Decimal('0')` to `Decimal('0e0')`. Used for producing canonical values for attributes of an equivalence class. For example, `Decimal('32.100')` and `Decimal('0.321000e+2')` both normalize to the equivalent value `Decimal('32.1')`.

number_class(*context=None*)
Return a string describing the *class* of the operand. The returned value is one of the following ten strings.

- `"-Infinity"`, indicating that the operand is negative infinity.
- `"-Normal"`, indicating that the operand is a negative normal number.
- `"-Subnormal"`, indicating that the operand is negative and subnormal.
- `"-Zero"`, indicating that the operand is a negative zero.
- `"+Zero"`, indicating that the operand is a positive zero.
- `"+Subnormal"`, indicating that the operand is positive and subnormal.
- `"+Normal"`, indicating that the operand is a positive normal number.
- `"+Infinity"`, indicating that the operand is positive infinity.
- `"NaN"`, indicating that the operand is a quiet NaN (Not a Number).
- `"sNaN"`, indicating that the operand is a signaling NaN.

quantize(*exp*, *rounding=None*, *context=None*)
Return a value equal to the first operand after rounding and having the exponent of the second operand.

```
>>> Decimal('1.41421356').quantize(Decimal('1.000'))
Decimal('1.414')
```

Unlike other operations, if the length of the coefficient after the quantize operation would be greater than precision, then an *InvalidOperation* is signaled. This guarantees that, unless there is an error condition, the quantized exponent is always equal to that of the right-hand operand.

Also unlike other operations, quantize never signals Underflow, even if the result is subnormal and inexact.

If the exponent of the second operand is larger than that of the first then rounding may be necessary. In this case, the rounding mode is determined by the `rounding` argument if given, else by the given `context` argument; if neither argument is given the rounding mode of the current thread's context is used.

An error is returned whenever the resulting exponent is greater than `Emax` or less than `Etiny`.

radix()
Return `Decimal(10)`, the radix (base) in which the *Decimal* class does all its arithmetic. Included for compatibility with the specification.

remainder_near(*other*, *context=None*)
Return the remainder from dividing *self* by *other*. This differs from `self % other` in that the sign of the remainder is chosen so as to minimize its absolute value. More precisely, the return value is `self - n * other` where `n` is the integer nearest to the exact value of `self / other`, and if two integers are equally near then the even one is chosen.

If the result is zero then its sign will be the sign of *self*.

```
>>> Decimal(18).remainder_near(Decimal(10))
Decimal('-2')
>>> Decimal(25).remainder_near(Decimal(10))
Decimal('5')
>>> Decimal(35).remainder_near(Decimal(10))
Decimal('-5')
```

rotate(*other*, *context=None*)
Return the result of rotating the digits of the first operand by an amount specified by the second operand. The second operand must be an integer in the range -precision through precision. The absolute value of the second operand gives the number of places to rotate. If the second operand is positive then rotation is to the left; otherwise rotation is to the right. The coefficient of the first operand is padded on the left with zeros to length precision if necessary. The sign and exponent of the first operand are unchanged.

same_quantum(*other*, *context=None*)
Test whether self and other have the same exponent or whether both are `NaN`.

This operation is unaffected by context and is quiet: no flags are changed and no rounding is performed. As an exception, the C version may raise InvalidOperation if the second operand cannot be converted exactly.

scaleb(*other*, *context=None*)
Return the first operand with exponent adjusted by the second. Equivalently, return the first operand multiplied by `10**other`. The second operand must be an integer.

shift(*other*, *context=None*)
Return the result of shifting the digits of the first operand by an amount specified by the second operand. The second operand must be an integer in the range -precision through precision. The absolute value of the second operand gives the number of places to shift. If the second operand is positive then the shift is to the left; otherwise the shift is to the right. Digits shifted into the coefficient are zeros. The sign and exponent of the first operand are unchanged.

sqrt(*context=None*)
Return the square root of the argument to full precision.

to_eng_string(*context=None*)
Convert to a string, using engineering notation if an exponent is needed.

Engineering notation has an exponent which is a multiple of 3. This can leave up to 3 digits to the left of the decimal place and may require the addition of either one or two trailing zeros.

For example, this converts `Decimal('123E+1')` to `Decimal('1.23E+3')`.

to_integral(*rounding=None*, *context=None*)
Identical to the *to_integral_value()* method. The `to_integral` name has been kept for compatibility with older versions.

to_integral_exact(*rounding=None*, *context=None*)
Round to the nearest integer, signaling *Inexact* or *Rounded* as appropriate if rounding occurs. The rounding mode is determined by the `rounding` parameter if given, else by the given `context`. If neither parameter is given then the rounding mode of the current context is used.

to_integral_value(*rounding=None*, *context=None*)
Round to the nearest integer without signaling *Inexact* or *Rounded*. If given, applies *rounding*; otherwise, uses the rounding method in either the supplied *context* or the current context.

Logical operands

The `logical_and()`, `logical_invert()`, `logical_or()`, and `logical_xor()` methods expect their arguments to be *logical operands*. A *logical operand* is a *Decimal* instance whose exponent and sign are both zero, and whose digits are all either `0` or `1`.

9.4.3 Context objects

Contexts are environments for arithmetic operations. They govern precision, set rules for rounding, determine which signals are treated as exceptions, and limit the range for exponents.

Each thread has its own current context which is accessed or changed using the *getcontext()* and *setcontext()* functions:

decimal.getcontext()
Return the current context for the active thread.

decimal.setcontext(*c*)
Set the current context for the active thread to *c*.

You can also use the **with** statement and the *localcontext()* function to temporarily change the active context.

decimal.localcontext(*ctx=None*)
Return a context manager that will set the current context for the active thread to a copy of *ctx* on entry to the with-statement and restore the previous context when exiting the with-statement. If no context is specified, a copy of the current context is used.

For example, the following code sets the current decimal precision to 42 places, performs a calculation, and then automatically restores the previous context:

```
from decimal import localcontext

with localcontext() as ctx:
    ctx.prec = 42   # Perform a high precision calculation
    s = calculate_something()
s = +s  # Round the final result back to the default precision
```

New contexts can also be created using the *Context* constructor described below. In addition, the module provides three pre-made contexts:

class decimal.BasicContext
This is a standard context defined by the General Decimal Arithmetic Specification. Precision is set to nine. Rounding is set to *ROUND_HALF_UP*. All flags are cleared. All traps are enabled (treated as exceptions) except *Inexact*, *Rounded*, and *Subnormal*.

Because many of the traps are enabled, this context is useful for debugging.

class decimal.ExtendedContext
This is a standard context defined by the General Decimal Arithmetic Specification. Precision is set to nine. Rounding is set to *ROUND_HALF_EVEN*. All flags are cleared. No traps are enabled (so that exceptions are not raised during computations).

Because the traps are disabled, this context is useful for applications that prefer to have result value of `NaN` or `Infinity` instead of raising exceptions. This allows an application to complete a run in the presence of conditions that would otherwise halt the program.

class decimal.DefaultContext
This context is used by the *Context* constructor as a prototype for new contexts. Changing a field (such a precision) has the effect of changing the default for new contexts created by the *Context* constructor.

This context is most useful in multi-threaded environments. Changing one of the fields before threads are started has the effect of setting system-wide defaults. Changing the fields after threads have started is not recommended as it would require thread synchronization to prevent race conditions.

In single threaded environments, it is preferable to not use this context at all. Instead, simply create contexts explicitly as described below.

The default values are `prec`=28, `rounding`=*ROUND_HALF_EVEN*, and enabled traps for *Overflow*, *InvalidOperation*, and *DivisionByZero*.

In addition to the three supplied contexts, new contexts can be created with the *Context* constructor.

class decimal.Context(*prec=None*, *rounding=None*, *Emin=None*, *Emax=None*, *capitals=None*, *clamp=None*, *flags=None*, *traps=None*)

Creates a new context. If a field is not specified or is *None*, the default values are copied from the *DefaultContext*. If the *flags* field is not specified or is *None*, all flags are cleared.

prec is an integer in the range [`1`, *MAX_PREC*] that sets the precision for arithmetic operations in the context.

The *rounding* option is one of the constants listed in the section *Rounding Modes*.

The *traps* and *flags* fields list any signals to be set. Generally, new contexts should only set traps and leave the flags clear.

The *Emin* and *Emax* fields are integers specifying the outer limits allowable for exponents. *Emin* must be in the range [*MIN_EMIN*, `0`], *Emax* in the range [`0`, *MAX_EMAX*].

The *capitals* field is either `0` or `1` (the default). If set to `1`, exponents are printed with a capital `E`; otherwise, a lowercase `e` is used: `Decimal('6.02e+23')`.

The *clamp* field is either `0` (the default) or `1`. If set to `1`, the exponent `e` of a *Decimal* instance representable in this context is strictly limited to the range `Emin - prec + 1 <= e <= Emax - prec + 1`. If *clamp* is `0` then a weaker condition holds: the adjusted exponent of the *Decimal* instance is at most `Emax`. When *clamp* is `1`, a large normal number will, where possible, have its exponent reduced and a corresponding number of zeros added to its coefficient, in order to fit the exponent constraints; this preserves the value of the number but loses information about significant trailing zeros. For example:

```
>>> Context(prec=6, Emax=999, clamp=1).create_decimal('1.23e999')
Decimal('1.23000E+999')
```

A *clamp* value of `1` allows compatibility with the fixed-width decimal interchange formats specified in IEEE 754.

The *Context* class defines several general purpose methods as well as a large number of methods for doing arithmetic directly in a given context. In addition, for each of the *Decimal* methods described above (with the exception of the `adjusted()` and `as_tuple()` methods) there is a corresponding *Context* method. For example, for a *Context* instance `C` and *Decimal* instance `x`, `C.exp(x)` is equivalent to `x.exp(context=C)`. Each *Context* method accepts a Python integer (an instance of *int*) anywhere that a Decimal instance is accepted.

clear_flags()
Resets all of the flags to `0`.

clear_traps()
Resets all of the traps to `0`.

New in version 3.3.

copy()
Return a duplicate of the context.

copy_decimal(*num*)
Return a copy of the Decimal instance num.

create_decimal(*num*)
Creates a new Decimal instance from *num* but using *self* as context. Unlike the *Decimal* constructor, the context precision, rounding method, flags, and traps are applied to the conversion.

This is useful because constants are often given to a greater precision than is needed by the application. Another benefit is that rounding immediately eliminates unintended effects from

digits beyond the current precision. In the following example, using unrounded inputs means that adding zero to a sum can change the result:

```
>>> getcontext().prec = 3
>>> Decimal('3.4445') + Decimal('1.0023')
Decimal('4.45')
>>> Decimal('3.4445') + Decimal(0) + Decimal('1.0023')
Decimal('4.44')
```

This method implements the to-number operation of the IBM specification. If the argument is a string, no leading or trailing whitespace or underscores are permitted.

create_decimal_from_float(*f*)
Creates a new Decimal instance from a float *f* but rounding using *self* as the context. Unlike the *Decimal.from_float()* class method, the context precision, rounding method, flags, and traps are applied to the conversion.

```
>>> context = Context(prec=5, rounding=ROUND_DOWN)
>>> context.create_decimal_from_float(math.pi)
Decimal('3.1415')
>>> context = Context(prec=5, traps=[Inexact])
>>> context.create_decimal_from_float(math.pi)
Traceback (most recent call last):
    ...
decimal.Inexact: None
```

New in version 3.1.

Etiny()
Returns a value equal to `Emin - prec + 1` which is the minimum exponent value for subnormal results. When underflow occurs, the exponent is set to *Etiny*.

Etop()
Returns a value equal to `Emax - prec + 1`.

The usual approach to working with decimals is to create *Decimal* instances and then apply arithmetic operations which take place within the current context for the active thread. An alternative approach is to use context methods for calculating within a specific context. The methods are similar to those for the *Decimal* class and are only briefly recounted here.

abs(*x*)
Returns the absolute value of *x*.

add(*x*, *y*)
Return the sum of *x* and *y*.

canonical(*x*)
Returns the same Decimal object *x*.

compare(*x*, *y*)
Compares *x* and *y* numerically.

compare_signal(*x*, *y*)
Compares the values of the two operands numerically.

compare_total(*x*, *y*)
Compares two operands using their abstract representation.

compare_total_mag(*x*, *y*)
Compares two operands using their abstract representation, ignoring sign.

copy_abs(*x*)
Returns a copy of *x* with the sign set to 0.

`copy_negate`(*x*)
Returns a copy of *x* with the sign inverted.

`copy_sign`(*x*, *y*)
Copies the sign from *y* to *x*.

`divide`(*x*, *y*)
Return *x* divided by *y*.

`divide_int`(*x*, *y*)
Return *x* divided by *y*, truncated to an integer.

`divmod`(*x*, *y*)
Divides two numbers and returns the integer part of the result.

`exp`(*x*)
Returns *e* ** *x*.

`fma`(*x*, *y*, *z*)
Returns *x* multiplied by *y*, plus *z*.

`is_canonical`(*x*)
Returns `True` if *x* is canonical; otherwise returns `False`.

`is_finite`(*x*)
Returns `True` if *x* is finite; otherwise returns `False`.

`is_infinite`(*x*)
Returns `True` if *x* is infinite; otherwise returns `False`.

`is_nan`(*x*)
Returns `True` if *x* is a qNaN or sNaN; otherwise returns `False`.

`is_normal`(*x*)
Returns `True` if *x* is a normal number; otherwise returns `False`.

`is_qnan`(*x*)
Returns `True` if *x* is a quiet NaN; otherwise returns `False`.

`is_signed`(*x*)
Returns `True` if *x* is negative; otherwise returns `False`.

`is_snan`(*x*)
Returns `True` if *x* is a signaling NaN; otherwise returns `False`.

`is_subnormal`(*x*)
Returns `True` if *x* is subnormal; otherwise returns `False`.

`is_zero`(*x*)
Returns `True` if *x* is a zero; otherwise returns `False`.

`ln`(*x*)
Returns the natural (base e) logarithm of *x*.

`log10`(*x*)
Returns the base 10 logarithm of *x*.

`logb`(*x*)
Returns the exponent of the magnitude of the operand's MSD.

`logical_and`(*x*, *y*)
Applies the logical operation *and* between each operand's digits.

`logical_invert`(*x*)
Invert all the digits in *x*.

logical_or(*x*, *y*)
Applies the logical operation *or* between each operand's digits.

logical_xor(*x*, *y*)
Applies the logical operation *xor* between each operand's digits.

max(*x*, *y*)
Compares two values numerically and returns the maximum.

max_mag(*x*, *y*)
Compares the values numerically with their sign ignored.

min(*x*, *y*)
Compares two values numerically and returns the minimum.

min_mag(*x*, *y*)
Compares the values numerically with their sign ignored.

minus(*x*)
Minus corresponds to the unary prefix minus operator in Python.

multiply(*x*, *y*)
Return the product of *x* and *y*.

next_minus(*x*)
Returns the largest representable number smaller than *x*.

next_plus(*x*)
Returns the smallest representable number larger than *x*.

next_toward(*x*, *y*)
Returns the number closest to *x*, in direction towards *y*.

normalize(*x*)
Reduces *x* to its simplest form.

number_class(*x*)
Returns an indication of the class of *x*.

plus(*x*)
Plus corresponds to the unary prefix plus operator in Python. This operation applies the context precision and rounding, so it is *not* an identity operation.

power(*x*, *y*, *modulo=None*)
Return `x` to the power of `y`, reduced modulo `modulo` if given.

With two arguments, compute `x**y`. If `x` is negative then `y` must be integral. The result will be inexact unless `y` is integral and the result is finite and can be expressed exactly in 'precision' digits. The rounding mode of the context is used. Results are always correctly-rounded in the Python version.

Changed in version 3.3: The C module computes *power()* in terms of the correctly-rounded *exp()* and *ln()* functions. The result is well-defined but only "almost always correctly-rounded".

With three arguments, compute `(x**y) % modulo`. For the three argument form, the following restrictions on the arguments hold:

- all three arguments must be integral
- `y` must be nonnegative
- at least one of `x` or `y` must be nonzero
- `modulo` must be nonzero and have at most 'precision' digits

The value resulting from `Context.power(x, y, modulo)` is equal to the value that would be obtained by computing `(x**y) % modulo` with unbounded precision, but is computed more efficiently. The exponent of the result is zero, regardless of the exponents of `x`, `y` and `modulo`. The result is always exact.

quantize(*x*, *y*)
Returns a value equal to *x* (rounded), having the exponent of *y*.

radix()
Just returns 10, as this is Decimal, :)

remainder(*x*, *y*)
Returns the remainder from integer division.

The sign of the result, if non-zero, is the same as that of the original dividend.

remainder_near(*x*, *y*)
Returns `x - y * n`, where *n* is the integer nearest the exact value of `x / y` (if the result is 0 then its sign will be the sign of *x*).

rotate(*x*, *y*)
Returns a rotated copy of *x*, *y* times.

same_quantum(*x*, *y*)
Returns `True` if the two operands have the same exponent.

scaleb(*x*, *y*)
Returns the first operand after adding the second value its exp.

shift(*x*, *y*)
Returns a shifted copy of *x*, *y* times.

sqrt(*x*)
Square root of a non-negative number to context precision.

subtract(*x*, *y*)
Return the difference between *x* and *y*.

to_eng_string(*x*)
Convert to a string, using engineering notation if an exponent is needed.

Engineering notation has an exponent which is a multiple of 3. This can leave up to 3 digits to the left of the decimal place and may require the addition of either one or two trailing zeros.

to_integral_exact(*x*)
Rounds to an integer.

to_sci_string(*x*)
Converts a number to a string using scientific notation.

9.4.4 Constants

The constants in this section are only relevant for the C module. They are also included in the pure Python version for compatibility.

	32-bit	64-bit
decimal.MAX_PREC	425000000	999999999999999999
decimal.MAX_EMAX	425000000	999999999999999999
decimal.MIN_EMIN	-425000000	-999999999999999999
decimal.MIN_ETINY	-849999999	-1999999999999999997

decimal.HAVE_THREADS
: The default value is True. If Python is compiled without threads, the C version automatically disables the expensive thread local context machinery. In this case, the value is False.

9.4.5 Rounding modes

decimal.ROUND_CEILING
: Round towards Infinity.

decimal.ROUND_DOWN
: Round towards zero.

decimal.ROUND_FLOOR
: Round towards -Infinity.

decimal.ROUND_HALF_DOWN
: Round to nearest with ties going towards zero.

decimal.ROUND_HALF_EVEN
: Round to nearest with ties going to nearest even integer.

decimal.ROUND_HALF_UP
: Round to nearest with ties going away from zero.

decimal.ROUND_UP
: Round away from zero.

decimal.ROUND_05UP
: Round away from zero if last digit after rounding towards zero would have been 0 or 5; otherwise round towards zero.

9.4.6 Signals

Signals represent conditions that arise during computation. Each corresponds to one context flag and one context trap enabler.

The context flag is set whenever the condition is encountered. After the computation, flags may be checked for informational purposes (for instance, to determine whether a computation was exact). After checking the flags, be sure to clear all flags before starting the next computation.

If the context's trap enabler is set for the signal, then the condition causes a Python exception to be raised. For example, if the *DivisionByZero* trap is set, then a *DivisionByZero* exception is raised upon encountering the condition.

class decimal.Clamped
Altered an exponent to fit representation constraints.

Typically, clamping occurs when an exponent falls outside the context's `Emin` and `Emax` limits. If possible, the exponent is reduced to fit by adding zeros to the coefficient.

class decimal.DecimalException
Base class for other signals and a subclass of *ArithmeticError*.

class decimal.DivisionByZero
Signals the division of a non-infinite number by zero.

Can occur with division, modulo division, or when raising a number to a negative power. If this signal is not trapped, returns `Infinity` or `-Infinity` with the sign determined by the inputs to the calculation.

class decimal.Inexact
Indicates that rounding occurred and the result is not exact.

Signals when non-zero digits were discarded during rounding. The rounded result is returned. The signal flag or trap is used to detect when results are inexact.

class decimal.InvalidOperation
An invalid operation was performed.

Indicates that an operation was requested that does not make sense. If not trapped, returns `NaN`. Possible causes include:

```
Infinity - Infinity
0 * Infinity
Infinity / Infinity
x % 0
Infinity % x
sqrt(-x) and x > 0
0 ** 0
x ** (non-integer)
x ** Infinity
```

class decimal.Overflow
Numerical overflow.

Indicates the exponent is larger than `Emax` after rounding has occurred. If not trapped, the result depends on the rounding mode, either pulling inward to the largest representable finite number or rounding outward to `Infinity`. In either case, *Inexact* and *Rounded* are also signaled.

class decimal.Rounded
Rounding occurred though possibly no information was lost.

Signaled whenever rounding discards digits; even if those digits are zero (such as rounding `5.00` to `5.0`). If not trapped, returns the result unchanged. This signal is used to detect loss of significant digits.

class decimal.Subnormal
Exponent was lower than `Emin` prior to rounding.

Occurs when an operation result is subnormal (the exponent is too small). If not trapped, returns the result unchanged.

class decimal.Underflow
Numerical underflow with result rounded to zero.

Occurs when a subnormal result is pushed to zero by rounding. *Inexact* and *Subnormal* are also signaled.

class decimal.FloatOperation

Enable stricter semantics for mixing floats and Decimals.

If the signal is not trapped (default), mixing floats and Decimals is permitted in the *Decimal* constructor, *create_decimal()* and all comparison operators. Both conversion and comparisons are exact. Any occurrence of a mixed operation is silently recorded by setting *FloatOperation* in the context flags. Explicit conversions with *from_float()* or *create_decimal_from_float()* do not set the flag.

Otherwise (the signal is trapped), only equality comparisons and explicit conversions are silent. All other mixed operations raise *FloatOperation*.

The following table summarizes the hierarchy of signals:

```
exceptions.ArithmeticError(exceptions.Exception)
    DecimalException
        Clamped
        DivisionByZero(DecimalException, exceptions.ZeroDivisionError)
        Inexact
            Overflow(Inexact, Rounded)
            Underflow(Inexact, Rounded, Subnormal)
        InvalidOperation
        Rounded
        Subnormal
        FloatOperation(DecimalException, exceptions.TypeError)
```

9.4.7 Floating Point Notes

Mitigating round-off error with increased precision

The use of decimal floating point eliminates decimal representation error (making it possible to represent `0.1` exactly); however, some operations can still incur round-off error when non-zero digits exceed the fixed precision.

The effects of round-off error can be amplified by the addition or subtraction of nearly offsetting quantities resulting in loss of significance. Knuth provides two instructive examples where rounded floating point arithmetic with insufficient precision causes the breakdown of the associative and distributive properties of addition:

```
# Examples from Seminumerical Algorithms, Section 4.2.2.
>>> from decimal import Decimal, getcontext
>>> getcontext().prec = 8

>>> u, v, w = Decimal(11111113), Decimal(-11111111), Decimal('7.51111111')
>>> (u + v) + w
Decimal('9.5111111')
>>> u + (v + w)
Decimal('10')

>>> u, v, w = Decimal(20000), Decimal(-6), Decimal('6.0000003')
>>> (u*v) + (u*w)
Decimal('0.01')
>>> u * (v+w)
Decimal('0.0060000')
```

The *decimal* module makes it possible to restore the identities by expanding the precision sufficiently to avoid loss of significance:

```
>>> getcontext().prec = 20
>>> u, v, w = Decimal(11111113), Decimal(-11111111), Decimal('7.51111111')
>>> (u + v) + w
Decimal('9.51111111')
>>> u + (v + w)
Decimal('9.51111111')
>>>
>>> u, v, w = Decimal(20000), Decimal(-6), Decimal('6.0000003')
>>> (u*v) + (u*w)
Decimal('0.0060000')
>>> u * (v+w)
Decimal('0.0060000')
```

Special values

The number system for the *decimal* module provides special values including `NaN`, `sNaN`, `-Infinity`, `Infinity`, and two zeros, `+0` and `-0`.

Infinities can be constructed directly with: `Decimal('Infinity')`. Also, they can arise from dividing by zero when the *DivisionByZero* signal is not trapped. Likewise, when the *Overflow* signal is not trapped, infinity can result from rounding beyond the limits of the largest representable number.

The infinities are signed (affine) and can be used in arithmetic operations where they get treated as very large, indeterminate numbers. For instance, adding a constant to infinity gives another infinite result.

Some operations are indeterminate and return `NaN`, or if the *InvalidOperation* signal is trapped, raise an exception. For example, `0/0` returns `NaN` which means "not a number". This variety of `NaN` is quiet and, once created, will flow through other computations always resulting in another `NaN`. This behavior can be useful for a series of computations that occasionally have missing inputs — it allows the calculation to proceed while flagging specific results as invalid.

A variant is `sNaN` which signals rather than remaining quiet after every operation. This is a useful return value when an invalid result needs to interrupt a calculation for special handling.

The behavior of Python's comparison operators can be a little surprising where a `NaN` is involved. A test for equality where one of the operands is a quiet or signaling `NaN` always returns *False* (even when doing `Decimal('NaN')==Decimal('NaN')`), while a test for inequality always returns *True*. An attempt to compare two Decimals using any of the `<`, `<=`, `>` or `>=` operators will raise the *InvalidOperation* signal if either operand is a `NaN`, and return *False* if this signal is not trapped. Note that the General Decimal Arithmetic specification does not specify the behavior of direct comparisons; these rules for comparisons involving a `NaN` were taken from the IEEE 854 standard (see Table 3 in section 5.7). To ensure strict standards-compliance, use the `compare()` and `compare-signal()` methods instead.

The signed zeros can result from calculations that underflow. They keep the sign that would have resulted if the calculation had been carried out to greater precision. Since their magnitude is zero, both positive and negative zeros are treated as equal and their sign is informational.

In addition to the two signed zeros which are distinct yet equal, there are various representations of zero with differing precisions yet equivalent in value. This takes a bit of getting used to. For an eye accustomed to normalized floating point representations, it is not immediately obvious that the following calculation returns a value equal to zero:

```
>>> 1 / Decimal('Infinity')
Decimal('0E-1000026')
```

9.4.8 Working with threads

The *getcontext()* function accesses a different *Context* object for each thread. Having separate thread contexts means that threads may make changes (such as `getcontext().prec=10`) without interfering with other threads.

Likewise, the *setcontext()* function automatically assigns its target to the current thread.

If *setcontext()* has not been called before *getcontext()*, then *getcontext()* will automatically create a new context for use in the current thread.

The new context is copied from a prototype context called *DefaultContext*. To control the defaults so that each thread will use the same values throughout the application, directly modify the *DefaultContext* object. This should be done *before* any threads are started so that there won't be a race condition between threads calling *getcontext()*. For example:

```
# Set applicationwide defaults for all threads about to be launched
DefaultContext.prec = 12
DefaultContext.rounding = ROUND_DOWN
DefaultContext.traps = ExtendedContext.traps.copy()
DefaultContext.traps[InvalidOperation] = 1
setcontext(DefaultContext)

# Afterwards, the threads can be started
t1.start()
t2.start()
t3.start()
 . . .
```

9.4.9 Recipes

Here are a few recipes that serve as utility functions and that demonstrate ways to work with the *Decimal* class:

```
def moneyfmt(value, places=2, curr='', sep=',', dp='.',
             pos='', neg='-', trailneg=''):
    """Convert Decimal to a money formatted string.

    places:  required number of places after the decimal point
    curr:    optional currency symbol before the sign (may be blank)
    sep:     optional grouping separator (comma, period, space, or blank)
    dp:      decimal point indicator (comma or period)
             only specify as blank when places is zero
    pos:     optional sign for positive numbers: '+', space or blank
    neg:     optional sign for negative numbers: '-', '(', space or blank
    trailneg:optional trailing minus indicator:  '-', ')', space or blank

    >>> d = Decimal('-1234567.8901')
    >>> moneyfmt(d, curr='$')
    '-$1,234,567.89'
    >>> moneyfmt(d, places=0, sep='.', dp='', neg='', trailneg='-')
    '1.234.568-'
    >>> moneyfmt(d, curr='$', neg='(', trailneg=')')
    '($1,234,567.89)'
    >>> moneyfmt(Decimal(123456789), sep=' ')
    '123 456 789.00'
    >>> moneyfmt(Decimal('-0.02'), neg='<', trailneg='>')
```

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```
    '<0.02>'

    """
    q = Decimal(10) ** -places      # 2 places --> '0.01'
    sign, digits, exp = value.quantize(q).as_tuple()
    result = []
    digits = list(map(str, digits))
    build, next = result.append, digits.pop
    if sign:
        build(trailneg)
    for i in range(places):
        build(next() if digits else '0')
    if places:
        build(dp)
    if not digits:
        build('0')
    i = 0
    while digits:
        build(next())
        i += 1
        if i == 3 and digits:
            i = 0
            build(sep)
    build(curr)
    build(neg if sign else pos)
    return ''.join(reversed(result))

def pi():
    """Compute Pi to the current precision.

    >>> print(pi())
    3.141592653589793238462643383

    """
    getcontext().prec += 2  # extra digits for intermediate steps
    three = Decimal(3)      # substitute "three=3.0" for regular floats
    lasts, t, s, n, na, d, da = 0, three, 3, 1, 0, 0, 24
    while s != lasts:
        lasts = s
        n, na = n+na, na+8
        d, da = d+da, da+32
        t = (t * n) / d
        s += t
    getcontext().prec -= 2
    return +s               # unary plus applies the new precision

def exp(x):
    """Return e raised to the power of x.  Result type matches input type.

    >>> print(exp(Decimal(1)))
    2.718281828459045235360287471
    >>> print(exp(Decimal(2)))
    7.389056098930650227230427461
    >>> print(exp(2.0))
    7.38905609893
    >>> print(exp(2+0j))
```

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```
    (7.38905609893+0j)

    """
    getcontext().prec += 2
    i, lasts, s, fact, num = 0, 0, 1, 1, 1
    while s != lasts:
        lasts = s
        i += 1
        fact *= i
        num *= x
        s += num / fact
    getcontext().prec -= 2
    return +s

def cos(x):
    """Return the cosine of x as measured in radians.

    The Taylor series approximation works best for a small value of x.
    For larger values, first compute x = x % (2 * pi).

    >>> print(cos(Decimal('0.5')))
    0.87758256189037271611628158260
    >>> print(cos(0.5))
    0.87758256189
    >>> print(cos(0.5+0j))
    (0.87758256189+0j)

    """
    getcontext().prec += 2
    i, lasts, s, fact, num, sign = 0, 0, 1, 1, 1, 1
    while s != lasts:
        lasts = s
        i += 2
        fact *= i * (i-1)
        num *= x * x
        sign *= -1
        s += num / fact * sign
    getcontext().prec -= 2
    return +s

def sin(x):
    """Return the sine of x as measured in radians.

    The Taylor series approximation works best for a small value of x.
    For larger values, first compute x = x % (2 * pi).

    >>> print(sin(Decimal('0.5')))
    0.47942553860420300027328793521
    >>> print(sin(0.5))
    0.479425538604
    >>> print(sin(0.5+0j))
    (0.479425538604+0j)

    """
    getcontext().prec += 2
    i, lasts, s, fact, num, sign = 1, 0, x, 1, x, 1
```

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```
    while s != lasts:
        lasts = s
        i += 2
        fact *= i * (i-1)
        num *= x * x
        sign *= -1
        s += num / fact * sign
    getcontext().prec -= 2
    return +s
```

9.4.10 Decimal FAQ

Q. It is cumbersome to type `decimal.Decimal('1234.5')`. Is there a way to minimize typing when using the interactive interpreter?

A. Some users abbreviate the constructor to just a single letter:

```
>>> D = decimal.Decimal
>>> D('1.23') + D('3.45')
Decimal('4.68')
```

Q. In a fixed-point application with two decimal places, some inputs have many places and need to be rounded. Others are not supposed to have excess digits and need to be validated. What methods should be used?

A. The `quantize()` method rounds to a fixed number of decimal places. If the *Inexact* trap is set, it is also useful for validation:

```
>>> TWOPLACES = Decimal(10) ** -2       # same as Decimal('0.01')
```

```
>>> # Round to two places
>>> Decimal('3.214').quantize(TWOPLACES)
Decimal('3.21')
```

```
>>> # Validate that a number does not exceed two places
>>> Decimal('3.21').quantize(TWOPLACES, context=Context(traps=[Inexact]))
Decimal('3.21')
```

```
>>> Decimal('3.214').quantize(TWOPLACES, context=Context(traps=[Inexact]))
Traceback (most recent call last):
   ...
Inexact: None
```

Q. Once I have valid two place inputs, how do I maintain that invariant throughout an application?

A. Some operations like addition, subtraction, and multiplication by an integer will automatically preserve fixed point. Others operations, like division and non-integer multiplication, will change the number of decimal places and need to be followed-up with a `quantize()` step:

```
>>> a = Decimal('102.72')           # Initial fixed-point values
>>> b = Decimal('3.17')
>>> a + b                           # Addition preserves fixed-point
Decimal('105.89')
>>> a - b
Decimal('99.55')
```

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```
>>> a * 42                          # So does integer multiplication
Decimal('4314.24')
>>> (a * b).quantize(TWOPLACES)     # Must quantize non-integer multiplication
Decimal('325.62')
>>> (b / a).quantize(TWOPLACES)     # And quantize division
Decimal('0.03')
```

In developing fixed-point applications, it is convenient to define functions to handle the `quantize()` step:

```
>>> def mul(x, y, fp=TWOPLACES):
...     return (x * y).quantize(fp)
>>> def div(x, y, fp=TWOPLACES):
...     return (x / y).quantize(fp)
```

```
>>> mul(a, b)                       # Automatically preserve fixed-point
Decimal('325.62')
>>> div(b, a)
Decimal('0.03')
```

Q. There are many ways to express the same value. The numbers `200`, `200.000`, `2E2`, and `02E+4` all have the same value at various precisions. Is there a way to transform them to a single recognizable canonical value?

A. The `normalize()` method maps all equivalent values to a single representative:

```
>>> values = map(Decimal, '200 200.000 2E2 .02E+4'.split())
>>> [v.normalize() for v in values]
[Decimal('2E+2'), Decimal('2E+2'), Decimal('2E+2'), Decimal('2E+2')]
```

Q. Some decimal values always print with exponential notation. Is there a way to get a non-exponential representation?

A. For some values, exponential notation is the only way to express the number of significant places in the coefficient. For example, expressing `5.0E+3` as `5000` keeps the value constant but cannot show the original's two-place significance.

If an application does not care about tracking significance, it is easy to remove the exponent and trailing zeroes, losing significance, but keeping the value unchanged:

```
>>> def remove_exponent(d):
...     return d.quantize(Decimal(1)) if d == d.to_integral() else d.normalize()
```

```
>>> remove_exponent(Decimal('5E+3'))
Decimal('5000')
```

Q. Is there a way to convert a regular float to a *Decimal*?

A. Yes, any binary floating point number can be exactly expressed as a Decimal though an exact conversion may take more precision than intuition would suggest:

```
>>> Decimal(math.pi)
Decimal('3.141592653589793115997963468544185161590576171875')
```

Q. Within a complex calculation, how can I make sure that I haven't gotten a spurious result because of insufficient precision or rounding anomalies.

A. The decimal module makes it easy to test results. A best practice is to re-run calculations using greater precision and with various rounding modes. Widely differing results indicate insufficient precision, rounding mode issues, ill-conditioned inputs, or a numerically unstable algorithm.

Q. I noticed that context precision is applied to the results of operations but not to the inputs. Is there anything to watch out for when mixing values of different precisions?

A. Yes. The principle is that all values are considered to be exact and so is the arithmetic on those values. Only the results are rounded. The advantage for inputs is that "what you type is what you get". A disadvantage is that the results can look odd if you forget that the inputs haven't been rounded:

```
>>> getcontext().prec = 3
>>> Decimal('3.104') + Decimal('2.104')
Decimal('5.21')
>>> Decimal('3.104') + Decimal('0.000') + Decimal('2.104')
Decimal('5.20')
```

The solution is either to increase precision or to force rounding of inputs using the unary plus operation:

```
>>> getcontext().prec = 3
>>> +Decimal('1.23456789')      # unary plus triggers rounding
Decimal('1.23')
```

Alternatively, inputs can be rounded upon creation using the *Context.create_decimal()* method:

```
>>> Context(prec=5, rounding=ROUND_DOWN).create_decimal('1.2345678')
Decimal('1.2345')
```

9.5 fractions — Rational numbers

Source code: Lib/fractions.py

The *fractions* module provides support for rational number arithmetic.

A Fraction instance can be constructed from a pair of integers, from another rational number, or from a string.

class fractions.Fraction(*numerator=0*, *denominator=1*)
class fractions.Fraction(*other_fraction*)
class fractions.Fraction(*float*)
class fractions.Fraction(*decimal*)
class fractions.Fraction(*string*)

The first version requires that *numerator* and *denominator* are instances of *numbers.Rational* and returns a new *Fraction* instance with value `numerator/denominator`. If *denominator* is `0`, it raises a *ZeroDivisionError*. The second version requires that *other_fraction* is an instance of *numbers.Rational* and returns a *Fraction* instance with the same value. The next two versions accept either a *float* or a *decimal.Decimal* instance, and return a *Fraction* instance with exactly the same value. Note that due to the usual issues with binary floating-point (see tut-fp-issues), the argument to `Fraction(1.1)` is not exactly equal to 11/10, and so `Fraction(1.1)` does *not* return `Fraction(11, 10)` as one might expect. (But see the documentation for the *limit_denominator()* method below.) The last version of the constructor expects a string or unicode instance. The usual form for this instance is:

```
[sign] numerator ['/' denominator]
```

where the optional `sign` may be either '+' or '-' and `numerator` and `denominator` (if present) are strings of decimal digits. In addition, any string that represents a finite value and is accepted by the *float* constructor is also accepted by the *Fraction* constructor. In either form the input string may also have leading and/or trailing whitespace. Here are some examples:

```
>>> from fractions import Fraction
>>> Fraction(16, -10)
Fraction(-8, 5)
>>> Fraction(123)
Fraction(123, 1)
>>> Fraction()
Fraction(0, 1)
>>> Fraction('3/7')
Fraction(3, 7)
>>> Fraction(' -3/7 ')
Fraction(-3, 7)
>>> Fraction('1.414213 \t\n')
Fraction(1414213, 1000000)
>>> Fraction('-.125')
Fraction(-1, 8)
>>> Fraction('7e-6')
Fraction(7, 1000000)
>>> Fraction(2.25)
Fraction(9, 4)
>>> Fraction(1.1)
Fraction(2476979795053773, 2251799813685248)
>>> from decimal import Decimal
>>> Fraction(Decimal('1.1'))
Fraction(11, 10)
```

The *Fraction* class inherits from the abstract base class *numbers.Rational*, and implements all of the methods and operations from that class. *Fraction* instances are hashable, and should be treated as immutable. In addition, *Fraction* has the following properties and methods:

Changed in version 3.2: The *Fraction* constructor now accepts *float* and *decimal.Decimal* instances.

numerator
: Numerator of the Fraction in lowest term.

denominator
: Denominator of the Fraction in lowest term.

from_float(*flt*)
: This class method constructs a *Fraction* representing the exact value of *flt*, which must be a *float*. Beware that `Fraction.from_float(0.3)` is not the same value as `Fraction(3, 10)`.

Note: From Python 3.2 onwards, you can also construct a *Fraction* instance directly from a *float*.

---

from_decimal(*dec*)
: This class method constructs a *Fraction* representing the exact value of *dec*, which must be a *decimal.Decimal* instance.

Note: From Python 3.2 onwards, you can also construct a *Fraction* instance directly from a *decimal.Decimal* instance.

---

limit_denominator(*max_denominator=1000000*)
: Finds and returns the closest *Fraction* to `self` that has denominator at most max_denominator. This method is useful for finding rational approximations to a given floating-point number:

```
>>> from fractions import Fraction
>>> Fraction('3.1415926535897932').limit_denominator(1000)
Fraction(355, 113)
```

or for recovering a rational number that's represented as a float:

```
>>> from math import pi, cos
>>> Fraction(cos(pi/3))
Fraction(4503599627370497, 9007199254740992)
>>> Fraction(cos(pi/3)).limit_denominator()
Fraction(1, 2)
>>> Fraction(1.1).limit_denominator()
Fraction(11, 10)
```

`__floor__()`
: Returns the greatest *int* `<= self`. This method can also be accessed through the *math.floor()* function:

```
>>> from math import floor
>>> floor(Fraction(355, 113))
3
```

`__ceil__()`
: Returns the least *int* `>= self`. This method can also be accessed through the *math.ceil()* function.

`__round__()`
`__round__(`*ndigits*`)`
: The first version returns the nearest *int* to `self`, rounding half to even. The second version rounds `self` to the nearest multiple of `Fraction(1, 10**ndigits)` (logically, if `ndigits` is negative), again rounding half toward even. This method can also be accessed through the *round()* function.

`fractions.gcd(`*a*, *b*`)`
: Return the greatest common divisor of the integers *a* and *b*. If either *a* or *b* is nonzero, then the absolute value of `gcd(a, b)` is the largest integer that divides both *a* and *b*. `gcd(a,b)` has the same sign as *b* if *b* is nonzero; otherwise it takes the sign of *a*. `gcd(0, 0)` returns `0`.

  Deprecated since version 3.5: Use *math.gcd()* instead.

See also:

Module *numbers* The abstract base classes making up the numeric tower.

9.6 `random` — Generate pseudo-random numbers

Source code: Lib/random.py

This module implements pseudo-random number generators for various distributions.

For integers, there is uniform selection from a range. For sequences, there is uniform selection of a random element, a function to generate a random permutation of a list in-place, and a function for random sampling without replacement.

On the real line, there are functions to compute uniform, normal (Gaussian), lognormal, negative exponential, gamma, and beta distributions. For generating distributions of angles, the von Mises distribution is available.

Almost all module functions depend on the basic function *random()*, which generates a random float uniformly in the semi-open range [0.0, 1.0). Python uses the Mersenne Twister as the core generator. It produces 53-bit precision floats and has a period of 2**19937-1. The underlying implementation in C is both fast and threadsafe. The Mersenne Twister is one of the most extensively tested random number generators in existence. However, being completely deterministic, it is not suitable for all purposes, and is completely unsuitable for cryptographic purposes.

The functions supplied by this module are actually bound methods of a hidden instance of the `random.Random` class. You can instantiate your own instances of `Random` to get generators that don't share state.

Class `Random` can also be subclassed if you want to use a different basic generator of your own devising: in that case, override the `random()`, `seed()`, `getstate()`, and `setstate()` methods. Optionally, a new generator can supply a `getrandbits()` method — this allows *randrange()* to produce selections over an arbitrarily large range.

The *random* module also provides the *SystemRandom* class which uses the system function *os.urandom()* to generate random numbers from sources provided by the operating system.

Warning: The pseudo-random generators of this module should not be used for security purposes. For security or cryptographic uses, see the *secrets* module.

See also:

M. Matsumoto and T. Nishimura, "Mersenne Twister: A 623-dimensionally equidistributed uniform pseudorandom number generator", ACM Transactions on Modeling and Computer Simulation Vol. 8, No. 1, January pp.3–30 1998.

Complementary-Multiply-with-Carry recipe for a compatible alternative random number generator with a long period and comparatively simple update operations.

9.6.1 Bookkeeping functions

`random.seed(`*a=None*, *version=2*`)`

Initialize the random number generator.

If *a* is omitted or `None`, the current system time is used. If randomness sources are provided by the operating system, they are used instead of the system time (see the *os.urandom()* function for details on availability).

If *a* is an int, it is used directly.

With version 2 (the default), a *str*, *bytes*, or *bytearray* object gets converted to an *int* and all of its bits are used.

With version 1 (provided for reproducing random sequences from older versions of Python), the algorithm for *str* and *bytes* generates a narrower range of seeds.

Changed in version 3.2: Moved to the version 2 scheme which uses all of the bits in a string seed.

`random.getstate()`

Return an object capturing the current internal state of the generator. This object can be passed to *setstate()* to restore the state.

`random.setstate(`*state*`)`

state should have been obtained from a previous call to *getstate()*, and *setstate()* restores the internal state of the generator to what it was at the time *getstate()* was called.

`random.getrandbits(`*k*`)`

Returns a Python integer with *k* random bits. This method is supplied with the MersenneTwister

generator and some other generators may also provide it as an optional part of the API. When available, *getrandbits()* enables *randrange()* to handle arbitrarily large ranges.

9.6.2 Functions for integers

random.**randrange**(*stop*)

random.**randrange**(*start*, *stop*[, *step*])

Return a randomly selected element from `range(start, stop, step)`. This is equivalent to `choice(range(start, stop, step))`, but doesn't actually build a range object.

The positional argument pattern matches that of *range()*. Keyword arguments should not be used because the function may use them in unexpected ways.

Changed in version 3.2: *randrange()* is more sophisticated about producing equally distributed values. Formerly it used a style like `int(random()*n)` which could produce slightly uneven distributions.

random.**randint**(*a*, *b*)

Return a random integer *N* such that `a <= N <= b`. Alias for `randrange(a, b+1)`.

9.6.3 Functions for sequences

random.**choice**(*seq*)

Return a random element from the non-empty sequence *seq*. If *seq* is empty, raises *IndexError*.

random.**choices**(*population*, *weights=None*, ***, *cum_weights=None*, *k=1*)

Return a *k* sized list of elements chosen from the *population* with replacement. If the *population* is empty, raises *IndexError*.

If a *weights* sequence is specified, selections are made according to the relative weights. Alternatively, if a *cum_weights* sequence is given, the selections are made according to the cumulative weights (perhaps computed using *itertools.accumulate()*). For example, the relative weights `[10, 5, 30, 5]` are equivalent to the cumulative weights `[10, 15, 45, 50]`. Internally, the relative weights are converted to cumulative weights before making selections, so supplying the cumulative weights saves work.

If neither *weights* nor *cum_weights* are specified, selections are made with equal probability. If a weights sequence is supplied, it must be the same length as the *population* sequence. It is a *TypeError* to specify both *weights* and *cum_weights*.

The *weights* or *cum_weights* can use any numeric type that interoperates with the *float* values returned by *random()* (that includes integers, floats, and fractions but excludes decimals).

New in version 3.6.

random.**shuffle**(*x*[, *random*])

Shuffle the sequence *x* in place.

The optional argument *random* is a 0-argument function returning a random float in [0.0, 1.0); by default, this is the function *random()*.

To shuffle an immutable sequence and return a new shuffled list, use `sample(x, k=len(x))` instead.

Note that even for small `len(x)`, the total number of permutations of *x* can quickly grow larger than the period of most random number generators. This implies that most permutations of a long sequence can never be generated. For example, a sequence of length 2080 is the largest that can fit within the period of the Mersenne Twister random number generator.

random.**sample**(*population*, *k*)

Return a *k* length list of unique elements chosen from the population sequence or set. Used for random sampling without replacement.

Returns a new list containing elements from the population while leaving the original population unchanged. The resulting list is in selection order so that all sub-slices will also be valid random samples. This allows raffle winners (the sample) to be partitioned into grand prize and second place winners (the subslices).

Members of the population need not be *hashable* or unique. If the population contains repeats, then each occurrence is a possible selection in the sample.

To choose a sample from a range of integers, use a *range()* object as an argument. This is especially fast and space efficient for sampling from a large population: `sample(range(10000000), k=60)`.

If the sample size is larger than the population size, a *ValueError* is raised.

9.6.4 Real-valued distributions

The following functions generate specific real-valued distributions. Function parameters are named after the corresponding variables in the distribution's equation, as used in common mathematical practice; most of these equations can be found in any statistics text.

`random.random()`
Return the next random floating point number in the range [0.0, 1.0).

`random.uniform(`*a*, *b*`)`
Return a random floating point number *N* such that `a <= N <= b` for `a <= b` and `b <= N <= a` for `b < a`.

The end-point value `b` may or may not be included in the range depending on floating-point rounding in the equation `a + (b-a) * random()`.

`random.triangular(`*low*, *high*, *mode*`)`
Return a random floating point number *N* such that `low <= N <= high` and with the specified *mode* between those bounds. The *low* and *high* bounds default to zero and one. The *mode* argument defaults to the midpoint between the bounds, giving a symmetric distribution.

`random.betavariate(`*alpha*, *beta*`)`
Beta distribution. Conditions on the parameters are `alpha > 0` and `beta > 0`. Returned values range between 0 and 1.

`random.expovariate(`*lambd*`)`
Exponential distribution. *lambd* is 1.0 divided by the desired mean. It should be nonzero. (The parameter would be called "lambda", but that is a reserved word in Python.) Returned values range from 0 to positive infinity if *lambd* is positive, and from negative infinity to 0 if *lambd* is negative.

`random.gammavariate(`*alpha*, *beta*`)`
Gamma distribution. (*Not* the gamma function!) Conditions on the parameters are `alpha > 0` and `beta > 0`.

The probability distribution function is:

```
            x ** (alpha - 1) * math.exp(-x / beta)
pdf(x) =  --------------------------------------
            math.gamma(alpha) * beta ** alpha
```

`random.gauss(`*mu*, *sigma*`)`
Gaussian distribution. *mu* is the mean, and *sigma* is the standard deviation. This is slightly faster than the *normalvariate()* function defined below.

`random.lognormvariate(`*mu*, *sigma*`)`
Log normal distribution. If you take the natural logarithm of this distribution, you'll get a normal distribution with mean *mu* and standard deviation *sigma*. *mu* can have any value, and *sigma* must be greater than zero.

random.normalvariate(*mu*, *sigma*)
Normal distribution. *mu* is the mean, and *sigma* is the standard deviation.

random.vonmisesvariate(*mu*, *kappa*)
mu is the mean angle, expressed in radians between 0 and 2**pi*, and *kappa* is the concentration parameter, which must be greater than or equal to zero. If *kappa* is equal to zero, this distribution reduces to a uniform random angle over the range 0 to 2**pi*.

random.paretovariate(*alpha*)
Pareto distribution. *alpha* is the shape parameter.

random.weibullvariate(*alpha*, *beta*)
Weibull distribution. *alpha* is the scale parameter and *beta* is the shape parameter.

9.6.5 Alternative Generator

class random.SystemRandom([*seed*])
Class that uses the *os.urandom()* function for generating random numbers from sources provided by the operating system. Not available on all systems. Does not rely on software state, and sequences are not reproducible. Accordingly, the *seed()* method has no effect and is ignored. The *getstate()* and *setstate()* methods raise *NotImplementedError* if called.

9.6.6 Notes on Reproducibility

Sometimes it is useful to be able to reproduce the sequences given by a pseudo random number generator. By re-using a seed value, the same sequence should be reproducible from run to run as long as multiple threads are not running.

Most of the random module's algorithms and seeding functions are subject to change across Python versions, but two aspects are guaranteed not to change:

- If a new seeding method is added, then a backward compatible seeder will be offered.
- The generator's `random()` method will continue to produce the same sequence when the compatible seeder is given the same seed.

9.6.7 Examples and Recipes

Basic examples:

```
>>> random()                            # Random float:  0.0 <= x < 1.0
0.37444887175646646

>>> uniform(2.5, 10.0)                  # Random float:  2.5 <= x < 10.0
3.1800146073117523

>>> expovariate(1 / 5)                  # Interval between arrivals averaging 5 seconds
5.148957571865031

>>> randrange(10)                       # Integer from 0 to 9 inclusive
7

>>> randrange(0, 101, 2)                # Even integer from 0 to 100 inclusive
26

>>> choice(['win', 'lose', 'draw'])     # Single random element from a sequence
```

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```
'draw'

>>> deck = 'ace two three four'.split()
>>> shuffle(deck)                          # Shuffle a list
>>> deck
['four', 'two', 'ace', 'three']

>>> sample([10, 20, 30, 40, 50], k=4)     # Four samples without replacement
[40, 10, 50, 30]
```

Simulations:

```
>>> # Six roulette wheel spins (weighted sampling with replacement)
>>> choices(['red', 'black', 'green'], [18, 18, 2], k=6)
['red', 'green', 'black', 'black', 'red', 'black']

>>> # Deal 20 cards without replacement from a deck of 52 playing cards
>>> # and determine the proportion of cards with a ten-value
>>> # (a ten, jack, queen, or king).
>>> deck = collections.Counter(tens=16, low_cards=36)
>>> seen = sample(list(deck.elements()), k=20)
>>> seen.count('tens') / 20
0.15

>>> # Estimate the probability of getting 5 or more heads from 7 spins
>>> # of a biased coin that settles on heads 60% of the time.
>>> trial = lambda: choices('HT', cum_weights=(0.60, 1.00), k=7).count('H') >= 5
>>> sum(trial() for i in range(10000)) / 10000
0.4169

>>> # Probability of the median of 5 samples being in middle two quartiles
>>> trial = lambda : 2500 <= sorted(choices(range(10000), k=5))[2]  < 7500
>>> sum(trial() for i in range(10000)) / 10000
0.7958
```

Example of statistical bootstrapping using resampling with replacement to estimate a confidence interval for the mean of a sample of size five:

```
# http://statistics.about.com/od/Applications/a/Example-Of-Bootstrapping.htm
from statistics import mean
from random import choices

data = 1, 2, 4, 4, 10
means = sorted(mean(choices(data, k=5)) for i in range(20))
print(f'The sample mean of {mean(data):.1f} has a 90% confidence '
      f'interval from {means[1]:.1f} to {means[-2]:.1f}')
```

Example of a resampling permutation test to determine the statistical significance or p-value of an observed difference between the effects of a drug versus a placebo:

```
# Example from "Statistics is Easy" by Dennis Shasha and Manda Wilson
from statistics import mean
from random import shuffle

drug = [54, 73, 53, 70, 73, 68, 52, 65, 65]
placebo = [54, 51, 58, 44, 55, 52, 42, 47, 58, 46]
```

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```
observed_diff = mean(drug) - mean(placebo)

n = 10000
count = 0
combined = drug + placebo
for i in range(n):
    shuffle(combined)
    new_diff = mean(combined[:len(drug)]) - mean(combined[len(drug):])
    count += (new_diff >= observed_diff)

print(f'{n} label reshufflings produced only {count} instances with a difference')
print(f'at least as extreme as the observed difference of {observed_diff:.1f}.')
print(f'The one-sided p-value of {count / n:.4f} leads us to reject the null')
print(f'hypothesis that there is no difference between the drug and the placebo.')
```

Simulation of arrival times and service deliveries in a single server queue:

```
from random import expovariate, gauss
from statistics import mean, median, stdev

average_arrival_interval = 5.6
average_service_time = 5.0
stdev_service_time = 0.5

num_waiting = 0
arrivals = []
starts = []
arrival = service_end = 0.0
for i in range(20000):
    if arrival <= service_end:
        num_waiting += 1
        arrival += expovariate(1.0 / average_arrival_interval)
        arrivals.append(arrival)
    else:
        num_waiting -= 1
        service_start = service_end if num_waiting else arrival
        service_time = gauss(average_service_time, stdev_service_time)
        service_end = service_start + service_time
        starts.append(service_start)

waits = [start - arrival for arrival, start in zip(arrivals, starts)]
print(f'Mean wait: {mean(waits):.1f}.  Stdev wait: {stdev(waits):.1f}.')
print(f'Median wait: {median(waits):.1f}.  Max wait: {max(waits):.1f}.')
```

See also:

Statistics for Hackers a video tutorial by Jake Vanderplas on statistical analysis using just a few fundamental concepts including simulation, sampling, shuffling, and cross-validation.

Economics Simulation a simulation of a marketplace by Peter Norvig that shows effective use of many of the tools and distributions provided by this module (gauss, uniform, sample, betavariate, choice, triangular, and randrange).

A Concrete Introduction to Probability (using Python) a tutorial by Peter Norvig covering the basics of probability theory, how to write simulations, and how to perform data analysis using Python.

9.7 statistics — Mathematical statistics functions

New in version 3.4.

Source code: Lib/statistics.py

This module provides functions for calculating mathematical statistics of numeric (`Real`-valued) data.

Note: Unless explicitly noted otherwise, these functions support *int*, *float*, *decimal.Decimal* and *fractions.Fraction*. Behaviour with other types (whether in the numeric tower or not) is currently unsupported. Mixed types are also undefined and implementation-dependent. If your input data consists of mixed types, you may be able to use *map()* to ensure a consistent result, e.g. `map(float, input_data)`.

9.7.1 Averages and measures of central location

These functions calculate an average or typical value from a population or sample.

mean()	Arithmetic mean ("average") of data.
harmonic_mean()	Harmonic mean of data.
median()	Median (middle value) of data.
median_low()	Low median of data.
median_high()	High median of data.
median_grouped()	Median, or 50th percentile, of grouped data.
mode()	Mode (most common value) of discrete data.

9.7.2 Measures of spread

These functions calculate a measure of how much the population or sample tends to deviate from the typical or average values.

pstdev()	Population standard deviation of data.
pvariance()	Population variance of data.
stdev()	Sample standard deviation of data.
variance()	Sample variance of data.

9.7.3 Function details

Note: The functions do not require the data given to them to be sorted. However, for reading convenience, most of the examples show sorted sequences.

`statistics.mean(`*data*`)`

Return the sample arithmetic mean of *data* which can be a sequence or iterator.

The arithmetic mean is the sum of the data divided by the number of data points. It is commonly called "the average", although it is only one of many different mathematical averages. It is a measure of the central location of the data.

If *data* is empty, *StatisticsError* will be raised.

Some examples of use:

```
>>> mean([1, 2, 3, 4, 4])
2.8
>>> mean([-1.0, 2.5, 3.25, 5.75])
2.625

>>> from fractions import Fraction as F
>>> mean([F(3, 7), F(1, 21), F(5, 3), F(1, 3)])
Fraction(13, 21)

>>> from decimal import Decimal as D
>>> mean([D("0.5"), D("0.75"), D("0.625"), D("0.375")])
Decimal('0.5625')
```

Note: The mean is strongly affected by outliers and is not a robust estimator for central location: the mean is not necessarily a typical example of the data points. For more robust, although less efficient, measures of central location, see *median()* and *mode()*. (In this case, "efficient" refers to statistical efficiency rather than computational efficiency.)

The sample mean gives an unbiased estimate of the true population mean, which means that, taken on average over all the possible samples, `mean(sample)` converges on the true mean of the entire population. If *data* represents the entire population rather than a sample, then `mean(data)` is equivalent to calculating the true population mean μ.

`statistics.harmonic_mean(`*data*`)`

Return the harmonic mean of *data*, a sequence or iterator of real-valued numbers.

The harmonic mean, sometimes called the subcontrary mean, is the reciprocal of the arithmetic *mean()* of the reciprocals of the data. For example, the harmonic mean of three values a, b and c will be equivalent to `3/(1/a + 1/b + 1/c)`.

The harmonic mean is a type of average, a measure of the central location of the data. It is often appropriate when averaging quantities which are rates or ratios, for example speeds. For example:

Suppose an investor purchases an equal value of shares in each of three companies, with P/E (price/earning) ratios of 2.5, 3 and 10. What is the average P/E ratio for the investor's portfolio?

```
>>> harmonic_mean([2.5, 3, 10])  # For an equal investment portfolio.
3.6
```

Using the arithmetic mean would give an average of about 5.167, which is too high.

StatisticsError is raised if *data* is empty, or any element is less than zero.

New in version 3.6.

`statistics.median(`*data*`)`

Return the median (middle value) of numeric data, using the common "mean of middle two" method. If *data* is empty, *StatisticsError* is raised. *data* can be a sequence or iterator.

The median is a robust measure of central location, and is less affected by the presence of outliers in your data. When the number of data points is odd, the middle data point is returned:

```
>>> median([1, 3, 5])
3
```

When the number of data points is even, the median is interpolated by taking the average of the two middle values:

```
>>> median([1, 3, 5, 7])
4.0
```

This is suited for when your data is discrete, and you don't mind that the median may not be an actual data point.

If your data is ordinal (supports order operations) but not numeric (doesn't support addition), you should use *median_low()* or *median_high()* instead.

See also:

median_low(), *median_high()*, *median_grouped()*

statistics.**median_low**(*data*)

Return the low median of numeric data. If *data* is empty, *StatisticsError* is raised. *data* can be a sequence or iterator.

The low median is always a member of the data set. When the number of data points is odd, the middle value is returned. When it is even, the smaller of the two middle values is returned.

```
>>> median_low([1, 3, 5])
3
>>> median_low([1, 3, 5, 7])
3
```

Use the low median when your data are discrete and you prefer the median to be an actual data point rather than interpolated.

statistics.**median_high**(*data*)

Return the high median of data. If *data* is empty, *StatisticsError* is raised. *data* can be a sequence or iterator.

The high median is always a member of the data set. When the number of data points is odd, the middle value is returned. When it is even, the larger of the two middle values is returned.

```
>>> median_high([1, 3, 5])
3
>>> median_high([1, 3, 5, 7])
5
```

Use the high median when your data are discrete and you prefer the median to be an actual data point rather than interpolated.

statistics.**median_grouped**(*data*, *interval=1*)

Return the median of grouped continuous data, calculated as the 50th percentile, using interpolation. If *data* is empty, *StatisticsError* is raised. *data* can be a sequence or iterator.

```
>>> median_grouped([52, 52, 53, 54])
52.5
```

In the following example, the data are rounded, so that each value represents the midpoint of data classes, e.g. 1 is the midpoint of the class 0.5–1.5, 2 is the midpoint of 1.5–2.5, 3 is the midpoint of 2.5–3.5, etc. With the data given, the middle value falls somewhere in the class 3.5–4.5, and interpolation is used to estimate it:

```
>>> median_grouped([1, 2, 2, 3, 4, 4, 4, 4, 4, 5])
3.7
```

Optional argument *interval* represents the class interval, and defaults to 1. Changing the class interval naturally will change the interpolation:

```
>>> median_grouped([1, 3, 3, 5, 7], interval=1)
3.25
>>> median_grouped([1, 3, 3, 5, 7], interval=2)
3.5
```

This function does not check whether the data points are at least *interval* apart.

CPython implementation detail: Under some circumstances, *median_grouped()* may coerce data points to floats. This behaviour is likely to change in the future.

See also:

- "Statistics for the Behavioral Sciences", Frederick J Gravetter and Larry B Wallnau (8th Edition).
- The SSMEDIAN function in the Gnome Gnumeric spreadsheet, including this discussion.

`statistics.mode(`*data*`)`

Return the most common data point from discrete or nominal *data*. The mode (when it exists) is the most typical value, and is a robust measure of central location.

If *data* is empty, or if there is not exactly one most common value, *StatisticsError* is raised.

`mode` assumes discrete data, and returns a single value. This is the standard treatment of the mode as commonly taught in schools:

```
>>> mode([1, 1, 2, 3, 3, 3, 3, 4])
3
```

The mode is unique in that it is the only statistic which also applies to nominal (non-numeric) data:

```
>>> mode(["red", "blue", "blue", "red", "green", "red", "red"])
'red'
```

`statistics.pstdev(`*data*, *mu=None*`)`

Return the population standard deviation (the square root of the population variance). See *pvariance()* for arguments and other details.

```
>>> pstdev([1.5, 2.5, 2.5, 2.75, 3.25, 4.75])
0.986893273527251
```

`statistics.pvariance(`*data*, *mu=None*`)`

Return the population variance of *data*, a non-empty iterable of real-valued numbers. Variance, or second moment about the mean, is a measure of the variability (spread or dispersion) of data. A large variance indicates that the data is spread out; a small variance indicates it is clustered closely around the mean.

If the optional second argument *mu* is given, it should be the mean of *data*. If it is missing or `None` (the default), the mean is automatically calculated.

Use this function to calculate the variance from the entire population. To estimate the variance from a sample, the *variance()* function is usually a better choice.

Raises *StatisticsError* if *data* is empty.

Examples:

```
>>> data = [0.0, 0.25, 0.25, 1.25, 1.5, 1.75, 2.75, 3.25]
>>> pvariance(data)
1.25
```

If you have already calculated the mean of your data, you can pass it as the optional second argument *mu* to avoid recalculation:

```
>>> mu = mean(data)
>>> pvariance(data, mu)
1.25
```

This function does not attempt to verify that you have passed the actual mean as *mu*. Using arbitrary values for *mu* may lead to invalid or impossible results.

Decimals and Fractions are supported:

```
>>> from decimal import Decimal as D
>>> pvariance([D("27.5"), D("30.25"), D("30.25"), D("34.5"), D("41.75")])
Decimal('24.815')

>>> from fractions import Fraction as F
>>> pvariance([F(1, 4), F(5, 4), F(1, 2)])
Fraction(13, 72)
```

Note: When called with the entire population, this gives the population variance σ^2. When called on a sample instead, this is the biased sample variance s^2, also known as variance with N degrees of freedom.

If you somehow know the true population mean μ, you may use this function to calculate the variance of a sample, giving the known population mean as the second argument. Provided the data points are representative (e.g. independent and identically distributed), the result will be an unbiased estimate of the population variance.

`statistics.stdev(`*data*, *xbar=None*`)`

Return the sample standard deviation (the square root of the sample variance). See *variance()* for arguments and other details.

```
>>> stdev([1.5, 2.5, 2.5, 2.75, 3.25, 4.75])
1.0810874155219827
```

`statistics.variance(`*data*, *xbar=None*`)`

Return the sample variance of *data*, an iterable of at least two real-valued numbers. Variance, or second moment about the mean, is a measure of the variability (spread or dispersion) of data. A large variance indicates that the data is spread out; a small variance indicates it is clustered closely around the mean.

If the optional second argument *xbar* is given, it should be the mean of *data*. If it is missing or `None` (the default), the mean is automatically calculated.

Use this function when your data is a sample from a population. To calculate the variance from the entire population, see *pvariance()*.

Raises *StatisticsError* if *data* has fewer than two values.

Examples:

```
>>> data = [2.75, 1.75, 1.25, 0.25, 0.5, 1.25, 3.5]
>>> variance(data)
1.3720238095238095
```

If you have already calculated the mean of your data, you can pass it as the optional second argument *xbar* to avoid recalculation:

```
>>> m = mean(data)
>>> variance(data, m)
1.3720238095238095
```

This function does not attempt to verify that you have passed the actual mean as *xbar*. Using arbitrary values for *xbar* can lead to invalid or impossible results.

Decimal and Fraction values are supported:

```
>>> from decimal import Decimal as D
>>> variance([D("27.5"), D("30.25"), D("30.25"), D("34.5"), D("41.75")])
Decimal('31.01875')

>>> from fractions import Fraction as F
>>> variance([F(1, 6), F(1, 2), F(5, 3)])
Fraction(67, 108)
```

Note: This is the sample variance s^2 with Bessel's correction, also known as variance with N-1 degrees of freedom. Provided that the data points are representative (e.g. independent and identically distributed), the result should be an unbiased estimate of the true population variance.

If you somehow know the actual population mean μ you should pass it to the *pvariance()* function as the *mu* parameter to get the variance of a sample.

9.7.4 Exceptions

A single exception is defined:

exception statistics.StatisticsError
Subclass of *ValueError* for statistics-related exceptions.

CHAPTER

TEN

FUNCTIONAL PROGRAMMING MODULES

The modules described in this chapter provide functions and classes that support a functional programming style, and general operations on callables.

The following modules are documented in this chapter:

10.1 `itertools` — Functions creating iterators for efficient looping

This module implements a number of *iterator* building blocks inspired by constructs from APL, Haskell, and SML. Each has been recast in a form suitable for Python.

The module standardizes a core set of fast, memory efficient tools that are useful by themselves or in combination. Together, they form an "iterator algebra" making it possible to construct specialized tools succinctly and efficiently in pure Python.

For instance, SML provides a tabulation tool: `tabulate(f)` which produces a sequence `f(0), f(1), ...`. The same effect can be achieved in Python by combining *map()* and *count()* to form `map(f, count())`.

These tools and their built-in counterparts also work well with the high-speed functions in the *operator* module. For example, the multiplication operator can be mapped across two vectors to form an efficient dot-product: `sum(map(operator.mul, vector1, vector2))`.

Infinite iterators:

Iterator	Arguments	Results	Example
count()	start, [step]	start, start+step, start+2*step, …	`count(10) --> 10 11 12 13 14 ...`
cycle()	p	p0, p1, … plast, p0, p1, …	`cycle('ABCD') --> A B C D A B C D ...`
repeat()	elem [,n]	elem, elem, elem, … endlessly or up to n times	`repeat(10, 3) --> 10 10 10`

Iterators terminating on the shortest input sequence:

Iterator	Arguments	Results	Example
accumulate()	p [,func]	p0, p0+p1, p0+p1+p2, …	`accumulate([1,2,3,4,5]) --> 1 3 6 10 15`
chain()	p, q, …	p0, p1, … plast, q0, q1, …	`chain('ABC', 'DEF') --> A B C D E F`
chain.from_iterable()	iterable	p0, p1, … plast, q0, q1, …	`chain.from_iterable(['ABC', 'DEF']) --> A B C D E F`
compress()	data, selectors	(d[0] if s[0]), (d[1] if s[1]), …	`compress('ABCDEF', [1,0,1,0,1,1]) --> A C E F`
dropwhile()	pred, seq	seq[n], seq[n+1], starting when pred fails	`dropwhile(lambda x: x<5, [1,4,6,4,1]) --> 6 4 1`
filterfalse()	pred, seq	elements of seq where pred(elem) is false	`filterfalse(lambda x: x%2, range(10)) --> 0 2 4 6 8`
groupby()	iterable[, key]	sub-iterators grouped by value of key(v)	
islice()	seq, [start,] stop [, step]	elements from seq[start:stop:step]	`islice('ABCDEFG', 2, None) --> C D E F G`
starmap()	func, seq	func(*seq[0]), func(*seq[1]), …	`starmap(pow, [(2,5), (3,2), (10, 3)]) --> 32 9 1000`
takewhile()	pred, seq	seq[0], seq[1], until pred fails	`takewhile(lambda x: x<5, [1,4,6,4,1]) --> 1 4`
tee()	it, n	it1, it2, … itn splits one iterator into n	
zip_longest()	p, q, …	(p[0], q[0]), (p[1], q[1]), …	`zip_longest('ABCD', 'xy', fillvalue='-') --> Ax By C- D-`

Combinatoric iterators:

Iterator	Arguments	Results
product()	p, q, … [repeat=1]	cartesian product, equivalent to a nested for-loop
permutations()	p[, r]	r-length tuples, all possible orderings, no repeated elements
combinations()	p, r	r-length tuples, in sorted order, no repeated elements
combinations_with_replacement()	p, r	r-length tuples, in sorted order, with repeated elements
`product('ABCD', repeat=2)`		`AA AB AC AD BA BB BC BD CA CB CC CD DA DB DC DD`
`permutations('ABCD', 2)`		`AB AC AD BA BC BD CA CB CD DA DB DC`
`combinations('ABCD', 2)`		`AB AC AD BC BD CD`
`combinations_with_replacement('ABCD', 2)`		`AA AB AC AD BB BC BD CC CD DD`

10.1.1 Itertool functions

The following module functions all construct and return iterators. Some provide streams of infinite length, so they should only be accessed by functions or loops that truncate the stream.

`itertools.accumulate(`*iterable*`[,` *func*`])`

Make an iterator that returns accumulated sums, or accumulated results of other binary functions (specified via the optional *func* argument). If *func* is supplied, it should be a function of two arguments.

Elements of the input *iterable* may be any type that can be accepted as arguments to *func*. (For example, with the default operation of addition, elements may be any addable type including *Decimal* or *Fraction*.) If the input iterable is empty, the output iterable will also be empty.

Roughly equivalent to:

```
def accumulate(iterable, func=operator.add):
    'Return running totals'
    # accumulate([1,2,3,4,5]) --> 1 3 6 10 15
    # accumulate([1,2,3,4,5], operator.mul) --> 1 2 6 24 120
    it = iter(iterable)
    try:
        total = next(it)
    except StopIteration:
        return
    yield total
    for element in it:
        total = func(total, element)
        yield total
```

There are a number of uses for the *func* argument. It can be set to *min()* for a running minimum, *max()* for a running maximum, or *operator.mul()* for a running product. Amortization tables can be built by accumulating interest and applying payments. First-order recurrence relations can be modeled by supplying the initial value in the iterable and using only the accumulated total in *func* argument:

```
>>> data = [3, 4, 6, 2, 1, 9, 0, 7, 5, 8]
>>> list(accumulate(data, operator.mul))     # running product
[3, 12, 72, 144, 144, 1296, 0, 0, 0, 0]
>>> list(accumulate(data, max))              # running maximum
[3, 4, 6, 6, 6, 9, 9, 9, 9, 9]

# Amortize a 5% loan of 1000 with 4 annual payments of 90
>>> cashflows = [1000, -90, -90, -90, -90]
>>> list(accumulate(cashflows, lambda bal, pmt: bal*1.05 + pmt))
[1000, 960.0, 918.0, 873.9000000000001, 827.5950000000001]

# Chaotic recurrence relation https://en.wikipedia.org/wiki/Logistic_map
>>> logistic_map = lambda x, _:  r * x * (1 - x)
>>> r = 3.8
>>> x0 = 0.4
>>> inputs = repeat(x0, 36)     # only the initial value is used
>>> [format(x, '.2f') for x in accumulate(inputs, logistic_map)]
['0.40', '0.91', '0.30', '0.81', '0.60', '0.92', '0.29', '0.79', '0.63',
 '0.88', '0.39', '0.90', '0.33', '0.84', '0.52', '0.95', '0.18', '0.57',
 '0.93', '0.25', '0.71', '0.79', '0.63', '0.88', '0.39', '0.91', '0.32',
 '0.83', '0.54', '0.95', '0.20', '0.60', '0.91', '0.30', '0.80', '0.60']
```

See *functools.reduce()* for a similar function that returns only the final accumulated value.

New in version 3.2.

Changed in version 3.3: Added the optional *func* parameter.

itertools.**chain**(**iterables*)

Make an iterator that returns elements from the first iterable until it is exhausted, then proceeds to the next iterable, until all of the iterables are exhausted. Used for treating consecutive sequences as a single sequence. Roughly equivalent to:

```
def chain(*iterables):
    # chain('ABC', 'DEF') --> A B C D E F
    for it in iterables:
        for element in it:
            yield element
```

classmethod chain.**from_iterable**(*iterable*)

Alternate constructor for *chain()*. Gets chained inputs from a single iterable argument that is evaluated lazily. Roughly equivalent to:

```
def from_iterable(iterables):
    # chain.from_iterable(['ABC', 'DEF']) --> A B C D E F
    for it in iterables:
        for element in it:
            yield element
```

itertools.**combinations**(*iterable*, *r*)

Return *r* length subsequences of elements from the input *iterable*.

Combinations are emitted in lexicographic sort order. So, if the input *iterable* is sorted, the combination tuples will be produced in sorted order.

Elements are treated as unique based on their position, not on their value. So if the input elements are unique, there will be no repeat values in each combination.

Roughly equivalent to:

```
def combinations(iterable, r):
    # combinations('ABCD', 2) --> AB AC AD BC BD CD
    # combinations(range(4), 3) --> 012 013 023 123
    pool = tuple(iterable)
    n = len(pool)
    if r > n:
        return
    indices = list(range(r))
    yield tuple(pool[i] for i in indices)
    while True:
        for i in reversed(range(r)):
            if indices[i] != i + n - r:
                break
        else:
            return
        indices[i] += 1
        for j in range(i+1, r):
            indices[j] = indices[j-1] + 1
        yield tuple(pool[i] for i in indices)
```

The code for *combinations()* can be also expressed as a subsequence of *permutations()* after filtering entries where the elements are not in sorted order (according to their position in the input pool):

```
def combinations(iterable, r):
    pool = tuple(iterable)
    n = len(pool)
    for indices in permutations(range(n), r):
        if sorted(indices) == list(indices):
            yield tuple(pool[i] for i in indices)
```

The number of items returned is `n! / r! / (n-r)!` when `0 <= r <= n` or zero when `r > n`.

itertools.**combinations_with_replacement**(*iterable*, *r*)

Return *r* length subsequences of elements from the input *iterable* allowing individual elements to be repeated more than once.

Combinations are emitted in lexicographic sort order. So, if the input *iterable* is sorted, the combination tuples will be produced in sorted order.

Elements are treated as unique based on their position, not on their value. So if the input elements are unique, the generated combinations will also be unique.

Roughly equivalent to:

```
def combinations_with_replacement(iterable, r):
    # combinations_with_replacement('ABC', 2) --> AA AB AC BB BC CC
    pool = tuple(iterable)
    n = len(pool)
    if not n and r:
        return
    indices = [0] * r
    yield tuple(pool[i] for i in indices)
    while True:
        for i in reversed(range(r)):
            if indices[i] != n - 1:
                break
        else:
            return
        indices[i:] = [indices[i] + 1] * (r - i)
        yield tuple(pool[i] for i in indices)
```

The code for *combinations_with_replacement()* can be also expressed as a subsequence of *product()* after filtering entries where the elements are not in sorted order (according to their position in the input pool):

```
def combinations_with_replacement(iterable, r):
    pool = tuple(iterable)
    n = len(pool)
    for indices in product(range(n), repeat=r):
        if sorted(indices) == list(indices):
            yield tuple(pool[i] for i in indices)
```

The number of items returned is `(n+r-1)! / r! / (n-1)!` when `n > 0`.

New in version 3.1.

itertools.**compress**(*data*, *selectors*)

Make an iterator that filters elements from *data* returning only those that have a corresponding element in *selectors* that evaluates to `True`. Stops when either the *data* or *selectors* iterables has been exhausted. Roughly equivalent to:

```
def compress(data, selectors):
    # compress('ABCDEF', [1,0,1,0,1,1]) --> A C E F
    return (d for d, s in zip(data, selectors) if s)
```

New in version 3.1.

itertools.**count**(*start=0*, *step=1*)

Make an iterator that returns evenly spaced values starting with number *start*. Often used as an argument to *map()* to generate consecutive data points. Also, used with *zip()* to add sequence numbers. Roughly equivalent to:

```
def count(start=0, step=1):
    # count(10) --> 10 11 12 13 14 ...
    # count(2.5, 0.5) -> 2.5 3.0 3.5 ...
    n = start
    while True:
        yield n
        n += step
```

When counting with floating point numbers, better accuracy can sometimes be achieved by substituting multiplicative code such as: `(start + step * i for i in count())`.

Changed in version 3.1: Added *step* argument and allowed non-integer arguments.

`itertools.cycle`(*iterable*)

Make an iterator returning elements from the iterable and saving a copy of each. When the iterable is exhausted, return elements from the saved copy. Repeats indefinitely. Roughly equivalent to:

```
def cycle(iterable):
    # cycle('ABCD') --> A B C D A B C D A B C D ...
    saved = []
    for element in iterable:
        yield element
        saved.append(element)
    while saved:
        for element in saved:
              yield element
```

Note, this member of the toolkit may require significant auxiliary storage (depending on the length of the iterable).

`itertools.dropwhile`(*predicate*, *iterable*)

Make an iterator that drops elements from the iterable as long as the predicate is true; afterwards, returns every element. Note, the iterator does not produce *any* output until the predicate first becomes false, so it may have a lengthy start-up time. Roughly equivalent to:

```
def dropwhile(predicate, iterable):
    # dropwhile(lambda x: x<5, [1,4,6,4,1]) --> 6 4 1
    iterable = iter(iterable)
    for x in iterable:
        if not predicate(x):
            yield x
            break
    for x in iterable:
        yield x
```

`itertools.filterfalse`(*predicate*, *iterable*)

Make an iterator that filters elements from iterable returning only those for which the predicate is `False`. If *predicate* is `None`, return the items that are false. Roughly equivalent to:

```
def filterfalse(predicate, iterable):
    # filterfalse(lambda x: x%2, range(10)) --> 0 2 4 6 8
    if predicate is None:
        predicate = bool
    for x in iterable:
        if not predicate(x):
            yield x
```

`itertools.groupby`(*iterable*, *key=None*)

Make an iterator that returns consecutive keys and groups from the *iterable*. The *key* is a function

computing a key value for each element. If not specified or is `None`, *key* defaults to an identity function and returns the element unchanged. Generally, the iterable needs to already be sorted on the same key function.

The operation of *groupby()* is similar to the `uniq` filter in Unix. It generates a break or new group every time the value of the key function changes (which is why it is usually necessary to have sorted the data using the same key function). That behavior differs from SQL's GROUP BY which aggregates common elements regardless of their input order.

The returned group is itself an iterator that shares the underlying iterable with *groupby()*. Because the source is shared, when the *groupby()* object is advanced, the previous group is no longer visible. So, if that data is needed later, it should be stored as a list:

```
groups = []
uniquekeys = []
data = sorted(data, key=keyfunc)
for k, g in groupby(data, keyfunc):
    groups.append(list(g))      # Store group iterator as a list
    uniquekeys.append(k)
```

groupby() is roughly equivalent to:

```
class groupby:
    # [k for k, g in groupby('AAAABBBCCDAABBB')] --> A B C D A B
    # [list(g) for k, g in groupby('AAAABBBCCD')] --> AAAA BBB CC D
    def __init__(self, iterable, key=None):
        if key is None:
            key = lambda x: x
        self.keyfunc = key
        self.it = iter(iterable)
        self.tgtkey = self.currkey = self.currvalue = object()
    def __iter__(self):
        return self
    def __next__(self):
        self.id = object()
        while self.currkey == self.tgtkey:
            self.currvalue = next(self.it)    # Exit on StopIteration
            self.currkey = self.keyfunc(self.currvalue)
        self.tgtkey = self.currkey
        return (self.currkey, self._grouper(self.tgtkey, self.id))
    def _grouper(self, tgtkey, id):
        while self.id is id and self.currkey == tgtkey:
            yield self.currvalue
            try:
                self.currvalue = next(self.it)
            except StopIteration:
                return
            self.currkey = self.keyfunc(self.currvalue)
```

`itertools.islice`(*iterable*, *stop*)
`itertools.islice`(*iterable*, *start*, *stop*[, *step*])

Make an iterator that returns selected elements from the iterable. If *start* is non-zero, then elements from the iterable are skipped until start is reached. Afterward, elements are returned consecutively unless *step* is set higher than one which results in items being skipped. If *stop* is `None`, then iteration continues until the iterator is exhausted, if at all; otherwise, it stops at the specified position. Unlike regular slicing, *islice()* does not support negative values for *start*, *stop*, or *step*. Can be used to extract related fields from data where the internal structure has been flattened (for example, a multi-line report may list a name field on every third line). Roughly equivalent to:

```
def islice(iterable, *args):
    # islice('ABCDEFG', 2) --> A B
    # islice('ABCDEFG', 2, 4) --> C D
    # islice('ABCDEFG', 2, None) --> C D E F G
    # islice('ABCDEFG', 0, None, 2) --> A C E G
    s = slice(*args)
    start, stop, step = s.start or 0, s.stop or sys.maxsize, s.step or 1
    it = iter(range(start, stop, step))
    try:
        nexti = next(it)
    except StopIteration:
        # Consume *iterable* up to the *start* position.
        for i, element in zip(range(start), iterable):
            pass
        return
    try:
        for i, element in enumerate(iterable):
            if i == nexti:
                yield element
                nexti = next(it)
    except StopIteration:
        # Consume to *stop*.
        for i, element in zip(range(i + 1, stop), iterable):
            pass
```

If *start* is `None`, then iteration starts at zero. If *step* is `None`, then the step defaults to one.

`itertools.permutations`(*iterable*, *r=None*)

Return successive *r* length permutations of elements in the *iterable*.

If *r* is not specified or is `None`, then *r* defaults to the length of the *iterable* and all possible full-length permutations are generated.

Permutations are emitted in lexicographic sort order. So, if the input *iterable* is sorted, the permutation tuples will be produced in sorted order.

Elements are treated as unique based on their position, not on their value. So if the input elements are unique, there will be no repeat values in each permutation.

Roughly equivalent to:

```
def permutations(iterable, r=None):
    # permutations('ABCD', 2) --> AB AC AD BA BC BD CA CB CD DA DB DC
    # permutations(range(3)) --> 012 021 102 120 201 210
    pool = tuple(iterable)
    n = len(pool)
    r = n if r is None else r
    if r > n:
        return
    indices = list(range(n))
    cycles = list(range(n, n-r, -1))
    yield tuple(pool[i] for i in indices[:r])
    while n:
        for i in reversed(range(r)):
            cycles[i] -= 1
            if cycles[i] == 0:
                indices[i:] = indices[i+1:] + indices[i:i+1]
                cycles[i] = n - i
            else:
```

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```
                j = cycles[i]
                indices[i], indices[-j] = indices[-j], indices[i]
                yield tuple(pool[i] for i in indices[:r])
                break
        else:
            return
```

The code for *permutations()* can be also expressed as a subsequence of *product()*, filtered to exclude entries with repeated elements (those from the same position in the input pool):

```
def permutations(iterable, r=None):
    pool = tuple(iterable)
    n = len(pool)
    r = n if r is None else r
    for indices in product(range(n), repeat=r):
        if len(set(indices)) == r:
            yield tuple(pool[i] for i in indices)
```

The number of items returned is `n! / (n-r)!` when `0 <= r <= n` or zero when `r > n`.

itertools.**product**(**iterables*, *repeat=1*)

Cartesian product of input iterables.

Roughly equivalent to nested for-loops in a generator expression. For example, `product(A, B)` returns the same as `((x,y) for x in A for y in B)`.

The nested loops cycle like an odometer with the rightmost element advancing on every iteration. This pattern creates a lexicographic ordering so that if the input's iterables are sorted, the product tuples are emitted in sorted order.

To compute the product of an iterable with itself, specify the number of repetitions with the optional *repeat* keyword argument. For example, `product(A, repeat=4)` means the same as `product(A, A, A, A)`.

This function is roughly equivalent to the following code, except that the actual implementation does not build up intermediate results in memory:

```
def product(*args, repeat=1):
    # product('ABCD', 'xy') --> Ax Ay Bx By Cx Cy Dx Dy
    # product(range(2), repeat=3) --> 000 001 010 011 100 101 110 111
    pools = [tuple(pool) for pool in args] * repeat
    result = [[]]
    for pool in pools:
        result = [x+[y] for x in result for y in pool]
    for prod in result:
        yield tuple(prod)
```

itertools.**repeat**(*object*[, *times*])

Make an iterator that returns *object* over and over again. Runs indefinitely unless the *times* argument is specified. Used as argument to *map()* for invariant parameters to the called function. Also used with *zip()* to create an invariant part of a tuple record.

Roughly equivalent to:

```
def repeat(object, times=None):
    # repeat(10, 3) --> 10 10 10
    if times is None:
        while True:
```

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```
            yield object
    else:
        for i in range(times):
            yield object
```

A common use for *repeat* is to supply a stream of constant values to *map* or *zip*:

```
>>> list(map(pow, range(10), repeat(2)))
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

itertools.**starmap**(*function*, *iterable*)

Make an iterator that computes the function using arguments obtained from the iterable. Used instead of *map()* when argument parameters are already grouped in tuples from a single iterable (the data has been "pre-zipped"). The difference between *map()* and *starmap()* parallels the distinction between `function(a,b)` and `function(*c)`. Roughly equivalent to:

```
def starmap(function, iterable):
    # starmap(pow, [(2,5), (3,2), (10,3)]) --> 32 9 1000
    for args in iterable:
        yield function(*args)
```

itertools.**takewhile**(*predicate*, *iterable*)

Make an iterator that returns elements from the iterable as long as the predicate is true. Roughly equivalent to:

```
def takewhile(predicate, iterable):
    # takewhile(lambda x: x<5, [1,4,6,4,1]) --> 1 4
    for x in iterable:
        if predicate(x):
            yield x
        else:
            break
```

itertools.**tee**(*iterable*, *n=2*)

Return *n* independent iterators from a single iterable.

The following Python code helps explain what *tee* does (although the actual implementation is more complex and uses only a single underlying FIFO queue).

Roughly equivalent to:

```
def tee(iterable, n=2):
    it = iter(iterable)
    deques = [collections.deque() for i in range(n)]
    def gen(mydeque):
        while True:
            if not mydeque:             # when the local deque is empty
                try:
                    newval = next(it)   # fetch a new value and
                except StopIteration:
                    return
                for d in deques:        # load it to all the deques
                    d.append(newval)
            yield mydeque.popleft()
    return tuple(gen(d) for d in deques)
```

Once *tee()* has made a split, the original *iterable* should not be used anywhere else; otherwise, the *iterable* could get advanced without the tee objects being informed.

This itertool may require significant auxiliary storage (depending on how much temporary data needs to be stored). In general, if one iterator uses most or all of the data before another iterator starts, it is faster to use *list()* instead of *tee()*.

itertools.**zip_longest**(**iterables*, *fillvalue=None*)

Make an iterator that aggregates elements from each of the iterables. If the iterables are of uneven length, missing values are filled-in with *fillvalue*. Iteration continues until the longest iterable is exhausted. Roughly equivalent to:

```
def zip_longest(*args, fillvalue=None):
    # zip_longest('ABCD', 'xy', fillvalue='-') --> Ax By C- D-
    iterators = [iter(it) for it in args]
    num_active = len(iterators)
    if not num_active:
        return
    while True:
        values = []
        for i, it in enumerate(iterators):
            try:
                value = next(it)
            except StopIteration:
                num_active -= 1
                if not num_active:
                    return
                iterators[i] = repeat(fillvalue)
                value = fillvalue
            values.append(value)
        yield tuple(values)
```

If one of the iterables is potentially infinite, then the *zip_longest()* function should be wrapped with something that limits the number of calls (for example *islice()* or *takewhile()*). If not specified, *fillvalue* defaults to `None`.

10.1.2 Itertools Recipes

This section shows recipes for creating an extended toolset using the existing itertools as building blocks.

The extended tools offer the same high performance as the underlying toolset. The superior memory performance is kept by processing elements one at a time rather than bringing the whole iterable into memory all at once. Code volume is kept small by linking the tools together in a functional style which helps eliminate temporary variables. High speed is retained by preferring "vectorized" building blocks over the use of for-loops and *generator*s which incur interpreter overhead.

```
def take(n, iterable):
    "Return first n items of the iterable as a list"
    return list(islice(iterable, n))

def prepend(value, iterator):
    "Prepend a single value in front of an iterator"
    # prepend(1, [2, 3, 4]) -> 1 2 3 4
    return chain([value], iterator)

def tabulate(function, start=0):
    "Return function(0), function(1), ..."
    return map(function, count(start))

def tail(n, iterable):
```

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```
    "Return an iterator over the last n items"
    # tail(3, 'ABCDEFG') --> E F G
    return iter(collections.deque(iterable, maxlen=n))

def consume(iterator, n=None):
    "Advance the iterator n-steps ahead. If n is None, consume entirely."
    # Use functions that consume iterators at C speed.
    if n is None:
        # feed the entire iterator into a zero-length deque
        collections.deque(iterator, maxlen=0)
    else:
        # advance to the empty slice starting at position n
        next(islice(iterator, n, n), None)

def nth(iterable, n, default=None):
    "Returns the nth item or a default value"
    return next(islice(iterable, n, None), default)

def all_equal(iterable):
    "Returns True if all the elements are equal to each other"
    g = groupby(iterable)
    return next(g, True) and not next(g, False)

def quantify(iterable, pred=bool):
    "Count how many times the predicate is true"
    return sum(map(pred, iterable))

def padnone(iterable):
    """Returns the sequence elements and then returns None indefinitely.

    Useful for emulating the behavior of the built-in map() function.
    """
    return chain(iterable, repeat(None))

def ncycles(iterable, n):
    "Returns the sequence elements n times"
    return chain.from_iterable(repeat(tuple(iterable), n))

def dotproduct(vec1, vec2):
    return sum(map(operator.mul, vec1, vec2))

def flatten(listOfLists):
    "Flatten one level of nesting"
    return chain.from_iterable(listOfLists)

def repeatfunc(func, times=None, *args):
    """Repeat calls to func with specified arguments.

    Example:  repeatfunc(random.random)
    """
    if times is None:
        return starmap(func, repeat(args))
    return starmap(func, repeat(args, times))

def pairwise(iterable):
    "s -> (s0,s1), (s1,s2), (s2, s3), ..."
```

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```
    a, b = tee(iterable)
    next(b, None)
    return zip(a, b)

def grouper(iterable, n, fillvalue=None):
    "Collect data into fixed-length chunks or blocks"
    # grouper('ABCDEFG', 3, 'x') --> ABC DEF Gxx"
    args = [iter(iterable)] * n
    return zip_longest(*args, fillvalue=fillvalue)

def roundrobin(*iterables):
    "roundrobin('ABC', 'D', 'EF') --> A D E B F C"
    # Recipe credited to George Sakkis
    num_active = len(iterables)
    nexts = cycle(iter(it).__next__ for it in iterables)
    while num_active:
        try:
            for next in nexts:
                yield next()
        except StopIteration:
            # Remove the iterator we just exhausted from the cycle.
            num_active -= 1
            nexts = cycle(islice(nexts, num_active))

def partition(pred, iterable):
    'Use a predicate to partition entries into false entries and true entries'
    # partition(is_odd, range(10)) --> 0 2 4 6 8   and  1 3 5 7 9
    t1, t2 = tee(iterable)
    return filterfalse(pred, t1), filter(pred, t2)

def powerset(iterable):
    "powerset([1,2,3]) --> () (1,) (2,) (3,) (1,2) (1,3) (2,3) (1,2,3)"
    s = list(iterable)
    return chain.from_iterable(combinations(s, r) for r in range(len(s)+1))

def unique_everseen(iterable, key=None):
    "List unique elements, preserving order. Remember all elements ever seen."
    # unique_everseen('AAAABBBCCDAABBB') --> A B C D
    # unique_everseen('ABBCcAD', str.lower) --> A B C D
    seen = set()
    seen_add = seen.add
    if key is None:
        for element in filterfalse(seen.__contains__, iterable):
            seen_add(element)
            yield element
    else:
        for element in iterable:
            k = key(element)
            if k not in seen:
                seen_add(k)
                yield element

def unique_justseen(iterable, key=None):
    "List unique elements, preserving order. Remember only the element just seen."
    # unique_justseen('AAAABBBCCDAABBB') --> A B C D A B
    # unique_justseen('ABBCcAD', str.lower) --> A B C A D
```

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```
    return map(next, map(itemgetter(1), groupby(iterable, key)))

def iter_except(func, exception, first=None):
    """ Call a function repeatedly until an exception is raised.

    Converts a call-until-exception interface to an iterator interface.
    Like builtins.iter(func, sentinel) but uses an exception instead
    of a sentinel to end the loop.

    Examples:
        iter_except(functools.partial(heappop, h), IndexError)   # priority queue iterator
        iter_except(d.popitem, KeyError)                         # non-blocking dict iterator
        iter_except(d.popleft, IndexError)                       # non-blocking deque iterator
        iter_except(q.get_nowait, Queue.Empty)                   # loop over a producer Queue
        iter_except(s.pop, KeyError)                             # non-blocking set iterator

    """
    try:
        if first is not None:
            yield first()            # For database APIs needing an initial cast to db.first()
        while True:
            yield func()
    except exception:
        pass

def first_true(iterable, default=False, pred=None):
    """Returns the first true value in the iterable.

    If no true value is found, returns *default*

    If *pred* is not None, returns the first item
    for which pred(item) is true.

    """
    # first_true([a,b,c], x) --> a or b or c or x
    # first_true([a,b], x, f) --> a if f(a) else b if f(b) else x
    return next(filter(pred, iterable), default)

def random_product(*args, repeat=1):
    "Random selection from itertools.product(*args, **kwds)"
    pools = [tuple(pool) for pool in args] * repeat
    return tuple(random.choice(pool) for pool in pools)

def random_permutation(iterable, r=None):
    "Random selection from itertools.permutations(iterable, r)"
    pool = tuple(iterable)
    r = len(pool) if r is None else r
    return tuple(random.sample(pool, r))

def random_combination(iterable, r):
    "Random selection from itertools.combinations(iterable, r)"
    pool = tuple(iterable)
    n = len(pool)
    indices = sorted(random.sample(range(n), r))
    return tuple(pool[i] for i in indices)
```

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```
def random_combination_with_replacement(iterable, r):
    "Random selection from itertools.combinations_with_replacement(iterable, r)"
    pool = tuple(iterable)
    n = len(pool)
    indices = sorted(random.randrange(n) for i in range(r))
    return tuple(pool[i] for i in indices)

def nth_combination(iterable, r, index):
    'Equivalent to list(combinations(iterable, r))[index]'
    pool = tuple(iterable)
    n = len(pool)
    if r < 0 or r > n:
        raise ValueError
    c = 1
    k = min(r, n-r)
    for i in range(1, k+1):
        c = c * (n - k + i) // i
    if index < 0:
        index += c
    if index < 0 or index >= c:
        raise IndexError
    result = []
    while r:
        c, n, r = c*r//n, n-1, r-1
        while index >= c:
            index -= c
            c, n = c*(n-r)//n, n-1
        result.append(pool[-1-n])
    return tuple(result)
```

Note, many of the above recipes can be optimized by replacing global lookups with local variables defined as default values. For example, the *dotproduct* recipe can be written as:

```
def dotproduct(vec1, vec2, sum=sum, map=map, mul=operator.mul):
    return sum(map(mul, vec1, vec2))
```

10.2 `functools` — Higher-order functions and operations on callable objects

Source code: Lib/functools.py

The *functools* module is for higher-order functions: functions that act on or return other functions. In general, any callable object can be treated as a function for the purposes of this module.

The *functools* module defines the following functions:

`functools.cmp_to_key(func)`

Transform an old-style comparison function to a *key function*. Used with tools that accept key functions (such as *sorted()*, *min()*, *max()*, *heapq.nlargest()*, *heapq.nsmallest()*, *itertools.groupby()*). This function is primarily used as a transition tool for programs being converted from Python 2 which supported the use of comparison functions.

A comparison function is any callable that accept two arguments, compares them, and returns a negative number for less-than, zero for equality, or a positive number for greater-than. A key function is a callable that accepts one argument and returns another value to be used as the sort key.

Example:

```
sorted(iterable, key=cmp_to_key(locale.strcoll))  # locale-aware sort order
```

For sorting examples and a brief sorting tutorial, see sortinghowto.

New in version 3.2.

@functools.lru_cache(*maxsize=128*, *typed=False*)

Decorator to wrap a function with a memoizing callable that saves up to the *maxsize* most recent calls. It can save time when an expensive or I/O bound function is periodically called with the same arguments.

Since a dictionary is used to cache results, the positional and keyword arguments to the function must be hashable.

If *maxsize* is set to `None`, the LRU feature is disabled and the cache can grow without bound. The LRU feature performs best when *maxsize* is a power-of-two.

If *typed* is set to true, function arguments of different types will be cached separately. For example, `f(3)` and `f(3.0)` will be treated as distinct calls with distinct results.

To help measure the effectiveness of the cache and tune the *maxsize* parameter, the wrapped function is instrumented with a `cache_info()` function that returns a *named tuple* showing *hits*, *misses*, *maxsize* and *currsize*. In a multi-threaded environment, the hits and misses are approximate.

The decorator also provides a `cache_clear()` function for clearing or invalidating the cache.

The original underlying function is accessible through the `__wrapped__` attribute. This is useful for introspection, for bypassing the cache, or for rewrapping the function with a different cache.

An LRU (least recently used) cache works best when the most recent calls are the best predictors of upcoming calls (for example, the most popular articles on a news server tend to change each day). The cache's size limit assures that the cache does not grow without bound on long-running processes such as web servers.

Example of an LRU cache for static web content:

```
@lru_cache(maxsize=32)
def get_pep(num):
    'Retrieve text of a Python Enhancement Proposal'
    resource = 'http://www.python.org/dev/peps/pep-%04d/' % num
    try:
        with urllib.request.urlopen(resource) as s:
            return s.read()
    except urllib.error.HTTPError:
        return 'Not Found'

>>> for n in 8, 290, 308, 320, 8, 218, 320, 279, 289, 320, 9991:
...     pep = get_pep(n)
...     print(n, len(pep))

>>> get_pep.cache_info()
CacheInfo(hits=3, misses=8, maxsize=32, currsize=8)
```

Example of efficiently computing Fibonacci numbers using a cache to implement a dynamic programming technique:

```
@lru_cache(maxsize=None)
def fib(n):
    if n < 2:
        return n
    return fib(n-1) + fib(n-2)

>>> [fib(n) for n in range(16)]
[0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610]

>>> fib.cache_info()
CacheInfo(hits=28, misses=16, maxsize=None, currsize=16)
```

New in version 3.2.

Changed in version 3.3: Added the *typed* option.

@functools.total_ordering

Given a class defining one or more rich comparison ordering methods, this class decorator supplies the rest. This simplifies the effort involved in specifying all of the possible rich comparison operations:

The class must define one of `__lt__()`, `__le__()`, `__gt__()`, or `__ge__()`. In addition, the class should supply an `__eq__()` method.

For example:

```
@total_ordering
class Student:
    def _is_valid_operand(self, other):
        return (hasattr(other, "lastname") and
                hasattr(other, "firstname"))
    def __eq__(self, other):
        if not self._is_valid_operand(other):
            return NotImplemented
        return ((self.lastname.lower(), self.firstname.lower()) ==
                (other.lastname.lower(), other.firstname.lower()))
    def __lt__(self, other):
        if not self._is_valid_operand(other):
            return NotImplemented
        return ((self.lastname.lower(), self.firstname.lower()) <
                (other.lastname.lower(), other.firstname.lower()))
```

Note: While this decorator makes it easy to create well behaved totally ordered types, it *does* come at the cost of slower execution and more complex stack traces for the derived comparison methods. If performance benchmarking indicates this is a bottleneck for a given application, implementing all six rich comparison methods instead is likely to provide an easy speed boost.

New in version 3.2.

Changed in version 3.4: Returning NotImplemented from the underlying comparison function for unrecognised types is now supported.

functools.partial(*func*, **args*, ***keywords*)

Return a new *partial* object which when called will behave like *func* called with the positional arguments *args* and keyword arguments *keywords*. If more arguments are supplied to the call, they are appended to *args*. If additional keyword arguments are supplied, they extend and override *keywords*. Roughly equivalent to:

```
def partial(func, *args, **keywords):
    def newfunc(*fargs, **fkeywords):
        newkeywords = keywords.copy()
        newkeywords.update(fkeywords)
        return func(*args, *fargs, **newkeywords)
    newfunc.func = func
    newfunc.args = args
    newfunc.keywords = keywords
    return newfunc
```

The *partial()* is used for partial function application which "freezes" some portion of a function's arguments and/or keywords resulting in a new object with a simplified signature. For example, *partial()* can be used to create a callable that behaves like the *int()* function where the *base* argument defaults to two:

```
>>> from functools import partial
>>> basetwo = partial(int, base=2)
>>> basetwo.__doc__ = 'Convert base 2 string to an int.'
>>> basetwo('10010')
18
```

class functools.partialmethod(*func*, **args*, ***keywords*)

Return a new *partialmethod* descriptor which behaves like *partial* except that it is designed to be used as a method definition rather than being directly callable.

func must be a *descriptor* or a callable (objects which are both, like normal functions, are handled as descriptors).

When *func* is a descriptor (such as a normal Python function, *classmethod()*, *staticmethod()*, `abstractmethod()` or another instance of *partialmethod*), calls to `__get__` are delegated to the underlying descriptor, and an appropriate *partial* object returned as the result.

When *func* is a non-descriptor callable, an appropriate bound method is created dynamically. This behaves like a normal Python function when used as a method: the *self* argument will be inserted as the first positional argument, even before the *args* and *keywords* supplied to the *partialmethod* constructor.

Example:

```
>>> class Cell(object):
...     def __init__(self):
...         self._alive = False
...     @property
...     def alive(self):
...         return self._alive
...     def set_state(self, state):
...         self._alive = bool(state)
...     set_alive = partialmethod(set_state, True)
...     set_dead = partialmethod(set_state, False)
...
>>> c = Cell()
>>> c.alive
False
>>> c.set_alive()
>>> c.alive
True
```

New in version 3.4.

`functools.reduce`(*function*, *iterable*[, *initializer*])

Apply *function* of two arguments cumulatively to the items of *sequence*, from left to right, so as to reduce the sequence to a single value. For example, `reduce(lambda x, y: x+y, [1, 2, 3, 4, 5])` calculates `((((1+2)+3)+4)+5)`. The left argument, *x*, is the accumulated value and the right argument, *y*, is the update value from the *sequence*. If the optional *initializer* is present, it is placed before the items of the sequence in the calculation, and serves as a default when the sequence is empty. If *initializer* is not given and *sequence* contains only one item, the first item is returned.

Roughly equivalent to:

```
def reduce(function, iterable, initializer=None):
    it = iter(iterable)
    if initializer is None:
        value = next(it)
    else:
        value = initializer
    for element in it:
        value = function(value, element)
    return value
```

`@functools.singledispatch`

Transform a function into a *single-dispatch generic function*.

To define a generic function, decorate it with the `@singledispatch` decorator. Note that the dispatch happens on the type of the first argument, create your function accordingly:

```
>>> from functools import singledispatch
>>> @singledispatch
... def fun(arg, verbose=False):
...     if verbose:
...         print("Let me just say,", end=" ")
...     print(arg)
```

To add overloaded implementations to the function, use the `register()` attribute of the generic function. It is a decorator. For functions annotated with types, the decorator will infer the type of the first argument automatically:

```
>>> @fun.register
... def _(arg: int, verbose=False):
...     if verbose:
...         print("Strength in numbers, eh?", end=" ")
...     print(arg)
...
>>> @fun.register
... def _(arg: list, verbose=False):
...     if verbose:
...         print("Enumerate this:")
...     for i, elem in enumerate(arg):
...         print(i, elem)
```

For code which doesn't use type annotations, the appropriate type argument can be passed explicitly to the decorator itself:

```
>>> @fun.register(complex)
... def _(arg, verbose=False):
...     if verbose:
...         print("Better than complicated.", end=" ")
```

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```
...     print(arg.real, arg.imag)
...
```

To enable registering lambdas and pre-existing functions, the `register()` attribute can be used in a functional form:

```
>>> def nothing(arg, verbose=False):
...     print("Nothing.")
...
>>> fun.register(type(None), nothing)
```

The `register()` attribute returns the undecorated function which enables decorator stacking, pickling, as well as creating unit tests for each variant independently:

```
>>> @fun.register(float)
... @fun.register(Decimal)
... def fun_num(arg, verbose=False):
...     if verbose:
...         print("Half of your number:", end=" ")
...     print(arg / 2)
...
>>> fun_num is fun
False
```

When called, the generic function dispatches on the type of the first argument:

```
>>> fun("Hello, world.")
Hello, world.
>>> fun("test.", verbose=True)
Let me just say, test.
>>> fun(42, verbose=True)
Strength in numbers, eh? 42
>>> fun(['spam', 'spam', 'eggs', 'spam'], verbose=True)
Enumerate this:
0 spam
1 spam
2 eggs
3 spam
>>> fun(None)
Nothing.
>>> fun(1.23)
0.615
```

Where there is no registered implementation for a specific type, its method resolution order is used to find a more generic implementation. The original function decorated with `@singledispatch` is registered for the base `object` type, which means it is used if no better implementation is found.

To check which implementation will the generic function choose for a given type, use the `dispatch()` attribute:

```
>>> fun.dispatch(float)
<function fun_num at 0x1035a2840>
>>> fun.dispatch(dict)    # note: default implementation
<function fun at 0x103fe0000>
```

To access all registered implementations, use the read-only `registry` attribute:

```
>>> fun.registry.keys()
dict_keys([<class 'NoneType'>, <class 'int'>, <class 'object'>,
           <class 'decimal.Decimal'>, <class 'list'>,
           <class 'float'>])
>>> fun.registry[float]
<function fun_num at 0x1035a2840>
>>> fun.registry[object]
<function fun at 0x103fe0000>
```

New in version 3.4.

Changed in version 3.7: The `register()` attribute supports using type annotations.

`functools.update_wrapper(`*wrapper*, *wrapped*, *assigned=WRAPPER_ASSIGNMENTS*, *updated=WRAPPER_UPDATES*`)`

Update a *wrapper* function to look like the *wrapped* function. The optional arguments are tuples to specify which attributes of the original function are assigned directly to the matching attributes on the wrapper function and which attributes of the wrapper function are updated with the corresponding attributes from the original function. The default values for these arguments are the module level constants `WRAPPER_ASSIGNMENTS` (which assigns to the wrapper function's `__module__`, `__name__`, `__qualname__`, `__annotations__` and `__doc__`, the documentation string) and `WRAPPER_UPDATES` (which updates the wrapper function's `__dict__`, i.e. the instance dictionary).

To allow access to the original function for introspection and other purposes (e.g. bypassing a caching decorator such as *lru_cache()*), this function automatically adds a `__wrapped__` attribute to the wrapper that refers to the function being wrapped.

The main intended use for this function is in *decorator* functions which wrap the decorated function and return the wrapper. If the wrapper function is not updated, the metadata of the returned function will reflect the wrapper definition rather than the original function definition, which is typically less than helpful.

update_wrapper() may be used with callables other than functions. Any attributes named in *assigned* or *updated* that are missing from the object being wrapped are ignored (i.e. this function will not attempt to set them on the wrapper function). *AttributeError* is still raised if the wrapper function itself is missing any attributes named in *updated*.

New in version 3.2: Automatic addition of the `__wrapped__` attribute.

New in version 3.2: Copying of the `__annotations__` attribute by default.

Changed in version 3.2: Missing attributes no longer trigger an *AttributeError*.

Changed in version 3.4: The `__wrapped__` attribute now always refers to the wrapped function, even if that function defined a `__wrapped__` attribute. (see bpo-17482)

`@functools.wraps(`*wrapped*, *assigned=WRAPPER_ASSIGNMENTS*, *updated=WRAPPER_UPDATES*`)`

This is a convenience function for invoking *update_wrapper()* as a function decorator when defining a wrapper function. It is equivalent to `partial(update_wrapper, wrapped=wrapped, assigned=assigned, updated=updated)`. For example:

```
>>> from functools import wraps
>>> def my_decorator(f):
...     @wraps(f)
...     def wrapper(*args, **kwds):
...         print('Calling decorated function')
...         return f(*args, **kwds)
...     return wrapper
...
```

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```
>>> @my_decorator
... def example():
...     """Docstring"""
...     print('Called example function')
...
>>> example()
Calling decorated function
Called example function
>>> example.__name__
'example'
>>> example.__doc__
'Docstring'
```

Without the use of this decorator factory, the name of the example function would have been `'wrapper'`, and the docstring of the original `example()` would have been lost.

10.2.1 `partial` Objects

partial objects are callable objects created by *partial()*. They have three read-only attributes:

partial.func
A callable object or function. Calls to the *partial* object will be forwarded to *func* with new arguments and keywords.

partial.args
The leftmost positional arguments that will be prepended to the positional arguments provided to a *partial* object call.

partial.keywords
The keyword arguments that will be supplied when the *partial* object is called.

partial objects are like `function` objects in that they are callable, weak referencable, and can have attributes. There are some important differences. For instance, the *__name__* and `__doc__` attributes are not created automatically. Also, *partial* objects defined in classes behave like static methods and do not transform into bound methods during instance attribute look-up.

10.3 `operator` — Standard operators as functions

Source code: Lib/operator.py

The *operator* module exports a set of efficient functions corresponding to the intrinsic operators of Python. For example, `operator.add(x, y)` is equivalent to the expression `x+y`. Many function names are those used for special methods, without the double underscores. For backward compatibility, many of these have a variant with the double underscores kept. The variants without the double underscores are preferred for clarity.

The functions fall into categories that perform object comparisons, logical operations, mathematical operations and sequence operations.

The object comparison functions are useful for all objects, and are named after the rich comparison operators they support:

`operator.lt(`*a*, *b*`)`
`operator.le(`*a*, *b*`)`

operator.**eq**(*a*, *b*)
operator.**ne**(*a*, *b*)
operator.**ge**(*a*, *b*)
operator.**gt**(*a*, *b*)
operator.**__lt__**(*a*, *b*)
operator.**__le__**(*a*, *b*)
operator.**__eq__**(*a*, *b*)
operator.**__ne__**(*a*, *b*)
operator.**__ge__**(*a*, *b*)
operator.**__gt__**(*a*, *b*)

Perform "rich comparisons" between *a* and *b*. Specifically, `lt(a, b)` is equivalent to `a < b`, `le(a, b)` is equivalent to `a <= b`, `eq(a, b)` is equivalent to `a == b`, `ne(a, b)` is equivalent to `a != b`, `gt(a, b)` is equivalent to `a > b` and `ge(a, b)` is equivalent to `a >= b`. Note that these functions can return any value, which may or may not be interpretable as a Boolean value. See comparisons for more information about rich comparisons.

The logical operations are also generally applicable to all objects, and support truth tests, identity tests, and boolean operations:

operator.**not_**(*obj*)
operator.**__not__**(*obj*)

Return the outcome of `not` *obj*. (Note that there is no *__not__()* method for object instances; only the interpreter core defines this operation. The result is affected by the `__bool__()` and `__len__()` methods.)

operator.**truth**(*obj*)

Return *True* if *obj* is true, and *False* otherwise. This is equivalent to using the *bool* constructor.

operator.**is_**(*a*, *b*)

Return `a is b`. Tests object identity.

operator.**is_not**(*a*, *b*)

Return `a is not b`. Tests object identity.

The mathematical and bitwise operations are the most numerous:

operator.**abs**(*obj*)
operator.**__abs__**(*obj*)

Return the absolute value of *obj*.

operator.**add**(*a*, *b*)
operator.**__add__**(*a*, *b*)

Return `a + b`, for *a* and *b* numbers.

operator.**and_**(*a*, *b*)
operator.**__and__**(*a*, *b*)

Return the bitwise and of *a* and *b*.

operator.**floordiv**(*a*, *b*)
operator.**__floordiv__**(*a*, *b*)

Return `a // b`.

operator.**index**(*a*)
operator.**__index__**(*a*)

Return *a* converted to an integer. Equivalent to `a.__index__()`.

operator.**inv**(*obj*)
operator.**invert**(*obj*)
operator.**__inv__**(*obj*)
operator.**__invert__**(*obj*)

Return the bitwise inverse of the number *obj*. This is equivalent to `~obj`.

operator.**lshift**(*a*, *b*)
operator.**__lshift__**(*a*, *b*)
Return *a* shifted left by *b*.

operator.**mod**(*a*, *b*)
operator.**__mod__**(*a*, *b*)
Return `a % b`.

operator.**mul**(*a*, *b*)
operator.**__mul__**(*a*, *b*)
Return `a * b`, for *a* and *b* numbers.

operator.**matmul**(*a*, *b*)
operator.**__matmul__**(*a*, *b*)
Return `a @ b`.

New in version 3.5.

operator.**neg**(*obj*)
operator.**__neg__**(*obj*)
Return *obj* negated (`-obj`).

operator.**or_**(*a*, *b*)
operator.**__or__**(*a*, *b*)
Return the bitwise or of *a* and *b*.

operator.**pos**(*obj*)
operator.**__pos__**(*obj*)
Return *obj* positive (`+obj`).

operator.**pow**(*a*, *b*)
operator.**__pow__**(*a*, *b*)
Return `a ** b`, for *a* and *b* numbers.

operator.**rshift**(*a*, *b*)
operator.**__rshift__**(*a*, *b*)
Return *a* shifted right by *b*.

operator.**sub**(*a*, *b*)
operator.**__sub__**(*a*, *b*)
Return `a - b`.

operator.**truediv**(*a*, *b*)
operator.**__truediv__**(*a*, *b*)
Return `a / b` where 2/3 is .66 rather than 0. This is also known as "true" division.

operator.**xor**(*a*, *b*)
operator.**__xor__**(*a*, *b*)
Return the bitwise exclusive or of *a* and *b*.

Operations which work with sequences (some of them with mappings too) include:

operator.**concat**(*a*, *b*)
operator.**__concat__**(*a*, *b*)
Return `a + b` for *a* and *b* sequences.

operator.**contains**(*a*, *b*)
operator.**__contains__**(*a*, *b*)
Return the outcome of the test `b in a`. Note the reversed operands.

operator.**countOf**(*a*, *b*)
Return the number of occurrences of *b* in *a*.

operator.**delitem**(*a*, *b*)

operator.__delitem__(*a*, *b*)
Remove the value of *a* at index *b*.

operator.getitem(*a*, *b*)
operator.__getitem__(*a*, *b*)
Return the value of *a* at index *b*.

operator.indexOf(*a*, *b*)
Return the index of the first of occurrence of *b* in *a*.

operator.setitem(*a*, *b*, *c*)
operator.__setitem__(*a*, *b*, *c*)
Set the value of *a* at index *b* to *c*.

operator.length_hint(*obj*, *default=0*)
Return an estimated length for the object *o*. First try to return its actual length, then an estimate using `object.__length_hint__()`, and finally return the default value.

New in version 3.4.

The *operator* module also defines tools for generalized attribute and item lookups. These are useful for making fast field extractors as arguments for *map()*, *sorted()*, *itertools.groupby()*, or other functions that expect a function argument.

operator.attrgetter(*attr*)
operator.attrgetter(**attrs*)
Return a callable object that fetches *attr* from its operand. If more than one attribute is requested, returns a tuple of attributes. The attribute names can also contain dots. For example:

- After `f = attrgetter('name')`, the call `f(b)` returns `b.name`.
- After `f = attrgetter('name', 'date')`, the call `f(b)` returns `(b.name, b.date)`.
- After `f = attrgetter('name.first', 'name.last')`, the call `f(b)` returns `(b.name.first, b.name.last)`.

Equivalent to:

```
def attrgetter(*items):
    if any(not isinstance(item, str) for item in items):
        raise TypeError('attribute name must be a string')
    if len(items) == 1:
        attr = items[0]
        def g(obj):
            return resolve_attr(obj, attr)
    else:
        def g(obj):
            return tuple(resolve_attr(obj, attr) for attr in items)
    return g

def resolve_attr(obj, attr):
    for name in attr.split("."):
        obj = getattr(obj, name)
    return obj
```

operator.itemgetter(*item*)
operator.itemgetter(**items*)
Return a callable object that fetches *item* from its operand using the operand's *__getitem__()* method. If multiple items are specified, returns a tuple of lookup values. For example:

- After `f = itemgetter(2)`, the call `f(r)` returns `r[2]`.
- After `g = itemgetter(2, 5, 3)`, the call `g(r)` returns `(r[2], r[5], r[3])`.

Equivalent to:

```
def itemgetter(*items):
    if len(items) == 1:
        item = items[0]
        def g(obj):
            return obj[item]
    else:
        def g(obj):
            return tuple(obj[item] for item in items)
    return g
```

The items can be any type accepted by the operand's *__getitem__()* method. Dictionaries accept any hashable value. Lists, tuples, and strings accept an index or a slice:

```
>>> itemgetter(1)('ABCDEFG')
'B'
>>> itemgetter(1,3,5)('ABCDEFG')
('B', 'D', 'F')
>>> itemgetter(slice(2,None))('ABCDEFG')
'CDEFG'
```

```
>>> soldier = dict(rank='captain', name='dotterbart')
>>> itemgetter('rank')(soldier)
'captain'
```

Example of using *itemgetter()* to retrieve specific fields from a tuple record:

```
>>> inventory = [('apple', 3), ('banana', 2), ('pear', 5), ('orange', 1)]
>>> getcount = itemgetter(1)
>>> list(map(getcount, inventory))
[3, 2, 5, 1]
>>> sorted(inventory, key=getcount)
[('orange', 1), ('banana', 2), ('apple', 3), ('pear', 5)]
```

operator.**methodcaller**(*name*[, *args...*])

Return a callable object that calls the method *name* on its operand. If additional arguments and/or keyword arguments are given, they will be given to the method as well. For example:

- After `f = methodcaller('name')`, the call `f(b)` returns `b.name()`.
- After `f = methodcaller('name', 'foo', bar=1)`, the call `f(b)` returns `b.name('foo', bar=1)`.

Equivalent to:

```
def methodcaller(name, *args, **kwargs):
    def caller(obj):
        return getattr(obj, name)(*args, **kwargs)
    return caller
```

10.3.1 Mapping Operators to Functions

This table shows how abstract operations correspond to operator symbols in the Python syntax and the functions in the *operator* module.

Operation	Syntax	Function
Addition	`a + b`	`add(a, b)`
Concatenation	`seq1 + seq2`	`concat(seq1, seq2)`
Containment Test	`obj in seq`	`contains(seq, obj)`
Division	`a / b`	`truediv(a, b)`
Division	`a // b`	`floordiv(a, b)`
Bitwise And	`a & b`	`and_(a, b)`
Bitwise Exclusive Or	`a ^ b`	`xor(a, b)`
Bitwise Inversion	`~ a`	`invert(a)`
Bitwise Or	`a | b`	`or_(a, b)`
Exponentiation	`a ** b`	`pow(a, b)`
Identity	`a is b`	`is_(a, b)`
Identity	`a is not b`	`is_not(a, b)`
Indexed Assignment	`obj[k] = v`	`setitem(obj, k, v)`
Indexed Deletion	`del obj[k]`	`delitem(obj, k)`
Indexing	`obj[k]`	`getitem(obj, k)`
Left Shift	`a << b`	`lshift(a, b)`
Modulo	`a % b`	`mod(a, b)`
Multiplication	`a * b`	`mul(a, b)`
Matrix Multiplication	`a @ b`	`matmul(a, b)`
Negation (Arithmetic)	`- a`	`neg(a)`
Negation (Logical)	`not a`	`not_(a)`
Positive	`+ a`	`pos(a)`
Right Shift	`a >> b`	`rshift(a, b)`
Slice Assignment	`seq[i:j] = values`	`setitem(seq, slice(i, j), values)`
Slice Deletion	`del seq[i:j]`	`delitem(seq, slice(i, j))`
Slicing	`seq[i:j]`	`getitem(seq, slice(i, j))`
String Formatting	`s % obj`	`mod(s, obj)`
Subtraction	`a - b`	`sub(a, b)`
Truth Test	`obj`	`truth(obj)`
Ordering	`a < b`	`lt(a, b)`
Ordering	`a <= b`	`le(a, b)`
Equality	`a == b`	`eq(a, b)`
Difference	`a != b`	`ne(a, b)`
Ordering	`a >= b`	`ge(a, b)`
Ordering	`a > b`	`gt(a, b)`

10.3.2 Inplace Operators

Many operations have an "in-place" version. Listed below are functions providing a more primitive access to in-place operators than the usual syntax does; for example, the *statement* `x += y` is equivalent to `x = operator.iadd(x, y)`. Another way to put it is to say that `z = operator.iadd(x, y)` is equivalent to the compound statement `z = x; z += y`.

In those examples, note that when an in-place method is called, the computation and assignment are performed in two separate steps. The in-place functions listed below only do the first step, calling the in-place method. The second step, assignment, is not handled.

For immutable targets such as strings, numbers, and tuples, the updated value is computed, but not assigned back to the input variable:

```
>>> a = 'hello'
>>> iadd(a, ' world')
```

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```
'hello world'
>>> a
'hello'
```

For mutable targets such as lists and dictionaries, the inplace method will perform the update, so no subsequent assignment is necessary:

```
>>> s = ['h', 'e', 'l', 'l', 'o']
>>> iadd(s, [' ', 'w', 'o', 'r', 'l', 'd'])
['h', 'e', 'l', 'l', 'o', ' ', 'w', 'o', 'r', 'l', 'd']
>>> s
['h', 'e', 'l', 'l', 'o', ' ', 'w', 'o', 'r', 'l', 'd']
```

operator.**iadd**(*a*, *b*)
operator.**__iadd__**(*a*, *b*)
`a = iadd(a, b)` is equivalent to `a += b`.

operator.**iand**(*a*, *b*)
operator.**__iand__**(*a*, *b*)
`a = iand(a, b)` is equivalent to `a &= b`.

operator.**iconcat**(*a*, *b*)
operator.**__iconcat__**(*a*, *b*)
`a = iconcat(a, b)` is equivalent to `a += b` for *a* and *b* sequences.

operator.**ifloordiv**(*a*, *b*)
operator.**__ifloordiv__**(*a*, *b*)
`a = ifloordiv(a, b)` is equivalent to `a //= b`.

operator.**ilshift**(*a*, *b*)
operator.**__ilshift__**(*a*, *b*)
`a = ilshift(a, b)` is equivalent to `a <<= b`.

operator.**imod**(*a*, *b*)
operator.**__imod__**(*a*, *b*)
`a = imod(a, b)` is equivalent to `a %= b`.

operator.**imul**(*a*, *b*)
operator.**__imul__**(*a*, *b*)
`a = imul(a, b)` is equivalent to `a *= b`.

operator.**imatmul**(*a*, *b*)
operator.**__imatmul__**(*a*, *b*)
`a = imatmul(a, b)` is equivalent to `a @= b`.

New in version 3.5.

operator.**ior**(*a*, *b*)
operator.**__ior__**(*a*, *b*)
`a = ior(a, b)` is equivalent to `a |= b`.

operator.**ipow**(*a*, *b*)
operator.**__ipow__**(*a*, *b*)
`a = ipow(a, b)` is equivalent to `a **= b`.

operator.**irshift**(*a*, *b*)
operator.**__irshift__**(*a*, *b*)
`a = irshift(a, b)` is equivalent to `a >>= b`.

operator.**isub**(*a*, *b*)

operator.__isub__(*a*, *b*)
    `a = isub(a, b)` is equivalent to `a -= b`.

operator.itruediv(*a*, *b*)
operator.__itruediv__(*a*, *b*)
    `a = itruediv(a, b)` is equivalent to `a /= b`.

operator.ixor(*a*, *b*)
operator.__ixor__(*a*, *b*)
    `a = ixor(a, b)` is equivalent to `a ^= b`.

CHAPTER

ELEVEN

FILE AND DIRECTORY ACCESS

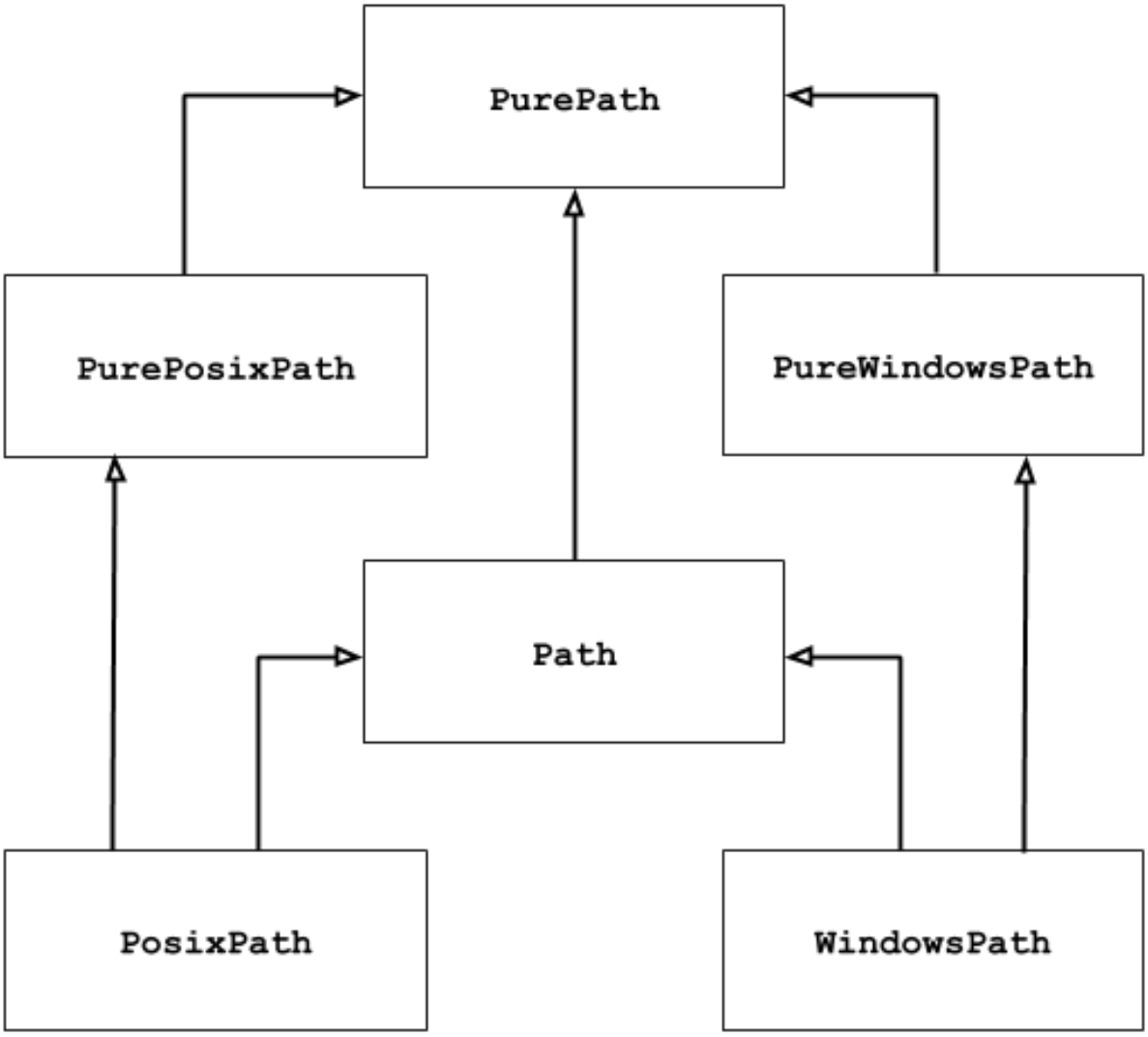
The modules described in this chapter deal with disk files and directories. For example, there are modules for reading the properties of files, manipulating paths in a portable way, and creating temporary files. The full list of modules in this chapter is:

11.1 `pathlib` — Object-oriented filesystem paths

New in version 3.4.

Source code: Lib/pathlib.py

This module offers classes representing filesystem paths with semantics appropriate for different operating systems. Path classes are divided between *pure paths*, which provide purely computational operations without I/O, and *concrete paths*, which inherit from pure paths but also provide I/O operations.



If you've never used this module before or just aren't sure which class is right for your task, *Path* is most likely what you need. It instantiates a *concrete path* for the platform the code is running on.

Pure paths are useful in some special cases; for example:

1. If you want to manipulate Windows paths on a Unix machine (or vice versa). You cannot instantiate a *WindowsPath* when running on Unix, but you can instantiate *PureWindowsPath*.
2. You want to make sure that your code only manipulates paths without actually accessing the OS. In this case, instantiating one of the pure classes may be useful since those simply don't have any OS-accessing operations.

See also:

PEP 428: The pathlib module – object-oriented filesystem paths.

See also:

For low-level path manipulation on strings, you can also use the *os.path* module.

11.1.1 Basic use

Importing the main class:

```
>>> from pathlib import Path
```

Listing subdirectories:

```
>>> p = Path('.')
>>> [x for x in p.iterdir() if x.is_dir()]
[PosixPath('.hg'), PosixPath('docs'), PosixPath('dist'),
 PosixPath('__pycache__'), PosixPath('build')]
```

Listing Python source files in this directory tree:

```
>>> list(p.glob('**/*.py'))
[PosixPath('test_pathlib.py'), PosixPath('setup.py'),
 PosixPath('pathlib.py'), PosixPath('docs/conf.py'),
 PosixPath('build/lib/pathlib.py')]
```

Navigating inside a directory tree:

```
>>> p = Path('/etc')
>>> q = p / 'init.d' / 'reboot'
>>> q
PosixPath('/etc/init.d/reboot')
>>> q.resolve()
PosixPath('/etc/rc.d/init.d/halt')
```

Querying path properties:

```
>>> q.exists()
True
>>> q.is_dir()
False
```

Opening a file:

```
>>> with q.open() as f: f.readline()
...
'#!/bin/bash\n'
```

11.1.2 Pure paths

Pure path objects provide path-handling operations which don't actually access a filesystem. There are three ways to access these classes, which we also call *flavours*:

class pathlib.**PurePath**(**pathsegments*)

A generic class that represents the system's path flavour (instantiating it creates either a *PurePosixPath* or a *PureWindowsPath*):

```
>>> PurePath('setup.py')      # Running on a Unix machine
PurePosixPath('setup.py')
```

Each element of *pathsegments* can be either a string representing a path segment, an object implementing the *os.PathLike* interface which returns a string, or another path object:

```
>>> PurePath('foo', 'some/path', 'bar')
PurePosixPath('foo/some/path/bar')
>>> PurePath(Path('foo'), Path('bar'))
PurePosixPath('foo/bar')
```

When *pathsegments* is empty, the current directory is assumed:

```
>>> PurePath()
PurePosixPath('.')
```

When several absolute paths are given, the last is taken as an anchor (mimicking *os.path.join()*'s behaviour):

```
>>> PurePath('/etc', '/usr', 'lib64')
PurePosixPath('/usr/lib64')
>>> PureWindowsPath('c:/Windows', 'd:bar')
PureWindowsPath('d:bar')
```

However, in a Windows path, changing the local root doesn't discard the previous drive setting:

```
>>> PureWindowsPath('c:/Windows', '/Program Files')
PureWindowsPath('c:/Program Files')
```

Spurious slashes and single dots are collapsed, but double dots (`'..'`) are not, since this would change the meaning of a path in the face of symbolic links:

```
>>> PurePath('foo//bar')
PurePosixPath('foo/bar')
>>> PurePath('foo/./bar')
PurePosixPath('foo/bar')
>>> PurePath('foo/../bar')
PurePosixPath('foo/../bar')
```

(a naïve approach would make `PurePosixPath('foo/../bar')` equivalent to `PurePosixPath('bar')`, which is wrong if `foo` is a symbolic link to another directory)

Pure path objects implement the *os.PathLike* interface, allowing them to be used anywhere the interface is accepted.

Changed in version 3.6: Added support for the *os.PathLike* interface.

class pathlib.PurePosixPath(**pathsegments*)

A subclass of *PurePath*, this path flavour represents non-Windows filesystem paths:

```
>>> PurePosixPath('/etc')
PurePosixPath('/etc')
```

pathsegments is specified similarly to *PurePath*.

class pathlib.PureWindowsPath(**pathsegments*)

A subclass of *PurePath*, this path flavour represents Windows filesystem paths:

```
>>> PureWindowsPath('c:/Program Files/')
PureWindowsPath('c:/Program Files')
```

pathsegments is specified similarly to *PurePath*.

Regardless of the system you're running on, you can instantiate all of these classes, since they don't provide any operation that does system calls.

General properties

Paths are immutable and hashable. Paths of a same flavour are comparable and orderable. These properties respect the flavour's case-folding semantics:

```
>>> PurePosixPath('foo') == PurePosixPath('FOO')
False
>>> PureWindowsPath('foo') == PureWindowsPath('FOO')
True
>>> PureWindowsPath('FOO') in { PureWindowsPath('foo') }
True
>>> PureWindowsPath('C:') < PureWindowsPath('d:')
True
```

Paths of a different flavour compare unequal and cannot be ordered:

```
>>> PureWindowsPath('foo') == PurePosixPath('foo')
False
>>> PureWindowsPath('foo') < PurePosixPath('foo')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: '<' not supported between instances of 'PureWindowsPath' and 'PurePosixPath'
```

Operators

The slash operator helps create child paths, similarly to *os.path.join()*:

```
>>> p = PurePath('/etc')
>>> p
PurePosixPath('/etc')
>>> p / 'init.d' / 'apache2'
PurePosixPath('/etc/init.d/apache2')
>>> q = PurePath('bin')
>>> '/usr' / q
PurePosixPath('/usr/bin')
```

A path object can be used anywhere an object implementing *os.PathLike* is accepted:

```
>>> import os
>>> p = PurePath('/etc')
>>> os.fspath(p)
'/etc'
```

The string representation of a path is the raw filesystem path itself (in native form, e.g. with backslashes under Windows), which you can pass to any function taking a file path as a string:

```
>>> p = PurePath('/etc')
>>> str(p)
'/etc'
>>> p = PureWindowsPath('c:/Program Files')
>>> str(p)
'c:\\Program Files'
```

Similarly, calling *bytes* on a path gives the raw filesystem path as a bytes object, as encoded by *os.fsencode()*:

```
>>> bytes(p)
b'/etc'
```

Note: Calling *bytes* is only recommended under Unix. Under Windows, the unicode form is the canonical representation of filesystem paths.

Accessing individual parts

To access the individual "parts" (components) of a path, use the following property:

PurePath.parts

A tuple giving access to the path's various components:

```
>>> p = PurePath('/usr/bin/python3')
>>> p.parts
('/', 'usr', 'bin', 'python3')

>>> p = PureWindowsPath('c:/Program Files/PSF')
>>> p.parts
('c:\\', 'Program Files', 'PSF')
```

(note how the drive and local root are regrouped in a single part)

Methods and properties

Pure paths provide the following methods and properties:

PurePath.drive

A string representing the drive letter or name, if any:

```
>>> PureWindowsPath('c:/Program Files/').drive
'c:'
>>> PureWindowsPath('/Program Files/').drive
''
>>> PurePosixPath('/etc').drive
''
```

UNC shares are also considered drives:

```
>>> PureWindowsPath('//host/share/foo.txt').drive
'\\\\host\\share'
```

PurePath.root

A string representing the (local or global) root, if any:

```
>>> PureWindowsPath('c:/Program Files/').root
'\\'
>>> PureWindowsPath('c:Program Files/').root
''
>>> PurePosixPath('/etc').root
'/'
```

UNC shares always have a root:

```
>>> PureWindowsPath('//host/share').root
'\\'
```

PurePath.**anchor**

The concatenation of the drive and root:

```
>>> PureWindowsPath('c:/Program Files/').anchor
'c:\\'
>>> PureWindowsPath('c:Program Files/').anchor
'c:'
>>> PurePosixPath('/etc').anchor
'/'
>>> PureWindowsPath('//host/share').anchor
'\\\\host\\share\\'
```

PurePath.**parents**

An immutable sequence providing access to the logical ancestors of the path:

```
>>> p = PureWindowsPath('c:/foo/bar/setup.py')
>>> p.parents[0]
PureWindowsPath('c:/foo/bar')
>>> p.parents[1]
PureWindowsPath('c:/foo')
>>> p.parents[2]
PureWindowsPath('c:/')
```

PurePath.**parent**

The logical parent of the path:

```
>>> p = PurePosixPath('/a/b/c/d')
>>> p.parent
PurePosixPath('/a/b/c')
```

You cannot go past an anchor, or empty path:

```
>>> p = PurePosixPath('/')
>>> p.parent
PurePosixPath('/')
>>> p = PurePosixPath('.')
>>> p.parent
PurePosixPath('.')
```

Note: This is a purely lexical operation, hence the following behaviour:

```
>>> p = PurePosixPath('foo/..')
>>> p.parent
PurePosixPath('foo')
```

If you want to walk an arbitrary filesystem path upwards, it is recommended to first call *Path.resolve()* so as to resolve symlinks and eliminate "..." components.

PurePath.**name**

A string representing the final path component, excluding the drive and root, if any:

```
>>> PurePosixPath('my/library/setup.py').name
'setup.py'
```

UNC drive names are not considered:

```
>>> PureWindowsPath('//some/share/setup.py').name
'setup.py'
>>> PureWindowsPath('//some/share').name
''
```

PurePath.suffix

The file extension of the final component, if any:

```
>>> PurePosixPath('my/library/setup.py').suffix
'.py'
>>> PurePosixPath('my/library.tar.gz').suffix
'.gz'
>>> PurePosixPath('my/library').suffix
''
```

PurePath.suffixes

A list of the path's file extensions:

```
>>> PurePosixPath('my/library.tar.gar').suffixes
['.tar', '.gar']
>>> PurePosixPath('my/library.tar.gz').suffixes
['.tar', '.gz']
>>> PurePosixPath('my/library').suffixes
[]
```

PurePath.stem

The final path component, without its suffix:

```
>>> PurePosixPath('my/library.tar.gz').stem
'library.tar'
>>> PurePosixPath('my/library.tar').stem
'library'
>>> PurePosixPath('my/library').stem
'library'
```

PurePath.as_posix()

Return a string representation of the path with forward slashes (/):

```
>>> p = PureWindowsPath('c:\\windows')
>>> str(p)
'c:\\windows'
>>> p.as_posix()
'c:/windows'
```

PurePath.as_uri()

Represent the path as a `file` URI. *ValueError* is raised if the path isn't absolute.

```
>>> p = PurePosixPath('/etc/passwd')
>>> p.as_uri()
'file:///etc/passwd'
>>> p = PureWindowsPath('c:/Windows')
>>> p.as_uri()
'file:///c:/Windows'
```

PurePath.is_absolute()

Return whether the path is absolute or not. A path is considered absolute if it has both a root and (if the flavour allows) a drive:

```
>>> PurePosixPath('/a/b').is_absolute()
True
>>> PurePosixPath('a/b').is_absolute()
False

>>> PureWindowsPath('c:/a/b').is_absolute()
True
>>> PureWindowsPath('/a/b').is_absolute()
False
>>> PureWindowsPath('c:').is_absolute()
False
>>> PureWindowsPath('//some/share').is_absolute()
True
```

PurePath.**is_reserved**()

With *PureWindowsPath*, return `True` if the path is considered reserved under Windows, `False` otherwise. With *PurePosixPath*, `False` is always returned.

```
>>> PureWindowsPath('nul').is_reserved()
True
>>> PurePosixPath('nul').is_reserved()
False
```

File system calls on reserved paths can fail mysteriously or have unintended effects.

PurePath.**joinpath**(**other*)

Calling this method is equivalent to combining the path with each of the *other* arguments in turn:

```
>>> PurePosixPath('/etc').joinpath('passwd')
PurePosixPath('/etc/passwd')
>>> PurePosixPath('/etc').joinpath(PurePosixPath('passwd'))
PurePosixPath('/etc/passwd')
>>> PurePosixPath('/etc').joinpath('init.d', 'apache2')
PurePosixPath('/etc/init.d/apache2')
>>> PureWindowsPath('c:').joinpath('/Program Files')
PureWindowsPath('c:/Program Files')
```

PurePath.**match**(*pattern*)

Match this path against the provided glob-style pattern. Return `True` if matching is successful, `False` otherwise.

If *pattern* is relative, the path can be either relative or absolute, and matching is done from the right:

```
>>> PurePath('a/b.py').match('*.py')
True
>>> PurePath('/a/b/c.py').match('b/*.py')
True
>>> PurePath('/a/b/c.py').match('a/*.py')
False
```

If *pattern* is absolute, the path must be absolute, and the whole path must match:

```
>>> PurePath('/a.py').match('/*.py')
True
>>> PurePath('a/b.py').match('/*.py')
False
```

As with other methods, case-sensitivity is observed:

```
>>> PureWindowsPath('b.py').match('*.PY')
True
```

PurePath.**relative_to**(**other*)

Compute a version of this path relative to the path represented by *other*. If it's impossible, ValueError is raised:

```
>>> p = PurePosixPath('/etc/passwd')
>>> p.relative_to('/')
PurePosixPath('etc/passwd')
>>> p.relative_to('/etc')
PurePosixPath('passwd')
>>> p.relative_to('/usr')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "pathlib.py", line 694, in relative_to
    .format(str(self), str(formatted)))
ValueError: '/etc/passwd' does not start with '/usr'
```

PurePath.**with_name**(*name*)

Return a new path with the *name* changed. If the original path doesn't have a name, ValueError is raised:

```
>>> p = PureWindowsPath('c:/Downloads/pathlib.tar.gz')
>>> p.with_name('setup.py')
PureWindowsPath('c:/Downloads/setup.py')
>>> p = PureWindowsPath('c:/')
>>> p.with_name('setup.py')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "/home/antoine/cpython/default/Lib/pathlib.py", line 751, in with_name
    raise ValueError("%r has an empty name" % (self,))
ValueError: PureWindowsPath('c:/') has an empty name
```

PurePath.**with_suffix**(*suffix*)

Return a new path with the *suffix* changed. If the original path doesn't have a suffix, the new *suffix* is appended instead:

```
>>> p = PureWindowsPath('c:/Downloads/pathlib.tar.gz')
>>> p.with_suffix('.bz2')
PureWindowsPath('c:/Downloads/pathlib.tar.bz2')
>>> p = PureWindowsPath('README')
>>> p.with_suffix('.txt')
PureWindowsPath('README.txt')
```

11.1.3 Concrete paths

Concrete paths are subclasses of the pure path classes. In addition to operations provided by the latter, they also provide methods to do system calls on path objects. There are three ways to instantiate concrete paths:

class pathlib.**Path**(**pathsegments*)

A subclass of *PurePath*, this class represents concrete paths of the system's path flavour (instantiating it creates either a *PosixPath* or a *WindowsPath*):

```
>>> Path('setup.py')
PosixPath('setup.py')
```

pathsegments is specified similarly to *PurePath*.

class pathlib.**PosixPath**(**pathsegments*)

A subclass of *Path* and *PurePosixPath*, this class represents concrete non-Windows filesystem paths:

```
>>> PosixPath('/etc')
PosixPath('/etc')
```

pathsegments is specified similarly to *PurePath*.

class pathlib.**WindowsPath**(**pathsegments*)

A subclass of *Path* and *PureWindowsPath*, this class represents concrete Windows filesystem paths:

```
>>> WindowsPath('c:/Program Files/')
WindowsPath('c:/Program Files')
```

pathsegments is specified similarly to *PurePath*.

You can only instantiate the class flavour that corresponds to your system (allowing system calls on non-compatible path flavours could lead to bugs or failures in your application):

```
>>> import os
>>> os.name
'posix'
>>> Path('setup.py')
PosixPath('setup.py')
>>> PosixPath('setup.py')
PosixPath('setup.py')
>>> WindowsPath('setup.py')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "pathlib.py", line 798, in __new__
    % (cls.__name__,))
NotImplementedError: cannot instantiate 'WindowsPath' on your system
```

Methods

Concrete paths provide the following methods in addition to pure paths methods. Many of these methods can raise an *OSError* if a system call fails (for example because the path doesn't exist):

classmethod Path.**cwd**()

Return a new path object representing the current directory (as returned by *os.getcwd()*):

```
>>> Path.cwd()
PosixPath('/home/antoine/pathlib')
```

classmethod Path.**home**()

Return a new path object representing the user's home directory (as returned by *os.path.expanduser()* with ~ construct):

```
>>> Path.home()
PosixPath('/home/antoine')
```

New in version 3.5.

Path.stat()
Return information about this path (similarly to *os.stat()*). The result is looked up at each call to this method.

```
>>> p = Path('setup.py')
>>> p.stat().st_size
956
>>> p.stat().st_mtime
1327883547.852554
```

Path.chmod(*mode*)
Change the file mode and permissions, like *os.chmod()*:

```
>>> p = Path('setup.py')
>>> p.stat().st_mode
33277
>>> p.chmod(0o444)
>>> p.stat().st_mode
33060
```

Path.exists()
Whether the path points to an existing file or directory:

```
>>> Path('.').exists()
True
>>> Path('setup.py').exists()
True
>>> Path('/etc').exists()
True
>>> Path('nonexistentfile').exists()
False
```

Note: If the path points to a symlink, *exists()* returns whether the symlink *points to* an existing file or directory.

Path.expanduser()
Return a new path with expanded ~ and ~user constructs, as returned by *os.path.expanduser()*:

```
>>> p = PosixPath('~/films/Monty Python')
>>> p.expanduser()
PosixPath('/home/eric/films/Monty Python')
```

New in version 3.5.

Path.glob(*pattern*)
Glob the given *pattern* in the directory represented by this path, yielding all matching files (of any kind):

```
>>> sorted(Path('.').glob('*.py'))
[PosixPath('pathlib.py'), PosixPath('setup.py'), PosixPath('test_pathlib.py')]
>>> sorted(Path('.').glob('*/*.py'))
[PosixPath('docs/conf.py')]
```

The "**" pattern means "this directory and all subdirectories, recursively". In other words, it enables recursive globbing:

```
>>> sorted(Path('.').glob('**/*.py'))
[PosixPath('build/lib/pathlib.py'),
 PosixPath('docs/conf.py'),
 PosixPath('pathlib.py'),
 PosixPath('setup.py'),
 PosixPath('test_pathlib.py')]
```

Note: Using the "**" pattern in large directory trees may consume an inordinate amount of time.

`Path.group()`
Return the name of the group owning the file. *KeyError* is raised if the file's gid isn't found in the system database.

`Path.is_dir()`
Return `True` if the path points to a directory (or a symbolic link pointing to a directory), `False` if it points to another kind of file.

`False` is also returned if the path doesn't exist or is a broken symlink; other errors (such as permission errors) are propagated.

`Path.is_file()`
Return `True` if the path points to a regular file (or a symbolic link pointing to a regular file), `False` if it points to another kind of file.

`False` is also returned if the path doesn't exist or is a broken symlink; other errors (such as permission errors) are propagated.

`Path.is_mount()`
Return `True` if the path is a *mount point*: a point in a file system where a different file system has been mounted. On POSIX, the function checks whether *path*'s parent, `path/..`, is on a different device than *path*, or whether `path/..` and *path* point to the same i-node on the same device — this should detect mount points for all Unix and POSIX variants. Not implemented on Windows.

New in version 3.7.

`Path.is_symlink()`
Return `True` if the path points to a symbolic link, `False` otherwise.

`False` is also returned if the path doesn't exist; other errors (such as permission errors) are propagated.

`Path.is_socket()`
Return `True` if the path points to a Unix socket (or a symbolic link pointing to a Unix socket), `False` if it points to another kind of file.

`False` is also returned if the path doesn't exist or is a broken symlink; other errors (such as permission errors) are propagated.

`Path.is_fifo()`
Return `True` if the path points to a FIFO (or a symbolic link pointing to a FIFO), `False` if it points to another kind of file.

`False` is also returned if the path doesn't exist or is a broken symlink; other errors (such as permission errors) are propagated.

`Path.is_block_device()`
Return `True` if the path points to a block device (or a symbolic link pointing to a block device), `False` if it points to another kind of file.

`False` is also returned if the path doesn't exist or is a broken symlink; other errors (such as permission errors) are propagated.

Path.**is_char_device**()
Return True if the path points to a character device (or a symbolic link pointing to a character device), False if it points to another kind of file.

False is also returned if the path doesn't exist or is a broken symlink; other errors (such as permission errors) are propagated.

Path.**iterdir**()
When the path points to a directory, yield path objects of the directory contents:

```
>>> p = Path('docs')
>>> for child in p.iterdir(): child
...
PosixPath('docs/conf.py')
PosixPath('docs/_templates')
PosixPath('docs/make.bat')
PosixPath('docs/index.rst')
PosixPath('docs/_build')
PosixPath('docs/_static')
PosixPath('docs/Makefile')
```

Path.**lchmod**(*mode*)
Like *Path.chmod()* but, if the path points to a symbolic link, the symbolic link's mode is changed rather than its target's.

Path.**lstat**()
Like *Path.stat()* but, if the path points to a symbolic link, return the symbolic link's information rather than its target's.

Path.**mkdir**(*mode=0o777*, *parents=False*, *exist_ok=False*)
Create a new directory at this given path. If *mode* is given, it is combined with the process' umask value to determine the file mode and access flags. If the path already exists, *FileExistsError* is raised.

If *parents* is true, any missing parents of this path are created as needed; they are created with the default permissions without taking *mode* into account (mimicking the POSIX mkdir -p command).

If *parents* is false (the default), a missing parent raises *FileNotFoundError*.

If *exist_ok* is false (the default), *FileExistsError* is raised if the target directory already exists.

If *exist_ok* is true, *FileExistsError* exceptions will be ignored (same behavior as the POSIX mkdir -p command), but only if the last path component is not an existing non-directory file.

Changed in version 3.5: The *exist_ok* parameter was added.

Path.**open**(*mode='r'*, *buffering=-1*, *encoding=None*, *errors=None*, *newline=None*)
Open the file pointed to by the path, like the built-in *open()* function does:

```
>>> p = Path('setup.py')
>>> with p.open() as f:
...     f.readline()
...
'#!/usr/bin/env python3\n'
```

Path.**owner**()
Return the name of the user owning the file. *KeyError* is raised if the file's uid isn't found in the system database.

Path.**read_bytes**()
Return the binary contents of the pointed-to file as a bytes object:

```
>>> p = Path('my_binary_file')
>>> p.write_bytes(b'Binary file contents')
20
>>> p.read_bytes()
b'Binary file contents'
```

New in version 3.5.

Path.read_text(*encoding=None*, *errors=None*)
Return the decoded contents of the pointed-to file as a string:

```
>>> p = Path('my_text_file')
>>> p.write_text('Text file contents')
18
>>> p.read_text()
'Text file contents'
```

The optional parameters have the same meaning as in *open()*.

New in version 3.5.

Path.rename(*target*)
Rename this file or directory to the given *target*. On Unix, if *target* exists and is a file, it will be replaced silently if the user has permission. *target* can be either a string or another path object:

```
>>> p = Path('foo')
>>> p.open('w').write('some text')
9
>>> target = Path('bar')
>>> p.rename(target)
>>> target.open().read()
'some text'
```

Path.replace(*target*)
Rename this file or directory to the given *target*. If *target* points to an existing file or directory, it will be unconditionally replaced.

Path.resolve(*strict=False*)
Make the path absolute, resolving any symlinks. A new path object is returned:

```
>>> p = Path()
>>> p
PosixPath('.')
>>> p.resolve()
PosixPath('/home/antoine/pathlib')
```

"`..`" components are also eliminated (this is the only method to do so):

```
>>> p = Path('docs/../setup.py')
>>> p.resolve()
PosixPath('/home/antoine/pathlib/setup.py')
```

If the path doesn't exist and *strict* is `True`, *FileNotFoundError* is raised. If *strict* is `False`, the path is resolved as far as possible and any remainder is appended without checking whether it exists. If an infinite loop is encountered along the resolution path, *RuntimeError* is raised.

New in version 3.6: The *strict* argument.

Path.rglob(*pattern*)
This is like calling *Path.glob()* with "`**`" added in front of the given *pattern*:

```
>>> sorted(Path().rglob("*.py"))
[PosixPath('build/lib/pathlib.py'),
 PosixPath('docs/conf.py'),
 PosixPath('pathlib.py'),
 PosixPath('setup.py'),
 PosixPath('test_pathlib.py')]
```

`Path.rmdir()`
Remove this directory. The directory must be empty.

`Path.samefile(`*other_path*`)`
Return whether this path points to the same file as *other_path*, which can be either a Path object, or a string. The semantics are similar to *os.path.samefile()* and *os.path.samestat()*.

An *OSError* can be raised if either file cannot be accessed for some reason.

```
>>> p = Path('spam')
>>> q = Path('eggs')
>>> p.samefile(q)
False
>>> p.samefile('spam')
True
```

New in version 3.5.

`Path.symlink_to(`*target*, *target_is_directory=False*`)`
Make this path a symbolic link to *target*. Under Windows, *target_is_directory* must be true (default `False`) if the link's target is a directory. Under POSIX, *target_is_directory*'s value is ignored.

```
>>> p = Path('mylink')
>>> p.symlink_to('setup.py')
>>> p.resolve()
PosixPath('/home/antoine/pathlib/setup.py')
>>> p.stat().st_size
956
>>> p.lstat().st_size
8
```

Note: The order of arguments (link, target) is the reverse of *os.symlink()*'s.

`Path.touch(`*mode=0o666*, *exist_ok=True*`)`
Create a file at this given path. If *mode* is given, it is combined with the process' `umask` value to determine the file mode and access flags. If the file already exists, the function succeeds if *exist_ok* is true (and its modification time is updated to the current time), otherwise *FileExistsError* is raised.

`Path.unlink()`
Remove this file or symbolic link. If the path points to a directory, use *Path.rmdir()* instead.

`Path.write_bytes(`*data*`)`
Open the file pointed to in bytes mode, write *data* to it, and close the file:

```
>>> p = Path('my_binary_file')
>>> p.write_bytes(b'Binary file contents')
20
>>> p.read_bytes()
b'Binary file contents'
```

An existing file of the same name is overwritten.

New in version 3.5.

`Path.write_text`(*data*, *encoding=None*, *errors=None*)

Open the file pointed to in text mode, write *data* to it, and close the file:

```
>>> p = Path('my_text_file')
>>> p.write_text('Text file contents')
18
>>> p.read_text()
'Text file contents'
```

New in version 3.5.

11.1.4 Correspondence to tools in the os module

Below is a table mapping various *os* functions to their corresponding *PurePath*/*Path* equivalent.

Note: Although *os.path.relpath()* and *PurePath.relative_to()* have some overlapping use-cases, their semantics differ enough to warrant not considering them equivalent.

os and os.path	pathlib
os.path.abspath()	*Path.resolve()*
os.getcwd()	*Path.cwd()*
os.path.exists()	*Path.exists()*
os.path.expanduser()	*Path.expanduser()* and *Path.home()*
os.path.isdir()	*Path.is_dir()*
os.path.isfile()	*Path.is_file()*
os.path.islink()	*Path.is_symlink()*
os.stat()	*Path.stat()*, *Path.owner()*, *Path.group()*
os.path.isabs()	*PurePath.is_absolute()*
os.path.join()	*PurePath.joinpath()*
os.path.basename()	*PurePath.name*
os.path.dirname()	*PurePath.parent*
os.path.splitext()	*PurePath.suffix*

11.2 os.path — Common pathname manipulations

Source code: Lib/posixpath.py (for POSIX), Lib/ntpath.py (for Windows NT), and Lib/macpath.py (for Macintosh)

This module implements some useful functions on pathnames. To read or write files see *open()*, and for accessing the filesystem see the *os* module. The path parameters can be passed as either strings, or bytes. Applications are encouraged to represent file names as (Unicode) character strings. Unfortunately, some file names may not be representable as strings on Unix, so applications that need to support arbitrary file names on Unix should use bytes objects to represent path names. Vice versa, using bytes objects cannot represent all file names on Windows (in the standard `mbcs` encoding), hence Windows applications should use string objects to access all files.

Unlike a unix shell, Python does not do any *automatic* path expansions. Functions such as *expanduser()* and *expandvars()* can be invoked explicitly when an application desires shell-like path expansion. (See also the *glob* module.)

See also:

The *pathlib* module offers high-level path objects.

Note: All of these functions accept either only bytes or only string objects as their parameters. The result is an object of the same type, if a path or file name is returned.

Note: Since different operating systems have different path name conventions, there are several versions of this module in the standard library. The *os.path* module is always the path module suitable for the operating system Python is running on, and therefore usable for local paths. However, you can also import and use the individual modules if you want to manipulate a path that is *always* in one of the different formats. They all have the same interface:

- `posixpath` for UNIX-style paths
- `ntpath` for Windows paths
- *macpath* for old-style MacOS paths

`os.path.abspath(`*path*`)`
Return a normalized absolutized version of the pathname *path*. On most platforms, this is equivalent to calling the function *normpath()* as follows: `normpath(join(os.getcwd(), path))`.

Changed in version 3.6: Accepts a *path-like object*.

`os.path.basename(`*path*`)`
Return the base name of pathname *path*. This is the second element of the pair returned by passing *path* to the function *split()*. Note that the result of this function is different from the Unix **basename** program; where **basename** for `'/foo/bar/'` returns `'bar'`, the *basename()* function returns an empty string (`''`).

Changed in version 3.6: Accepts a *path-like object*.

`os.path.commonpath(`*paths*`)`
Return the longest common sub-path of each pathname in the sequence *paths*. Raise ValueError if *paths* contains both absolute and relative pathnames, or if *paths* is empty. Unlike *commonprefix()*, this returns a valid path.

Availability: Unix, Windows

New in version 3.5.

Changed in version 3.6: Accepts a sequence of *path-like objects*.

`os.path.commonprefix(`*list*`)`
Return the longest path prefix (taken character-by-character) that is a prefix of all paths in *list*. If *list* is empty, return the empty string (`''`).

Note: This function may return invalid paths because it works a character at a time. To obtain a valid path, see *commonpath()*.

```
>>> os.path.commonprefix(['/usr/lib', '/usr/local/lib'])
'/usr/l'

>>> os.path.commonpath(['/usr/lib', '/usr/local/lib'])
'/usr'
```

Changed in version 3.6: Accepts a *path-like object*.

os.path.dirname(*path*)
Return the directory name of pathname *path*. This is the first element of the pair returned by passing *path* to the function *split()*.

Changed in version 3.6: Accepts a *path-like object*.

os.path.exists(*path*)
Return True if *path* refers to an existing path or an open file descriptor. Returns False for broken symbolic links. On some platforms, this function may return False if permission is not granted to execute *os.stat()* on the requested file, even if the *path* physically exists.

Changed in version 3.3: *path* can now be an integer: True is returned if it is an open file descriptor, False otherwise.

Changed in version 3.6: Accepts a *path-like object*.

os.path.lexists(*path*)
Return True if *path* refers to an existing path. Returns True for broken symbolic links. Equivalent to *exists()* on platforms lacking *os.lstat()*.

Changed in version 3.6: Accepts a *path-like object*.

os.path.expanduser(*path*)
On Unix and Windows, return the argument with an initial component of ~ or ~user replaced by that *user*'s home directory.

On Unix, an initial ~ is replaced by the environment variable HOME if it is set; otherwise the current user's home directory is looked up in the password directory through the built-in module *pwd*. An initial ~user is looked up directly in the password directory.

On Windows, HOME and USERPROFILE will be used if set, otherwise a combination of HOMEPATH and HOMEDRIVE will be used. An initial ~user is handled by stripping the last directory component from the created user path derived above.

If the expansion fails or if the path does not begin with a tilde, the path is returned unchanged.

Changed in version 3.6: Accepts a *path-like object*.

os.path.expandvars(*path*)
Return the argument with environment variables expanded. Substrings of the form $name or ${name} are replaced by the value of environment variable *name*. Malformed variable names and references to non-existing variables are left unchanged.

On Windows, %name% expansions are supported in addition to $name and ${name}.

Changed in version 3.6: Accepts a *path-like object*.

os.path.getatime(*path*)
Return the time of last access of *path*. The return value is a floating point number giving the number of seconds since the epoch (see the *time* module). Raise *OSError* if the file does not exist or is inaccessible.

os.path.getmtime(*path*)
Return the time of last modification of *path*. The return value is a floating point number giving the number of seconds since the epoch (see the *time* module). Raise *OSError* if the file does not exist or is inaccessible.

Changed in version 3.6: Accepts a *path-like object*.

os.path.getctime(*path*)
Return the system's ctime which, on some systems (like Unix) is the time of the last metadata change, and, on others (like Windows), is the creation time for *path*. The return value is a number giving the number of seconds since the epoch (see the *time* module). Raise *OSError* if the file does not exist or is inaccessible.

Changed in version 3.6: Accepts a *path-like object*.

os.path.getsize(*path*)
Return the size, in bytes, of *path*. Raise *OSError* if the file does not exist or is inaccessible.

Changed in version 3.6: Accepts a *path-like object*.

os.path.isabs(*path*)
Return True if *path* is an absolute pathname. On Unix, that means it begins with a slash, on Windows that it begins with a (back)slash after chopping off a potential drive letter.

Changed in version 3.6: Accepts a *path-like object*.

os.path.isfile(*path*)
Return True if *path* is an *existing* regular file. This follows symbolic links, so both *islink()* and *isfile()* can be true for the same path.

Changed in version 3.6: Accepts a *path-like object*.

os.path.isdir(*path*)
Return True if *path* is an *existing* directory. This follows symbolic links, so both *islink()* and *isdir()* can be true for the same path.

Changed in version 3.6: Accepts a *path-like object*.

os.path.islink(*path*)
Return True if *path* refers to an *existing* directory entry that is a symbolic link. Always False if symbolic links are not supported by the Python runtime.

Changed in version 3.6: Accepts a *path-like object*.

os.path.ismount(*path*)
Return True if pathname *path* is a *mount point*: a point in a file system where a different file system has been mounted. On POSIX, the function checks whether *path*'s parent, path/.., is on a different device than *path*, or whether path/.. and *path* point to the same i-node on the same device — this should detect mount points for all Unix and POSIX variants. On Windows, a drive letter root and a share UNC are always mount points, and for any other path GetVolumePathName is called to see if it is different from the input path.

New in version 3.4: Support for detecting non-root mount points on Windows.

Changed in version 3.6: Accepts a *path-like object*.

os.path.join(*path*, **paths*)
Join one or more path components intelligently. The return value is the concatenation of *path* and any members of **paths* with exactly one directory separator (os.sep) following each non-empty part except the last, meaning that the result will only end in a separator if the last part is empty. If a component is an absolute path, all previous components are thrown away and joining continues from the absolute path component.

On Windows, the drive letter is not reset when an absolute path component (e.g., r'\foo') is encountered. If a component contains a drive letter, all previous components are thrown away and the drive letter is reset. Note that since there is a current directory for each drive, os.path.join("c:", "foo") represents a path relative to the current directory on drive C: (c:foo), not c:\foo.

Changed in version 3.6: Accepts a *path-like object* for *path* and *paths*.

os.path.normcase(*path*)
Normalize the case of a pathname. On Unix and Mac OS X, this returns the path unchanged; on case-insensitive filesystems, it converts the path to lowercase. On Windows, it also converts forward slashes to backward slashes. Raise a TypeError if the type of *path* is not str or bytes (directly or indirectly through the *os.PathLike* interface).

Changed in version 3.6: Accepts a *path-like object*.

os.path.**normpath**(*path*)
Normalize a pathname by collapsing redundant separators and up-level references so that `A//B`, `A/B/`, `A/./B` and `A/foo/../B` all become `A/B`. This string manipulation may change the meaning of a path that contains symbolic links. On Windows, it converts forward slashes to backward slashes. To normalize case, use *normcase()*.

Changed in version 3.6: Accepts a *path-like object*.

os.path.**realpath**(*path*)
Return the canonical path of the specified filename, eliminating any symbolic links encountered in the path (if they are supported by the operating system).

Changed in version 3.6: Accepts a *path-like object*.

os.path.**relpath**(*path*, *start=os.curdir*)
Return a relative filepath to *path* either from the current directory or from an optional *start* directory. This is a path computation: the filesystem is not accessed to confirm the existence or nature of *path* or *start*.

start defaults to *os.curdir*.

Availability: Unix, Windows.

Changed in version 3.6: Accepts a *path-like object*.

os.path.**samefile**(*path1*, *path2*)
Return `True` if both pathname arguments refer to the same file or directory. This is determined by the device number and i-node number and raises an exception if an *os.stat()* call on either pathname fails.

Availability: Unix, Windows.

Changed in version 3.2: Added Windows support.

Changed in version 3.4: Windows now uses the same implementation as all other platforms.

Changed in version 3.6: Accepts a *path-like object*.

os.path.**sameopenfile**(*fp1*, *fp2*)
Return `True` if the file descriptors *fp1* and *fp2* refer to the same file.

Availability: Unix, Windows.

Changed in version 3.2: Added Windows support.

Changed in version 3.6: Accepts a *path-like object*.

os.path.**samestat**(*stat1*, *stat2*)
Return `True` if the stat tuples *stat1* and *stat2* refer to the same file. These structures may have been returned by *os.fstat()*, *os.lstat()*, or *os.stat()*. This function implements the underlying comparison used by *samefile()* and *sameopenfile()*.

Availability: Unix, Windows.

Changed in version 3.4: Added Windows support.

Changed in version 3.6: Accepts a *path-like object*.

os.path.**split**(*path*)
Split the pathname *path* into a pair, `(head, tail)` where *tail* is the last pathname component and *head* is everything leading up to that. The *tail* part will never contain a slash; if *path* ends in a slash, *tail* will be empty. If there is no slash in *path*, *head* will be empty. If *path* is empty, both *head* and *tail* are empty. Trailing slashes are stripped from *head* unless it is the root (one or more slashes only). In all cases, `join(head, tail)` returns a path to the same location as *path* (but the strings may differ). Also see the functions *dirname()* and *basename()*.

Changed in version 3.6: Accepts a *path-like object*.

os.path.splitdrive(*path*)
: Split the pathname *path* into a pair `(drive, tail)` where *drive* is either a mount point or the empty string. On systems which do not use drive specifications, *drive* will always be the empty string. In all cases, `drive + tail` will be the same as *path*.

  On Windows, splits a pathname into drive/UNC sharepoint and relative path.

  If the path contains a drive letter, drive will contain everything up to and including the colon. e.g. `splitdrive("c:/dir")` returns `("c:", "/dir")`

  If the path contains a UNC path, drive will contain the host name and share, up to but not including the fourth separator. e.g. `splitdrive("//host/computer/dir")` returns `("//host/computer", "/dir")`

  Changed in version 3.6: Accepts a *path-like object*.

os.path.splitext(*path*)
: Split the pathname *path* into a pair `(root, ext)` such that `root + ext == path`, and *ext* is empty or begins with a period and contains at most one period. Leading periods on the basename are ignored; `splitext('.cshrc')` returns `('.cshrc', '')`.

  Changed in version 3.6: Accepts a *path-like object*.

os.path.supports_unicode_filenames
: `True` if arbitrary Unicode strings can be used as file names (within limitations imposed by the file system).

11.3 `fileinput` — Iterate over lines from multiple input streams

Source code: Lib/fileinput.py

This module implements a helper class and functions to quickly write a loop over standard input or a list of files. If you just want to read or write one file see *open()*.

The typical use is:

```
import fileinput
for line in fileinput.input():
    process(line)
```

This iterates over the lines of all files listed in `sys.argv[1:]`, defaulting to `sys.stdin` if the list is empty. If a filename is `'-'`, it is also replaced by `sys.stdin`. To specify an alternative list of filenames, pass it as the first argument to *input()*. A single file name is also allowed.

All files are opened in text mode by default, but you can override this by specifying the *mode* parameter in the call to *input()* or *FileInput*. If an I/O error occurs during opening or reading a file, *OSError* is raised.

Changed in version 3.3: *IOError* used to be raised; it is now an alias of *OSError*.

If `sys.stdin` is used more than once, the second and further use will return no lines, except perhaps for interactive use, or if it has been explicitly reset (e.g. using `sys.stdin.seek(0)`).

Empty files are opened and immediately closed; the only time their presence in the list of filenames is noticeable at all is when the last file opened is empty.

Lines are returned with any newlines intact, which means that the last line in a file may not have one.

You can control how files are opened by providing an opening hook via the *openhook* parameter to *fileinput.input()* or *FileInput()*. The hook must be a function that takes two arguments, *filename* and *mode*, and returns an accordingly opened file-like object. Two useful hooks are already provided by this module.

The following function is the primary interface of this module:

fileinput.input(*files=None*, *inplace=False*, *backup=''*, *bufsize=0*, *mode='r'*, *openhook=None*)
Create an instance of the *FileInput* class. The instance will be used as global state for the functions of this module, and is also returned to use during iteration. The parameters to this function will be passed along to the constructor of the *FileInput* class.

The *FileInput* instance can be used as a context manager in the `with` statement. In this example, *input* is closed after the `with` statement is exited, even if an exception occurs:

```
with fileinput.input(files=('spam.txt', 'eggs.txt')) as f:
    for line in f:
        process(line)
```

Changed in version 3.2: Can be used as a context manager.

Deprecated since version 3.6, will be removed in version 3.8: The *bufsize* parameter.

The following functions use the global state created by *fileinput.input()*; if there is no active state, *RuntimeError* is raised.

fileinput.filename()
Return the name of the file currently being read. Before the first line has been read, returns `None`.

fileinput.fileno()
Return the integer "file descriptor" for the current file. When no file is opened (before the first line and between files), returns `-1`.

fileinput.lineno()
Return the cumulative line number of the line that has just been read. Before the first line has been read, returns `0`. After the last line of the last file has been read, returns the line number of that line.

fileinput.filelineno()
Return the line number in the current file. Before the first line has been read, returns `0`. After the last line of the last file has been read, returns the line number of that line within the file.

fileinput.isfirstline()
Returns true if the line just read is the first line of its file, otherwise returns false.

fileinput.isstdin()
Returns true if the last line was read from `sys.stdin`, otherwise returns false.

fileinput.nextfile()
Close the current file so that the next iteration will read the first line from the next file (if any); lines not read from the file will not count towards the cumulative line count. The filename is not changed until after the first line of the next file has been read. Before the first line has been read, this function has no effect; it cannot be used to skip the first file. After the last line of the last file has been read, this function has no effect.

fileinput.close()
Close the sequence.

The class which implements the sequence behavior provided by the module is available for subclassing as well:

class fileinput.FileInput(*files=None*, *inplace=False*, *backup=''*, *bufsize=0*, *mode='r'*, *openhook=None*)
Class *FileInput* is the implementation; its methods *filename()*, *fileno()*, *lineno()*, *filelineno()*, *isfirstline()*, *isstdin()*, *nextfile()* and *close()* correspond to the functions of the same name in the module. In addition it has a *readline()* method which returns the next input line, and a `__getitem__()` method which implements the sequence behavior. The sequence must be accessed in strictly sequential order; random access and *readline()* cannot be mixed.

With *mode* you can specify which file mode will be passed to *open()*. It must be one of `'r'`, `'rU'`, `'U'` and `'rb'`.

The *openhook*, when given, must be a function that takes two arguments, *filename* and *mode*, and returns an accordingly opened file-like object. You cannot use *inplace* and *openhook* together.

A *FileInput* instance can be used as a context manager in the `with` statement. In this example, *input* is closed after the `with` statement is exited, even if an exception occurs:

```
with FileInput(files=('spam.txt', 'eggs.txt')) as input:
    process(input)
```

Changed in version 3.2: Can be used as a context manager.

Deprecated since version 3.4: The `'rU'` and `'U'` modes.

Deprecated since version 3.6, will be removed in version 3.8: The *bufsize* parameter.

Optional in-place filtering: if the keyword argument `inplace=True` is passed to *fileinput.input()* or to the *FileInput* constructor, the file is moved to a backup file and standard output is directed to the input file (if a file of the same name as the backup file already exists, it will be replaced silently). This makes it possible to write a filter that rewrites its input file in place. If the *backup* parameter is given (typically as `backup='.<some extension>'`), it specifies the extension for the backup file, and the backup file remains around; by default, the extension is `'.bak'` and it is deleted when the output file is closed. In-place filtering is disabled when standard input is read.

The two following opening hooks are provided by this module:

`fileinput.hook_compressed`(*filename*, *mode*)

Transparently opens files compressed with gzip and bzip2 (recognized by the extensions `'.gz'` and `'.bz2'`) using the *gzip* and *bz2* modules. If the filename extension is not `'.gz'` or `'.bz2'`, the file is opened normally (ie, using *open()* without any decompression).

Usage example: `fi = fileinput.FileInput(openhook=fileinput.hook_compressed)`

`fileinput.hook_encoded`(*encoding*, *errors=None*)

Returns a hook which opens each file with *open()*, using the given *encoding* and *errors* to read the file.

Usage example: `fi = fileinput.FileInput(openhook=fileinput.hook_encoded("utf-8", "surrogateescape"))`

Changed in version 3.6: Added the optional *errors* parameter.

11.4 stat — Interpreting stat() results

Source code: Lib/stat.py

The *stat* module defines constants and functions for interpreting the results of *os.stat()*, *os.fstat()* and *os.lstat()* (if they exist). For complete details about the `stat()`, `fstat()` and `lstat()` calls, consult the documentation for your system.

Changed in version 3.4: The stat module is backed by a C implementation.

The *stat* module defines the following functions to test for specific file types:

`stat.S_ISDIR`(*mode*)

Return non-zero if the mode is from a directory.

`stat.S_ISCHR`(*mode*)

Return non-zero if the mode is from a character special device file.

stat.S_ISBLK(*mode*)
Return non-zero if the mode is from a block special device file.

stat.S_ISREG(*mode*)
Return non-zero if the mode is from a regular file.

stat.S_ISFIFO(*mode*)
Return non-zero if the mode is from a FIFO (named pipe).

stat.S_ISLNK(*mode*)
Return non-zero if the mode is from a symbolic link.

stat.S_ISSOCK(*mode*)
Return non-zero if the mode is from a socket.

stat.S_ISDOOR(*mode*)
Return non-zero if the mode is from a door.

New in version 3.4.

stat.S_ISPORT(*mode*)
Return non-zero if the mode is from an event port.

New in version 3.4.

stat.S_ISWHT(*mode*)
Return non-zero if the mode is from a whiteout.

New in version 3.4.

Two additional functions are defined for more general manipulation of the file's mode:

stat.S_IMODE(*mode*)
Return the portion of the file's mode that can be set by *os.chmod()*—that is, the file's permission bits, plus the sticky bit, set-group-id, and set-user-id bits (on systems that support them).

stat.S_IFMT(*mode*)
Return the portion of the file's mode that describes the file type (used by the S_IS*() functions above).

Normally, you would use the os.path.is*() functions for testing the type of a file; the functions here are useful when you are doing multiple tests of the same file and wish to avoid the overhead of the stat() system call for each test. These are also useful when checking for information about a file that isn't handled by *os.path*, like the tests for block and character devices.

Example:

```
import os, sys
from stat import *

def walktree(top, callback):
    '''recursively descend the directory tree rooted at top,
       calling the callback function for each regular file'''

    for f in os.listdir(top):
        pathname = os.path.join(top, f)
        mode = os.stat(pathname).st_mode
        if S_ISDIR(mode):
            # It's a directory, recurse into it
            walktree(pathname, callback)
        elif S_ISREG(mode):
            # It's a file, call the callback function
            callback(pathname)
        else:
```

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```
            # Unknown file type, print a message
            print('Skipping %s' % pathname)

def visitfile(file):
    print('visiting', file)

if __name__ == '__main__':
    walktree(sys.argv[1], visitfile)
```

An additional utility function is provided to convert a file's mode in a human readable string:

stat.filemode(*mode*)
Convert a file's mode to a string of the form '-rwxrwxrwx'.

New in version 3.3.

Changed in version 3.4: The function supports *S_IFDOOR*, *S_IFPORT* and *S_IFWHT*.

All the variables below are simply symbolic indexes into the 10-tuple returned by *os.stat()*, *os.fstat()* or *os.lstat()*.

stat.ST_MODE
Inode protection mode.

stat.ST_INO
Inode number.

stat.ST_DEV
Device inode resides on.

stat.ST_NLINK
Number of links to the inode.

stat.ST_UID
User id of the owner.

stat.ST_GID
Group id of the owner.

stat.ST_SIZE
Size in bytes of a plain file; amount of data waiting on some special files.

stat.ST_ATIME
Time of last access.

stat.ST_MTIME
Time of last modification.

stat.ST_CTIME
The "ctime" as reported by the operating system. On some systems (like Unix) is the time of the last metadata change, and, on others (like Windows), is the creation time (see platform documentation for details).

The interpretation of "file size" changes according to the file type. For plain files this is the size of the file in bytes. For FIFOs and sockets under most flavors of Unix (including Linux in particular), the "size" is the number of bytes waiting to be read at the time of the call to *os.stat()*, *os.fstat()*, or *os.lstat()*; this can sometimes be useful, especially for polling one of these special files after a non-blocking open. The meaning of the size field for other character and block devices varies more, depending on the implementation of the underlying system call.

The variables below define the flags used in the *ST_MODE* field.

Use of the functions above is more portable than use of the first set of flags:

stat.**S_IFSOCK**
Socket.

stat.**S_IFLNK**
Symbolic link.

stat.**S_IFREG**
Regular file.

stat.**S_IFBLK**
Block device.

stat.**S_IFDIR**
Directory.

stat.**S_IFCHR**
Character device.

stat.**S_IFIFO**
FIFO.

stat.**S_IFDOOR**
Door.

New in version 3.4.

stat.**S_IFPORT**
Event port.

New in version 3.4.

stat.**S_IFWHT**
Whiteout.

New in version 3.4.

Note: *S_IFDOOR*, *S_IFPORT* or *S_IFWHT* are defined as 0 when the platform does not have support for the file types.

The following flags can also be used in the *mode* argument of *os.chmod()*:

stat.**S_ISUID**
Set UID bit.

stat.**S_ISGID**
Set-group-ID bit. This bit has several special uses. For a directory it indicates that BSD semantics is to be used for that directory: files created there inherit their group ID from the directory, not from the effective group ID of the creating process, and directories created there will also get the *S_ISGID* bit set. For a file that does not have the group execution bit (*S_IXGRP*) set, the set-group-ID bit indicates mandatory file/record locking (see also *S_ENFMT*).

stat.**S_ISVTX**
Sticky bit. When this bit is set on a directory it means that a file in that directory can be renamed or deleted only by the owner of the file, by the owner of the directory, or by a privileged process.

stat.**S_IRWXU**
Mask for file owner permissions.

stat.**S_IRUSR**
Owner has read permission.

stat.**S_IWUSR**
Owner has write permission.

stat.S_IXUSR
Owner has execute permission.

stat.S_IRWXG
Mask for group permissions.

stat.S_IRGRP
Group has read permission.

stat.S_IWGRP
Group has write permission.

stat.S_IXGRP
Group has execute permission.

stat.S_IRWXO
Mask for permissions for others (not in group).

stat.S_IROTH
Others have read permission.

stat.S_IWOTH
Others have write permission.

stat.S_IXOTH
Others have execute permission.

stat.S_ENFMT
System V file locking enforcement. This flag is shared with *S_ISGID*: file/record locking is enforced on files that do not have the group execution bit (*S_IXGRP*) set.

stat.S_IREAD
Unix V7 synonym for *S_IRUSR*.

stat.S_IWRITE
Unix V7 synonym for *S_IWUSR*.

stat.S_IEXEC
Unix V7 synonym for *S_IXUSR*.

The following flags can be used in the *flags* argument of *os.chflags()*:

stat.UF_NODUMP
Do not dump the file.

stat.UF_IMMUTABLE
The file may not be changed.

stat.UF_APPEND
The file may only be appended to.

stat.UF_OPAQUE
The directory is opaque when viewed through a union stack.

stat.UF_NOUNLINK
The file may not be renamed or deleted.

stat.UF_COMPRESSED
The file is stored compressed (Mac OS X 10.6+).

stat.UF_HIDDEN
The file should not be displayed in a GUI (Mac OS X 10.5+).

stat.SF_ARCHIVED
The file may be archived.

stat.SF_IMMUTABLE
The file may not be changed.

stat.SF_APPEND
The file may only be appended to.

stat.SF_NOUNLINK
The file may not be renamed or deleted.

stat.SF_SNAPSHOT
The file is a snapshot file.

See the *BSD or Mac OS systems man page *chflags(2)* for more information.

On Windows, the following file attribute constants are available for use when testing bits in the st_file_attributes member returned by *os.stat()*. See the Windows API documentation for more detail on the meaning of these constants.

stat.FILE_ATTRIBUTE_ARCHIVE
stat.FILE_ATTRIBUTE_COMPRESSED
stat.FILE_ATTRIBUTE_DEVICE
stat.FILE_ATTRIBUTE_DIRECTORY
stat.FILE_ATTRIBUTE_ENCRYPTED
stat.FILE_ATTRIBUTE_HIDDEN
stat.FILE_ATTRIBUTE_INTEGRITY_STREAM
stat.FILE_ATTRIBUTE_NORMAL
stat.FILE_ATTRIBUTE_NOT_CONTENT_INDEXED
stat.FILE_ATTRIBUTE_NO_SCRUB_DATA
stat.FILE_ATTRIBUTE_OFFLINE
stat.FILE_ATTRIBUTE_READONLY
stat.FILE_ATTRIBUTE_REPARSE_POINT
stat.FILE_ATTRIBUTE_SPARSE_FILE
stat.FILE_ATTRIBUTE_SYSTEM
stat.FILE_ATTRIBUTE_TEMPORARY
stat.FILE_ATTRIBUTE_VIRTUAL
New in version 3.5.

11.5 filecmp — File and Directory Comparisons

Source code: Lib/filecmp.py

The *filecmp* module defines functions to compare files and directories, with various optional time/correctness trade-offs. For comparing files, see also the *difflib* module.

The *filecmp* module defines the following functions:

filecmp.cmp(*f1*, *f2*, *shallow=True*)
Compare the files named *f1* and *f2*, returning True if they seem equal, False otherwise.

If *shallow* is true, files with identical *os.stat()* signatures are taken to be equal. Otherwise, the contents of the files are compared.

Note that no external programs are called from this function, giving it portability and efficiency.

This function uses a cache for past comparisons and the results, with cache entries invalidated if the *os.stat()* information for the file changes. The entire cache may be cleared using *clear_cache()*.

filecmp.**cmpfiles**(*dir1*, *dir2*, *common*, *shallow=True*)
Compare the files in the two directories *dir1* and *dir2* whose names are given by *common*.

Returns three lists of file names: *match*, *mismatch*, *errors*. *match* contains the list of files that match, *mismatch* contains the names of those that don't, and *errors* lists the names of files which could not be compared. Files are listed in *errors* if they don't exist in one of the directories, the user lacks permission to read them or if the comparison could not be done for some other reason.

The *shallow* parameter has the same meaning and default value as for *filecmp.cmp()*.

For example, `cmpfiles('a', 'b', ['c', 'd/e'])` will compare `a/c` with `b/c` and `a/d/e` with `b/d/e`. `'c'` and `'d/e'` will each be in one of the three returned lists.

filecmp.**clear_cache**()
Clear the filecmp cache. This may be useful if a file is compared so quickly after it is modified that it is within the mtime resolution of the underlying filesystem.

New in version 3.4.

11.5.1 The `dircmp` class

class filecmp.**dircmp**(*a*, *b*, *ignore=None*, *hide=None*)
Construct a new directory comparison object, to compare the directories *a* and *b*. *ignore* is a list of names to ignore, and defaults to *filecmp.DEFAULT_IGNORES*. *hide* is a list of names to hide, and defaults to `[os.curdir, os.pardir]`.

The *dircmp* class compares files by doing *shallow* comparisons as described for *filecmp.cmp()*.

The *dircmp* class provides the following methods:

report()
Print (to *sys.stdout*) a comparison between *a* and *b*.

report_partial_closure()
Print a comparison between *a* and *b* and common immediate subdirectories.

report_full_closure()
Print a comparison between *a* and *b* and common subdirectories (recursively).

The *dircmp* class offers a number of interesting attributes that may be used to get various bits of information about the directory trees being compared.

Note that via `__getattr__()` hooks, all attributes are computed lazily, so there is no speed penalty if only those attributes which are lightweight to compute are used.

left
The directory *a*.

right
The directory *b*.

left_list
Files and subdirectories in *a*, filtered by *hide* and *ignore*.

right_list
Files and subdirectories in *b*, filtered by *hide* and *ignore*.

common
Files and subdirectories in both *a* and *b*.

left_only
Files and subdirectories only in *a*.

right_only
Files and subdirectories only in *b*.

common_dirs
Subdirectories in both *a* and *b*.

common_files
Files in both *a* and *b*.

common_funny
Names in both *a* and *b*, such that the type differs between the directories, or names for which *os.stat()* reports an error.

same_files
Files which are identical in both *a* and *b*, using the class's file comparison operator.

diff_files
Files which are in both *a* and *b*, whose contents differ according to the class's file comparison operator.

funny_files
Files which are in both *a* and *b*, but could not be compared.

subdirs
A dictionary mapping names in *common_dirs* to *dircmp* objects.

`filecmp.DEFAULT_IGNORES`
New in version 3.4.

List of directories ignored by *dircmp* by default.

Here is a simplified example of using the `subdirs` attribute to search recursively through two directories to show common different files:

```
>>> from filecmp import dircmp
>>> def print_diff_files(dcmp):
...     for name in dcmp.diff_files:
...         print("diff_file %s found in %s and %s" % (name, dcmp.left,
...               dcmp.right))
...     for sub_dcmp in dcmp.subdirs.values():
...         print_diff_files(sub_dcmp)
...
>>> dcmp = dircmp('dir1', 'dir2')
>>> print_diff_files(dcmp)
```

11.6 `tempfile` — Generate temporary files and directories

Source code: Lib/tempfile.py

This module creates temporary files and directories. It works on all supported platforms. *TemporaryFile*, *NamedTemporaryFile*, *TemporaryDirectory*, and *SpooledTemporaryFile* are high-level interfaces which provide automatic cleanup and can be used as context managers. *mkstemp()* and *mkdtemp()* are lower-level functions which require manual cleanup.

All the user-callable functions and constructors take additional arguments which allow direct control over the location and name of temporary files and directories. Files names used by this module include a string of random characters which allows those files to be securely created in shared temporary directories. To

maintain backward compatibility, the argument order is somewhat odd; it is recommended to use keyword arguments for clarity.

The module defines the following user-callable items:

tempfile.TemporaryFile(*mode='w+b'*, *buffering=None*, *encoding=None*, *newline=None*, *suffix=None*, *prefix=None*, *dir=None*)

Return a *file-like object* that can be used as a temporary storage area. The file is created securely, using the same rules as *mkstemp()*. It will be destroyed as soon as it is closed (including an implicit close when the object is garbage collected). Under Unix, the directory entry for the file is either not created at all or is removed immediately after the file is created. Other platforms do not support this; your code should not rely on a temporary file created using this function having or not having a visible name in the file system.

The resulting object can be used as a context manager (see *Examples*). On completion of the context or destruction of the file object the temporary file will be removed from the filesystem.

The *mode* parameter defaults to `'w+b'` so that the file created can be read and written without being closed. Binary mode is used so that it behaves consistently on all platforms without regard for the data that is stored. *buffering*, *encoding* and *newline* are interpreted as for *open()*.

The *dir*, *prefix* and *suffix* parameters have the same meaning and defaults as with *mkstemp()*.

The returned object is a true file object on POSIX platforms. On other platforms, it is a file-like object whose `file` attribute is the underlying true file object.

The *os.O_TMPFILE* flag is used if it is available and works (Linux-specific, requires Linux kernel 3.11 or later).

Changed in version 3.5: The *os.O_TMPFILE* flag is now used if available.

tempfile.NamedTemporaryFile(*mode='w+b'*, *buffering=None*, *encoding=None*, *newline=None*, *suffix=None*, *prefix=None*, *dir=None*, *delete=True*)

This function operates exactly as *TemporaryFile()* does, except that the file is guaranteed to have a visible name in the file system (on Unix, the directory entry is not unlinked). That name can be retrieved from the `name` attribute of the returned file-like object. Whether the name can be used to open the file a second time, while the named temporary file is still open, varies across platforms (it can be so used on Unix; it cannot on Windows NT or later). If *delete* is true (the default), the file is deleted as soon as it is closed. The returned object is always a file-like object whose `file` attribute is the underlying true file object. This file-like object can be used in a `with` statement, just like a normal file.

tempfile.SpooledTemporaryFile(*max_size=0*, *mode='w+b'*, *buffering=None*, *encoding=None*, *newline=None*, *suffix=None*, *prefix=None*, *dir=None*)

This function operates exactly as *TemporaryFile()* does, except that data is spooled in memory until the file size exceeds *max_size*, or until the file's `fileno()` method is called, at which point the contents are written to disk and operation proceeds as with *TemporaryFile()*.

The resulting file has one additional method, `rollover()`, which causes the file to roll over to an on-disk file regardless of its size.

The returned object is a file-like object whose `_file` attribute is either an *io.BytesIO* or *io.StringIO* object (depending on whether binary or text *mode* was specified) or a true file object, depending on whether `rollover()` has been called. This file-like object can be used in a `with` statement, just like a normal file.

Changed in version 3.3: the truncate method now accepts a `size` argument.

tempfile.TemporaryDirectory(*suffix=None*, *prefix=None*, *dir=None*)

This function securely creates a temporary directory using the same rules as *mkdtemp()*. The resulting object can be used as a context manager (see *Examples*). On completion of the context or destruction of the temporary directory object the newly created temporary directory and all its contents are removed from the filesystem.

The directory name can be retrieved from the `name` attribute of the returned object. When the returned object is used as a context manager, the `name` will be assigned to the target of the `as` clause in the `with` statement, if there is one.

The directory can be explicitly cleaned up by calling the `cleanup()` method.

New in version 3.2.

`tempfile.mkstemp`(*suffix=None*, *prefix=None*, *dir=None*, *text=False*)

Creates a temporary file in the most secure manner possible. There are no race conditions in the file's creation, assuming that the platform properly implements the *os.O_EXCL* flag for *os.open()*. The file is readable and writable only by the creating user ID. If the platform uses permission bits to indicate whether a file is executable, the file is executable by no one. The file descriptor is not inherited by child processes.

Unlike *TemporaryFile()*, the user of *mkstemp()* is responsible for deleting the temporary file when done with it.

If *suffix* is not `None`, the file name will end with that suffix, otherwise there will be no suffix. *mkstemp()* does not put a dot between the file name and the suffix; if you need one, put it at the beginning of *suffix*.

If *prefix* is not `None`, the file name will begin with that prefix; otherwise, a default prefix is used. The default is the return value of *gettempprefix()* or *gettempprefixb()*, as appropriate.

If *dir* is not `None`, the file will be created in that directory; otherwise, a default directory is used. The default directory is chosen from a platform-dependent list, but the user of the application can control the directory location by setting the *TMPDIR*, *TEMP* or *TMP* environment variables. There is thus no guarantee that the generated filename will have any nice properties, such as not requiring quoting when passed to external commands via `os.popen()`.

If any of *suffix*, *prefix*, and *dir* are not `None`, they must be the same type. If they are bytes, the returned name will be bytes instead of str. If you want to force a bytes return value with otherwise default behavior, pass `suffix=b''`.

If *text* is specified, it indicates whether to open the file in binary mode (the default) or text mode. On some platforms, this makes no difference.

mkstemp() returns a tuple containing an OS-level handle to an open file (as would be returned by *os.open()*) and the absolute pathname of that file, in that order.

Changed in version 3.5: *suffix*, *prefix*, and *dir* may now be supplied in bytes in order to obtain a bytes return value. Prior to this, only str was allowed. *suffix* and *prefix* now accept and default to `None` to cause an appropriate default value to be used.

`tempfile.mkdtemp`(*suffix=None*, *prefix=None*, *dir=None*)

Creates a temporary directory in the most secure manner possible. There are no race conditions in the directory's creation. The directory is readable, writable, and searchable only by the creating user ID.

The user of *mkdtemp()* is responsible for deleting the temporary directory and its contents when done with it.

The *prefix*, *suffix*, and *dir* arguments are the same as for *mkstemp()*.

mkdtemp() returns the absolute pathname of the new directory.

Changed in version 3.5: *suffix*, *prefix*, and *dir* may now be supplied in bytes in order to obtain a bytes return value. Prior to this, only str was allowed. *suffix* and *prefix* now accept and default to `None` to cause an appropriate default value to be used.

`tempfile.gettempdir`()

Return the name of the directory used for temporary files. This defines the default value for the *dir* argument to all functions in this module.

Python searches a standard list of directories to find one which the calling user can create files in. The list is:

1. The directory named by the `TMPDIR` environment variable.
2. The directory named by the `TEMP` environment variable.
3. The directory named by the `TMP` environment variable.
4. A platform-specific location:
   - On Windows, the directories `C:\TEMP`, `C:\TMP`, `\TEMP`, and `\TMP`, in that order.
   - On all other platforms, the directories `/tmp`, `/var/tmp`, and `/usr/tmp`, in that order.
5. As a last resort, the current working directory.

The result of this search is cached, see the description of *tempdir* below.

tempfile.gettempdirb()
Same as *gettempdir()* but the return value is in bytes.

New in version 3.5.

tempfile.gettempprefix()
Return the filename prefix used to create temporary files. This does not contain the directory component.

tempfile.gettempprefixb()
Same as *gettempprefix()* but the return value is in bytes.

New in version 3.5.

The module uses a global variable to store the name of the directory used for temporary files returned by *gettempdir()*. It can be set directly to override the selection process, but this is discouraged. All functions in this module take a *dir* argument which can be used to specify the directory and this is the recommended approach.

tempfile.tempdir
When set to a value other than `None`, this variable defines the default value for the *dir* argument to the functions defined in this module.

If `tempdir` is `None` (the default) at any call to any of the above functions except *gettempprefix()* it is initialized following the algorithm described in *gettempdir()*.

11.6.1 Examples

Here are some examples of typical usage of the *tempfile* module:

```
>>> import tempfile

# create a temporary file and write some data to it
>>> fp = tempfile.TemporaryFile()
>>> fp.write(b'Hello world!')
# read data from file
>>> fp.seek(0)
>>> fp.read()
b'Hello world!'
# close the file, it will be removed
>>> fp.close()

# create a temporary file using a context manager
>>> with tempfile.TemporaryFile() as fp:
```

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```
...     fp.write(b'Hello world!')
...     fp.seek(0)
...     fp.read()
b'Hello world!'
>>>
# file is now closed and removed

# create a temporary directory using the context manager
>>> with tempfile.TemporaryDirectory() as tmpdirname:
...     print('created temporary directory', tmpdirname)
>>>
# directory and contents have been removed
```

11.6.2 Deprecated functions and variables

A historical way to create temporary files was to first generate a file name with the *mktemp()* function and then create a file using this name. Unfortunately this is not secure, because a different process may create a file with this name in the time between the call to *mktemp()* and the subsequent attempt to create the file by the first process. The solution is to combine the two steps and create the file immediately. This approach is used by *mkstemp()* and the other functions described above.

tempfile.mktemp(*suffix=''*, *prefix='tmp'*, *dir=None*)

Deprecated since version 2.3: Use *mkstemp()* instead.

Return an absolute pathname of a file that did not exist at the time the call is made. The *prefix*, *suffix*, and *dir* arguments are similar to those of *mkstemp()*, except that bytes file names, `suffix=None` and `prefix=None` are not supported.

Warning: Use of this function may introduce a security hole in your program. By the time you get around to doing anything with the file name it returns, someone else may have beaten you to the punch. *mktemp()* usage can be replaced easily with *NamedTemporaryFile()*, passing it the `delete=False` parameter:

```
>>> f = NamedTemporaryFile(delete=False)
>>> f.name
'/tmp/tmptjujjt'
>>> f.write(b"Hello World!\n")
13
>>> f.close()
>>> os.unlink(f.name)
>>> os.path.exists(f.name)
False
```

11.7 glob — Unix style pathname pattern expansion

Source code: Lib/glob.py

The *glob* module finds all the pathnames matching a specified pattern according to the rules used by the Unix shell, although results are returned in arbitrary order. No tilde expansion is done, but `*`, `?`, and character ranges expressed with `[]` will be correctly matched. This is done by using the *os.scandir()*

and *fnmatch.fnmatch()* functions in concert, and not by actually invoking a subshell. Note that unlike *fnmatch.fnmatch()*, *glob* treats filenames beginning with a dot (`.`) as special cases. (For tilde and shell variable expansion, use *os.path.expanduser()* and *os.path.expandvars()*.)

For a literal match, wrap the meta-characters in brackets. For example, `'[?]'` matches the character `'?'`.

See also:

The *pathlib* module offers high-level path objects.

`glob.glob`(*pathname*, ***, *recursive=False*)

Return a possibly-empty list of path names that match *pathname*, which must be a string containing a path specification. *pathname* can be either absolute (like `/usr/src/Python-1.5/Makefile`) or relative (like `../../Tools/*/*.gif`), and can contain shell-style wildcards. Broken symlinks are included in the results (as in the shell).

If *recursive* is true, the pattern "`**`" will match any files and zero or more directories and subdirectories. If the pattern is followed by an `os.sep`, only directories and subdirectories match.

Note: Using the "`**`" pattern in large directory trees may consume an inordinate amount of time.

Changed in version 3.5: Support for recursive globs using "`**`".

`glob.iglob`(*pathname*, ***, *recursive=False*)

Return an *iterator* which yields the same values as *glob()* without actually storing them all simultaneously.

`glob.escape`(*pathname*)

Escape all special characters (`'?'`, `'*'` and `'['`). This is useful if you want to match an arbitrary literal string that may have special characters in it. Special characters in drive/UNC sharepoints are not escaped, e.g. on Windows `escape('//?/c:/Quo vadis?.txt')` returns `'//?/c:/Quo vadis[?].txt'`.

New in version 3.4.

For example, consider a directory containing the following files: `1.gif`, `2.txt`, `card.gif` and a subdirectory `sub` which contains only the file `3.txt`. *glob()* will produce the following results. Notice how any leading components of the path are preserved.

```
>>> import glob
>>> glob.glob('./[0-9].*')
['./1.gif', './2.txt']
>>> glob.glob('*.gif')
['1.gif', 'card.gif']
>>> glob.glob('?.gif')
['1.gif']
>>> glob.glob('**/*.txt', recursive=True)
['2.txt', 'sub/3.txt']
>>> glob.glob('./**/', recursive=True)
['./', './sub/']
```

If the directory contains files starting with `.` they won't be matched by default. For example, consider a directory containing `card.gif` and `.card.gif`:

```
>>> import glob
>>> glob.glob('*.gif')
['card.gif']
>>> glob.glob('.c*')
['.card.gif']
```

See also:

Module *fnmatch* Shell-style filename (not path) expansion

11.8 fnmatch — Unix filename pattern matching

Source code: Lib/fnmatch.py

This module provides support for Unix shell-style wildcards, which are *not* the same as regular expressions (which are documented in the *re* module). The special characters used in shell-style wildcards are:

Pattern	Meaning
*	matches everything
?	matches any single character
[seq]	matches any character in *seq*
[!seq]	matches any character not in *seq*

For a literal match, wrap the meta-characters in brackets. For example, '[?]' matches the character '?'.

Note that the filename separator ('/' on Unix) is *not* special to this module. See module *glob* for pathname expansion (*glob* uses *fnmatch()* to match pathname segments). Similarly, filenames starting with a period are not special for this module, and are matched by the * and ? patterns.

fnmatch.**fnmatch**(*filename*, *pattern*)

Test whether the *filename* string matches the *pattern* string, returning *True* or *False*. Both parameters are case-normalized using *os.path.normcase()*. *fnmatchcase()* can be used to perform a case-sensitive comparison, regardless of whether that's standard for the operating system.

This example will print all file names in the current directory with the extension .txt:

```
import fnmatch
import os

for file in os.listdir('.'):
    if fnmatch.fnmatch(file, '*.txt'):
        print(file)
```

fnmatch.**fnmatchcase**(*filename*, *pattern*)

Test whether *filename* matches *pattern*, returning *True* or *False*; the comparison is case-sensitive and does not apply *os.path.normcase()*.

fnmatch.**filter**(*names*, *pattern*)

Return the subset of the list of *names* that match *pattern*. It is the same as [n for n in names if fnmatch(n, pattern)], but implemented more efficiently.

fnmatch.**translate**(*pattern*)

Return the shell-style *pattern* converted to a regular expression for using with *re.match()*.

Example:

```
>>> import fnmatch, re
>>>
>>> regex = fnmatch.translate('*.txt')
>>> regex
'(?s:.*\\.txt)\\Z'
```

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```
>>> reobj = re.compile(regex)
>>> reobj.match('foobar.txt')
<re.Match object; span=(0, 10), match='foobar.txt'>
```

See also:

Module *glob* Unix shell-style path expansion.

11.9 linecache — Random access to text lines

Source code: Lib/linecache.py

The *linecache* module allows one to get any line from a Python source file, while attempting to optimize internally, using a cache, the common case where many lines are read from a single file. This is used by the *traceback* module to retrieve source lines for inclusion in the formatted traceback.

The *tokenize.open()* function is used to open files. This function uses *tokenize.detect_encoding()* to get the encoding of the file; in the absence of an encoding token, the file encoding defaults to UTF-8.

The *linecache* module defines the following functions:

linecache.getline(*filename*, *lineno*, *module_globals=None*)
: Get line *lineno* from file named *filename*. This function will never raise an exception — it will return `''` on errors (the terminating newline character will be included for lines that are found).

  If a file named *filename* is not found, the function will look for it in the module search path, `sys.path`, after first checking for a **PEP 302** `__loader__` in *module_globals*, in case the module was imported from a zipfile or other non-filesystem import source.

linecache.clearcache()
: Clear the cache. Use this function if you no longer need lines from files previously read using *getline()*.

linecache.checkcache(*filename=None*)
: Check the cache for validity. Use this function if files in the cache may have changed on disk, and you require the updated version. If *filename* is omitted, it will check all the entries in the cache.

linecache.lazycache(*filename*, *module_globals*)
: Capture enough detail about a non-file-based module to permit getting its lines later via *getline()* even if *module_globals* is `None` in the later call. This avoids doing I/O until a line is actually needed, without having to carry the module globals around indefinitely.

  New in version 3.5.

Example:

```
>>> import linecache
>>> linecache.getline(linecache.__file__, 8)
'import sys\n'
```

11.10 shutil — High-level file operations

Source code: Lib/shutil.py

The *shutil* module offers a number of high-level operations on files and collections of files. In particular, functions are provided which support file copying and removal. For operations on individual files, see also the *os* module.

Warning: Even the higher-level file copying functions (*shutil.copy()*, *shutil.copy2()*) cannot copy all file metadata.

On POSIX platforms, this means that file owner and group are lost as well as ACLs. On Mac OS, the resource fork and other metadata are not used. This means that resources will be lost and file type and creator codes will not be correct. On Windows, file owners, ACLs and alternate data streams are not copied.

11.10.1 Directory and files operations

shutil.copyfileobj(*fsrc*, *fdst*[, *length*])
Copy the contents of the file-like object *fsrc* to the file-like object *fdst*. The integer *length*, if given, is the buffer size. In particular, a negative *length* value means to copy the data without looping over the source data in chunks; by default the data is read in chunks to avoid uncontrolled memory consumption. Note that if the current file position of the *fsrc* object is not 0, only the contents from the current file position to the end of the file will be copied.

shutil.copyfile(*src*, *dst*, ***, *follow_symlinks=True*)
Copy the contents (no metadata) of the file named *src* to a file named *dst* and return *dst*. *src* and *dst* are path names given as strings. *dst* must be the complete target file name; look at *shutil.copy()* for a copy that accepts a target directory path. If *src* and *dst* specify the same file, *SameFileError* is raised.

The destination location must be writable; otherwise, an *OSError* exception will be raised. If *dst* already exists, it will be replaced. Special files such as character or block devices and pipes cannot be copied with this function.

If *follow_symlinks* is false and *src* is a symbolic link, a new symbolic link will be created instead of copying the file *src* points to.

Changed in version 3.3: *IOError* used to be raised instead of *OSError*. Added *follow_symlinks* argument. Now returns *dst*.

Changed in version 3.4: Raise *SameFileError* instead of *Error*. Since the former is a subclass of the latter, this change is backward compatible.

exception shutil.SameFileError
This exception is raised if source and destination in *copyfile()* are the same file.

New in version 3.4.

shutil.copymode(*src*, *dst*, ***, *follow_symlinks=True*)
Copy the permission bits from *src* to *dst*. The file contents, owner, and group are unaffected. *src* and *dst* are path names given as strings. If *follow_symlinks* is false, and both *src* and *dst* are symbolic links, *copymode()* will attempt to modify the mode of *dst* itself (rather than the file it points to). This functionality is not available on every platform; please see *copystat()* for more information. If *copymode()* cannot modify symbolic links on the local platform, and it is asked to do so, it will do nothing and return.

Changed in version 3.3: Added *follow_symlinks* argument.

shutil.copystat(*src*, *dst*, ***, *follow_symlinks=True*)
Copy the permission bits, last access time, last modification time, and flags from *src* to *dst*. On Linux,

copystat() also copies the "extended attributes" where possible. The file contents, owner, and group are unaffected. *src* and *dst* are path names given as strings.

If *follow_symlinks* is false, and *src* and *dst* both refer to symbolic links, *copystat()* will operate on the symbolic links themselves rather than the files the symbolic links refer to—reading the information from the *src* symbolic link, and writing the information to the *dst* symbolic link.

Note: Not all platforms provide the ability to examine and modify symbolic links. Python itself can tell you what functionality is locally available.

- If `os.chmod in os.supports_follow_symlinks` is `True`, *copystat()* can modify the permission bits of a symbolic link.
- If `os.utime in os.supports_follow_symlinks` is `True`, *copystat()* can modify the last access and modification times of a symbolic link.
- If `os.chflags in os.supports_follow_symlinks` is `True`, *copystat()* can modify the flags of a symbolic link. (`os.chflags` is not available on all platforms.)

On platforms where some or all of this functionality is unavailable, when asked to modify a symbolic link, *copystat()* will copy everything it can. *copystat()* never returns failure.

Please see *os.supports_follow_symlinks* for more information.

Changed in version 3.3: Added *follow_symlinks* argument and support for Linux extended attributes.

`shutil.copy`(*src*, *dst*, ***, *follow_symlinks=True*)

Copies the file *src* to the file or directory *dst*. *src* and *dst* should be strings. If *dst* specifies a directory, the file will be copied into *dst* using the base filename from *src*. Returns the path to the newly created file.

If *follow_symlinks* is false, and *src* is a symbolic link, *dst* will be created as a symbolic link. If *follow_symlinks* is true and *src* is a symbolic link, *dst* will be a copy of the file *src* refers to.

copy() copies the file data and the file's permission mode (see *os.chmod()*). Other metadata, like the file's creation and modification times, is not preserved. To preserve all file metadata from the original, use *copy2()* instead.

Changed in version 3.3: Added *follow_symlinks* argument. Now returns path to the newly created file.

`shutil.copy2`(*src*, *dst*, ***, *follow_symlinks=True*)

Identical to *copy()* except that *copy2()* also attempts to preserve all file metadata.

When *follow_symlinks* is false, and *src* is a symbolic link, *copy2()* attempts to copy all metadata from the *src* symbolic link to the newly-created *dst* symbolic link. However, this functionality is not available on all platforms. On platforms where some or all of this functionality is unavailable, *copy2()* will preserve all the metadata it can; *copy2()* never returns failure.

copy2() uses *copystat()* to copy the file metadata. Please see *copystat()* for more information about platform support for modifying symbolic link metadata.

Changed in version 3.3: Added *follow_symlinks* argument, try to copy extended file system attributes too (currently Linux only). Now returns path to the newly created file.

`shutil.ignore_patterns`(**patterns*)

This factory function creates a function that can be used as a callable for *copytree()*'s *ignore* argument, ignoring files and directories that match one of the glob-style *patterns* provided. See the example below.

`shutil.copytree`(*src*, *dst*, *symlinks=False*, *ignore=None*, *copy_function=copy2*, *ignore_dangling_symlinks=False*)

Recursively copy an entire directory tree rooted at *src*, returning the destination directory. The destination directory, named by *dst*, must not already exist; it will be created as well as missing parent

directories. Permissions and times of directories are copied with *copystat()*, individual files are copied using *shutil.copy2()*.

If *symlinks* is true, symbolic links in the source tree are represented as symbolic links in the new tree and the metadata of the original links will be copied as far as the platform allows; if false or omitted, the contents and metadata of the linked files are copied to the new tree.

When *symlinks* is false, if the file pointed by the symlink doesn't exist, an exception will be added in the list of errors raised in an *Error* exception at the end of the copy process. You can set the optional *ignore_dangling_symlinks* flag to true if you want to silence this exception. Notice that this option has no effect on platforms that don't support *os.symlink()*.

If *ignore* is given, it must be a callable that will receive as its arguments the directory being visited by *copytree()*, and a list of its contents, as returned by *os.listdir()*. Since *copytree()* is called recursively, the *ignore* callable will be called once for each directory that is copied. The callable must return a sequence of directory and file names relative to the current directory (i.e. a subset of the items in its second argument); these names will then be ignored in the copy process. *ignore_patterns()* can be used to create such a callable that ignores names based on glob-style patterns.

If exception(s) occur, an *Error* is raised with a list of reasons.

If *copy_function* is given, it must be a callable that will be used to copy each file. It will be called with the source path and the destination path as arguments. By default, *shutil.copy2()* is used, but any function that supports the same signature (like *shutil.copy()*) can be used.

Changed in version 3.3: Copy metadata when *symlinks* is false. Now returns *dst*.

Changed in version 3.2: Added the *copy_function* argument to be able to provide a custom copy function. Added the *ignore_dangling_symlinks* argument to silent dangling symlinks errors when *symlinks* is false.

shutil.rmtree(*path*, *ignore_errors=False*, *onerror=None*)

Delete an entire directory tree; *path* must point to a directory (but not a symbolic link to a directory). If *ignore_errors* is true, errors resulting from failed removals will be ignored; if false or omitted, such errors are handled by calling a handler specified by *onerror* or, if that is omitted, they raise an exception.

Note: On platforms that support the necessary fd-based functions a symlink attack resistant version of *rmtree()* is used by default. On other platforms, the *rmtree()* implementation is susceptible to a symlink attack: given proper timing and circumstances, attackers can manipulate symlinks on the filesystem to delete files they wouldn't be able to access otherwise. Applications can use the *rmtree.avoids_symlink_attacks* function attribute to determine which case applies.

If *onerror* is provided, it must be a callable that accepts three parameters: *function*, *path*, and *excinfo*.

The first parameter, *function*, is the function which raised the exception; it depends on the platform and implementation. The second parameter, *path*, will be the path name passed to *function*. The third parameter, *excinfo*, will be the exception information returned by *sys.exc_info()*. Exceptions raised by *onerror* will not be caught.

Changed in version 3.3: Added a symlink attack resistant version that is used automatically if platform supports fd-based functions.

rmtree.avoids_symlink_attacks

Indicates whether the current platform and implementation provides a symlink attack resistant version of *rmtree()*. Currently this is only true for platforms supporting fd-based directory access functions.

New in version 3.3.

shutil.move(*src*, *dst*, *copy_function=copy2*)
Recursively move a file or directory (*src*) to another location (*dst*) and return the destination.

If the destination is an existing directory, then *src* is moved inside that directory. If the destination already exists but is not a directory, it may be overwritten depending on *os.rename()* semantics.

If the destination is on the current filesystem, then *os.rename()* is used. Otherwise, *src* is copied to *dst* using *copy_function* and then removed. In case of symlinks, a new symlink pointing to the target of *src* will be created in or as *dst* and *src* will be removed.

If *copy_function* is given, it must be a callable that takes two arguments *src* and *dst*, and will be used to copy *src* to *dest* if *os.rename()* cannot be used. If the source is a directory, *copytree()* is called, passing it the `copy_function()`. The default *copy_function* is *copy2()*. Using *copy()* as the *copy_function* allows the move to succeed when it is not possible to also copy the metadata, at the expense of not copying any of the metadata.

Changed in version 3.3: Added explicit symlink handling for foreign filesystems, thus adapting it to the behavior of GNU's **mv**. Now returns *dst*.

Changed in version 3.5: Added the *copy_function* keyword argument.

shutil.disk_usage(*path*)
Return disk usage statistics about the given path as a *named tuple* with the attributes *total*, *used* and *free*, which are the amount of total, used and free space, in bytes. On Windows, *path* must be a directory; on Unix, it can be a file or directory.

New in version 3.3.

Availability: Unix, Windows.

shutil.chown(*path*, *user=None*, *group=None*)
Change owner *user* and/or *group* of the given *path*.

user can be a system user name or a uid; the same applies to *group*. At least one argument is required.

See also *os.chown()*, the underlying function.

Availability: Unix.

New in version 3.3.

shutil.which(*cmd*, *mode=os.F_OK | os.X_OK*, *path=None*)
Return the path to an executable which would be run if the given *cmd* was called. If no *cmd* would be called, return `None`.

mode is a permission mask passed to *os.access()*, by default determining if the file exists and executable.

When no *path* is specified, the results of *os.environ()* are used, returning either the "PATH" value or a fallback of *os.defpath*.

On Windows, the current directory is always prepended to the *path* whether or not you use the default or provide your own, which is the behavior the command shell uses when finding executables. Additionally, when finding the *cmd* in the *path*, the `PATHEXT` environment variable is checked. For example, if you call `shutil.which("python")`, *which()* will search `PATHEXT` to know that it should look for `python.exe` within the *path* directories. For example, on Windows:

```
>>> shutil.which("python")
'C:\\Python33\\python.EXE'
```

New in version 3.3.

exception shutil.Error
This exception collects exceptions that are raised during a multi-file operation. For *copytree()*, the exception argument is a list of 3-tuples (*srcname*, *dstname*, *exception*).

copytree example

This example is the implementation of the *copytree()* function, described above, with the docstring omitted. It demonstrates many of the other functions provided by this module.

```
def copytree(src, dst, symlinks=False):
    names = os.listdir(src)
    os.makedirs(dst)
    errors = []
    for name in names:
        srcname = os.path.join(src, name)
        dstname = os.path.join(dst, name)
        try:
            if symlinks and os.path.islink(srcname):
                linkto = os.readlink(srcname)
                os.symlink(linkto, dstname)
            elif os.path.isdir(srcname):
                copytree(srcname, dstname, symlinks)
            else:
                copy2(srcname, dstname)
            # XXX What about devices, sockets etc.?
        except OSError as why:
            errors.append((srcname, dstname, str(why)))
        # catch the Error from the recursive copytree so that we can
        # continue with other files
        except Error as err:
            errors.extend(err.args[0])
    try:
        copystat(src, dst)
    except OSError as why:
        # can't copy file access times on Windows
        if why.winerror is None:
            errors.extend((src, dst, str(why)))
    if errors:
        raise Error(errors)
```

Another example that uses the *ignore_patterns()* helper:

```
from shutil import copytree, ignore_patterns

copytree(source, destination, ignore=ignore_patterns('*.pyc', 'tmp*'))
```

This will copy everything except `.pyc` files and files or directories whose name starts with `tmp`.

Another example that uses the *ignore* argument to add a logging call:

```
from shutil import copytree
import logging

def _logpath(path, names):
    logging.info('Working in %s', path)
    return []   # nothing will be ignored

copytree(source, destination, ignore=_logpath)
```

rmtree example

This example shows how to remove a directory tree on Windows where some of the files have their read-only bit set. It uses the onerror callback to clear the readonly bit and reattempt the remove. Any subsequent failure will propagate.

```
import os, stat
import shutil

def remove_readonly(func, path, _):
    "Clear the readonly bit and reattempt the removal"
    os.chmod(path, stat.S_IWRITE)
    func(path)

shutil.rmtree(directory, onerror=remove_readonly)
```

11.10.2 Archiving operations

New in version 3.2.

Changed in version 3.5: Added support for the *xztar* format.

High-level utilities to create and read compressed and archived files are also provided. They rely on the *zipfile* and *tarfile* modules.

shutil.make_archive(*base_name*, *format*[, *root_dir*[, *base_dir*[, *verbose*[, *dry_run*[, *owner*[, *group*[, *logger*]]]]]]])

Create an archive file (such as zip or tar) and return its name.

base_name is the name of the file to create, including the path, minus any format-specific extension. *format* is the archive format: one of "zip" (if the *zlib* module is available), "tar", "gztar" (if the *zlib* module is available), "bztar" (if the *bz2* module is available), or "xztar" (if the *lzma* module is available).

root_dir is a directory that will be the root directory of the archive; for example, we typically chdir into *root_dir* before creating the archive.

base_dir is the directory where we start archiving from; i.e. *base_dir* will be the common prefix of all files and directories in the archive.

root_dir and *base_dir* both default to the current directory.

If *dry_run* is true, no archive is created, but the operations that would be executed are logged to *logger*.

owner and *group* are used when creating a tar archive. By default, uses the current owner and group.

logger must be an object compatible with **PEP 282**, usually an instance of *logging.Logger*.

The *verbose* argument is unused and deprecated.

shutil.get_archive_formats()

Return a list of supported formats for archiving. Each element of the returned sequence is a tuple `(name, description)`.

By default *shutil* provides these formats:

- *zip*: ZIP file (if the *zlib* module is available).
- *tar*: uncompressed tar file.
- *gztar*: gzip'ed tar-file (if the *zlib* module is available).

- *bztar*: bzip2'ed tar-file (if the *bz2* module is available).
- *xztar*: xz'ed tar-file (if the *lzma* module is available).

You can register new formats or provide your own archiver for any existing formats, by using *register_archive_format()*.

shutil.register_archive_format(*name*, *function*[, *extra_args*[, *description*]])
Register an archiver for the format *name*.

function is the callable that will be used to unpack archives. The callable will receive the *base_name* of the file to create, followed by the *base_dir* (which defaults to *os.curdir*) to start archiving from. Further arguments are passed as keyword arguments: *owner*, *group*, *dry_run* and *logger* (as passed in *make_archive()*).

If given, *extra_args* is a sequence of `(name, value)` pairs that will be used as extra keywords arguments when the archiver callable is used.

description is used by *get_archive_formats()* which returns the list of archivers. Defaults to an empty string.

shutil.unregister_archive_format(*name*)
Remove the archive format *name* from the list of supported formats.

shutil.unpack_archive(*filename*[, *extract_dir*[, *format*]])
Unpack an archive. *filename* is the full path of the archive.

extract_dir is the name of the target directory where the archive is unpacked. If not provided, the current working directory is used.

format is the archive format: one of "zip", "tar", "gztar", "bztar", or "xztar". Or any other format registered with *register_unpack_format()*. If not provided, *unpack_archive()* will use the archive file name extension and see if an unpacker was registered for that extension. In case none is found, a *ValueError* is raised.

Changed in version 3.7: Accepts a *path-like object* for *filename* and *extract_dir*.

shutil.register_unpack_format(*name*, *extensions*, *function*[, *extra_args*[, *description*]])
Registers an unpack format. *name* is the name of the format and *extensions* is a list of extensions corresponding to the format, like `.zip` for Zip files.

function is the callable that will be used to unpack archives. The callable will receive the path of the archive, followed by the directory the archive must be extracted to.

When provided, *extra_args* is a sequence of `(name, value)` tuples that will be passed as keywords arguments to the callable.

description can be provided to describe the format, and will be returned by the *get_unpack_formats()* function.

shutil.unregister_unpack_format(*name*)
Unregister an unpack format. *name* is the name of the format.

shutil.get_unpack_formats()
Return a list of all registered formats for unpacking. Each element of the returned sequence is a tuple `(name, extensions, description)`.

By default *shutil* provides these formats:

- *zip*: ZIP file (unpacking compressed files works only if the corresponding module is available).
- *tar*: uncompressed tar file.
- *gztar*: gzip'ed tar-file (if the *zlib* module is available).
- *bztar*: bzip2'ed tar-file (if the *bz2* module is available).

- *xztar*: xz'ed tar-file (if the *lzma* module is available).

You can register new formats or provide your own unpacker for any existing formats, by using *register_unpack_format()*.

Archiving example

In this example, we create a gzip'ed tar-file archive containing all files found in the `.ssh` directory of the user:

```
>>> from shutil import make_archive
>>> import os
>>> archive_name = os.path.expanduser(os.path.join('~', 'myarchive'))
>>> root_dir = os.path.expanduser(os.path.join('~', '.ssh'))
>>> make_archive(archive_name, 'gztar', root_dir)
'/Users/tarek/myarchive.tar.gz'
```

The resulting archive contains:

```
$ tar -tzvf /Users/tarek/myarchive.tar.gz
drwx------ tarek/staff       0 2010-02-01 16:23:40 ./
-rw-r--r-- tarek/staff     609 2008-06-09 13:26:54 ./authorized_keys
-rwxr-xr-x tarek/staff      65 2008-06-09 13:26:54 ./config
-rwx------ tarek/staff     668 2008-06-09 13:26:54 ./id_dsa
-rwxr-xr-x tarek/staff     609 2008-06-09 13:26:54 ./id_dsa.pub
-rw------- tarek/staff    1675 2008-06-09 13:26:54 ./id_rsa
-rw-r--r-- tarek/staff     397 2008-06-09 13:26:54 ./id_rsa.pub
-rw-r--r-- tarek/staff   37192 2010-02-06 18:23:10 ./known_hosts
```

11.10.3 Querying the size of the output terminal

shutil.get_terminal_size(*fallback=(columns, lines)*)

Get the size of the terminal window.

For each of the two dimensions, the environment variable, `COLUMNS` and `LINES` respectively, is checked. If the variable is defined and the value is a positive integer, it is used.

When `COLUMNS` or `LINES` is not defined, which is the common case, the terminal connected to *sys.__stdout__* is queried by invoking *os.get_terminal_size()*.

If the terminal size cannot be successfully queried, either because the system doesn't support querying, or because we are not connected to a terminal, the value given in `fallback` parameter is used. `fallback` defaults to `(80, 24)` which is the default size used by many terminal emulators.

The value returned is a named tuple of type *os.terminal_size*.

See also: The Single UNIX Specification, Version 2, Other Environment Variables.

New in version 3.3.

11.11 macpath — Mac OS 9 path manipulation functions

Source code: Lib/macpath.py

Deprecated since version 3.7, will be removed in version 3.8.

This module is the Mac OS 9 (and earlier) implementation of the *os.path* module. It can be used to manipulate old-style Macintosh pathnames on Mac OS X (or any other platform).

The following functions are available in this module: `normcase()`, `normpath()`, `isabs()`, `join()`, `split()`, `isdir()`, `isfile()`, `walk()`, `exists()`. For other functions available in *os.path* dummy counterparts are available.

See also:

Module *os* Operating system interfaces, including functions to work with files at a lower level than Python *file objects*.

Module *io* Python's built-in I/O library, including both abstract classes and some concrete classes such as file I/O.

Built-in function *open()* The standard way to open files for reading and writing with Python.

CHAPTER

TWELVE

DATA PERSISTENCE

The modules described in this chapter support storing Python data in a persistent form on disk. The *pickle* and *marshal* modules can turn many Python data types into a stream of bytes and then recreate the objects from the bytes. The various DBM-related modules support a family of hash-based file formats that store a mapping of strings to other strings.

The list of modules described in this chapter is:

12.1 pickle — Python object serialization

Source code: Lib/pickle.py

The *pickle* module implements binary protocols for serializing and de-serializing a Python object structure. *"Pickling"* is the process whereby a Python object hierarchy is converted into a byte stream, and *"unpickling"* is the inverse operation, whereby a byte stream (from a *binary file* or *bytes-like object*) is converted back into an object hierarchy. Pickling (and unpickling) is alternatively known as "serialization", "marshalling,"[1] or "flattening"; however, to avoid confusion, the terms used here are "pickling" and "unpickling".

Warning: The *pickle* module is not secure against erroneous or maliciously constructed data. Never unpickle data received from an untrusted or unauthenticated source.

12.1.1 Relationship to other Python modules

Comparison with marshal

Python has a more primitive serialization module called *marshal*, but in general *pickle* should always be the preferred way to serialize Python objects. *marshal* exists primarily to support Python's `.pyc` files.

The *pickle* module differs from *marshal* in several significant ways:

- The *pickle* module keeps track of the objects it has already serialized, so that later references to the same object won't be serialized again. *marshal* doesn't do this.

  This has implications both for recursive objects and object sharing. Recursive objects are objects that contain references to themselves. These are not handled by marshal, and in fact, attempting to marshal recursive objects will crash your Python interpreter. Object sharing happens when there are multiple references to the same object in different places in the object hierarchy being serialized. *pickle* stores such objects only once, and ensures that all other references point to the master copy. Shared objects remain shared, which can be very important for mutable objects.

[1] Don't confuse this with the *marshal* module

- *marshal* cannot be used to serialize user-defined classes and their instances. *pickle* can save and restore class instances transparently, however the class definition must be importable and live in the same module as when the object was stored.
- The *marshal* serialization format is not guaranteed to be portable across Python versions. Because its primary job in life is to support `.pyc` files, the Python implementers reserve the right to change the serialization format in non-backwards compatible ways should the need arise. The *pickle* serialization format is guaranteed to be backwards compatible across Python releases.

Comparison with `json`

There are fundamental differences between the pickle protocols and JSON (JavaScript Object Notation):

- JSON is a text serialization format (it outputs unicode text, although most of the time it is then encoded to `utf-8`), while pickle is a binary serialization format;
- JSON is human-readable, while pickle is not;
- JSON is interoperable and widely used outside of the Python ecosystem, while pickle is Python-specific;
- JSON, by default, can only represent a subset of the Python built-in types, and no custom classes; pickle can represent an extremely large number of Python types (many of them automatically, by clever usage of Python's introspection facilities; complex cases can be tackled by implementing *specific object APIs*).

See also:

The *json* module: a standard library module allowing JSON serialization and deserialization.

12.1.2 Data stream format

The data format used by *pickle* is Python-specific. This has the advantage that there are no restrictions imposed by external standards such as JSON or XDR (which can't represent pointer sharing); however it means that non-Python programs may not be able to reconstruct pickled Python objects.

By default, the *pickle* data format uses a relatively compact binary representation. If you need optimal size characteristics, you can efficiently *compress* pickled data.

The module *pickletools* contains tools for analyzing data streams generated by *pickle*. *pickletools* source code has extensive comments about opcodes used by pickle protocols.

There are currently 5 different protocols which can be used for pickling. The higher the protocol used, the more recent the version of Python needed to read the pickle produced.

- Protocol version 0 is the original "human-readable" protocol and is backwards compatible with earlier versions of Python.
- Protocol version 1 is an old binary format which is also compatible with earlier versions of Python.
- Protocol version 2 was introduced in Python 2.3. It provides much more efficient pickling of *new-style classes*. Refer to **PEP 307** for information about improvements brought by protocol 2.
- Protocol version 3 was added in Python 3.0. It has explicit support for *bytes* objects and cannot be unpickled by Python 2.x. This is the default protocol, and the recommended protocol when compatibility with other Python 3 versions is required.
- Protocol version 4 was added in Python 3.4. It adds support for very large objects, pickling more kinds of objects, and some data format optimizations. Refer to **PEP 3154** for information about improvements brought by protocol 4.

Note: Serialization is a more primitive notion than persistence; although *pickle* reads and writes file objects, it does not handle the issue of naming persistent objects, nor the (even more complicated) issue of concurrent access to persistent objects. The *pickle* module can transform a complex object into a byte stream and it can transform the byte stream into an object with the same internal structure. Perhaps the most obvious thing to do with these byte streams is to write them onto a file, but it is also conceivable to send them across a network or store them in a database. The *shelve* module provides a simple interface to pickle and unpickle objects on DBM-style database files.

12.1.3 Module Interface

To serialize an object hierarchy, you simply call the *dumps()* function. Similarly, to de-serialize a data stream, you call the *loads()* function. However, if you want more control over serialization and de-serialization, you can create a *Pickler* or an *Unpickler* object, respectively.

The *pickle* module provides the following constants:

pickle.HIGHEST_PROTOCOL
An integer, the highest *protocol version* available. This value can be passed as a *protocol* value to functions *dump()* and *dumps()* as well as the *Pickler* constructor.

pickle.DEFAULT_PROTOCOL
An integer, the default *protocol version* used for pickling. May be less than *HIGHEST_PROTOCOL*. Currently the default protocol is 3, a new protocol designed for Python 3.

The *pickle* module provides the following functions to make the pickling process more convenient:

pickle.dump(*obj*, *file*, *protocol=None*, ***, *fix_imports=True*)
Write a pickled representation of *obj* to the open *file object* *file*. This is equivalent to `Pickler(file, protocol).dump(obj)`.

The optional *protocol* argument, an integer, tells the pickler to use the given protocol; supported protocols are 0 to *HIGHEST_PROTOCOL*. If not specified, the default is *DEFAULT_PROTOCOL*. If a negative number is specified, *HIGHEST_PROTOCOL* is selected.

The *file* argument must have a write() method that accepts a single bytes argument. It can thus be an on-disk file opened for binary writing, an *io.BytesIO* instance, or any other custom object that meets this interface.

If *fix_imports* is true and *protocol* is less than 3, pickle will try to map the new Python 3 names to the old module names used in Python 2, so that the pickle data stream is readable with Python 2.

pickle.dumps(*obj*, *protocol=None*, ***, *fix_imports=True*)
Return the pickled representation of the object as a *bytes* object, instead of writing it to a file.

Arguments *protocol* and *fix_imports* have the same meaning as in *dump()*.

pickle.load(*file*, ***, *fix_imports=True*, *encoding="ASCII"*, *errors="strict"*)
Read a pickled object representation from the open *file object* *file* and return the reconstituted object hierarchy specified therein. This is equivalent to `Unpickler(file).load()`.

The protocol version of the pickle is detected automatically, so no protocol argument is needed. Bytes past the pickled object's representation are ignored.

The argument *file* must have two methods, a read() method that takes an integer argument, and a readline() method that requires no arguments. Both methods should return bytes. Thus *file* can be an on-disk file opened for binary reading, an *io.BytesIO* object, or any other custom object that meets this interface.

Optional keyword arguments are *fix_imports*, *encoding* and *errors*, which are used to control compatibility support for pickle stream generated by Python 2. If *fix_imports* is true, pickle will try to map the old Python 2 names to the new names used in Python 3. The *encoding* and *errors* tell pickle how to decode 8-bit string instances pickled by Python 2; these default to 'ASCII' and 'strict', respectively. The *encoding* can be 'bytes' to read these 8-bit string instances as bytes objects.

pickle.loads(*bytes_object*, ***, *fix_imports=True*, *encoding="ASCII"*, *errors="strict"*)
Read a pickled object hierarchy from a *bytes* object and return the reconstituted object hierarchy specified therein.

The protocol version of the pickle is detected automatically, so no protocol argument is needed. Bytes past the pickled object's representation are ignored.

Optional keyword arguments are *fix_imports*, *encoding* and *errors*, which are used to control compatibility support for pickle stream generated by Python 2. If *fix_imports* is true, pickle will try to map the old Python 2 names to the new names used in Python 3. The *encoding* and *errors* tell pickle how to decode 8-bit string instances pickled by Python 2; these default to 'ASCII' and 'strict', respectively. The *encoding* can be 'bytes' to read these 8-bit string instances as bytes objects.

The *pickle* module defines three exceptions:

exception pickle.PickleError
Common base class for the other pickling exceptions. It inherits *Exception*.

exception pickle.PicklingError
Error raised when an unpicklable object is encountered by *Pickler*. It inherits *PickleError*.

Refer to *What can be pickled and unpickled?* to learn what kinds of objects can be pickled.

exception pickle.UnpicklingError
Error raised when there is a problem unpickling an object, such as a data corruption or a security violation. It inherits *PickleError*.

Note that other exceptions may also be raised during unpickling, including (but not necessarily limited to) AttributeError, EOFError, ImportError, and IndexError.

The *pickle* module exports two classes, *Pickler* and *Unpickler*:

class pickle.Pickler(*file*, *protocol=None*, ***, *fix_imports=True*)
This takes a binary file for writing a pickle data stream.

The optional *protocol* argument, an integer, tells the pickler to use the given protocol; supported protocols are 0 to *HIGHEST_PROTOCOL*. If not specified, the default is *DEFAULT_PROTOCOL*. If a negative number is specified, *HIGHEST_PROTOCOL* is selected.

The *file* argument must have a write() method that accepts a single bytes argument. It can thus be an on-disk file opened for binary writing, an *io.BytesIO* instance, or any other custom object that meets this interface.

If *fix_imports* is true and *protocol* is less than 3, pickle will try to map the new Python 3 names to the old module names used in Python 2, so that the pickle data stream is readable with Python 2.

dump(*obj*)
Write a pickled representation of *obj* to the open file object given in the constructor.

persistent_id(*obj*)
Do nothing by default. This exists so a subclass can override it.

If *persistent_id()* returns `None`, *obj* is pickled as usual. Any other value causes *Pickler* to emit the returned value as a persistent ID for *obj*. The meaning of this persistent ID should be defined by *Unpickler.persistent_load()*. Note that the value returned by *persistent_id()* cannot itself have a persistent ID.

See *Persistence of External Objects* for details and examples of uses.

dispatch_table
A pickler object's dispatch table is a registry of *reduction functions* of the kind which can be declared using *copyreg.pickle()*. It is a mapping whose keys are classes and whose values are reduction functions. A reduction function takes a single argument of the associated class and should conform to the same interface as a *__reduce__()* method.

By default, a pickler object will not have a *dispatch_table* attribute, and it will instead use the global dispatch table managed by the *copyreg* module. However, to customize the pickling for a specific pickler object one can set the *dispatch_table* attribute to a dict-like object. Alternatively, if a subclass of *Pickler* has a *dispatch_table* attribute then this will be used as the default dispatch table for instances of that class.

See *Dispatch Tables* for usage examples.

New in version 3.3.

fast
Deprecated. Enable fast mode if set to a true value. The fast mode disables the usage of memo, therefore speeding the pickling process by not generating superfluous PUT opcodes. It should not be used with self-referential objects, doing otherwise will cause *Pickler* to recurse infinitely.

Use *pickletools.optimize()* if you need more compact pickles.

class pickle.Unpickler(*file*, ***, *fix_imports=True*, *encoding="ASCII"*, *errors="strict"*)
This takes a binary file for reading a pickle data stream.

The protocol version of the pickle is detected automatically, so no protocol argument is needed.

The argument *file* must have two methods, a read() method that takes an integer argument, and a readline() method that requires no arguments. Both methods should return bytes. Thus *file* can be an on-disk file object opened for binary reading, an *io.BytesIO* object, or any other custom object that meets this interface.

Optional keyword arguments are *fix_imports*, *encoding* and *errors*, which are used to control compatibility support for pickle stream generated by Python 2. If *fix_imports* is true, pickle will try to map the old Python 2 names to the new names used in Python 3. The *encoding* and *errors* tell pickle how to decode 8-bit string instances pickled by Python 2; these default to 'ASCII' and 'strict', respectively. The *encoding* can be 'bytes' to read these 8-bit string instances as bytes objects.

load()
Read a pickled object representation from the open file object given in the constructor, and return the reconstituted object hierarchy specified therein. Bytes past the pickled object's representation are ignored.

persistent_load(*pid*)
Raise an *UnpicklingError* by default.

If defined, *persistent_load()* should return the object specified by the persistent ID *pid*. If an invalid persistent ID is encountered, an *UnpicklingError* should be raised.

See *Persistence of External Objects* for details and examples of uses.

find_class(*module*, *name*)
Import *module* if necessary and return the object called *name* from it, where the *module* and *name* arguments are *str* objects. Note, unlike its name suggests, *find_class()* is also used for finding functions.

Subclasses may override this to gain control over what type of objects and how they can be loaded, potentially reducing security risks. Refer to *Restricting Globals* for details.

12.1.4 What can be pickled and unpickled?

The following types can be pickled:

- `None`, `True`, and `False`
- integers, floating point numbers, complex numbers
- strings, bytes, bytearrays
- tuples, lists, sets, and dictionaries containing only picklable objects
- functions defined at the top level of a module (using `def`, not `lambda`)
- built-in functions defined at the top level of a module
- classes that are defined at the top level of a module
- instances of such classes whose *__dict__* or the result of calling *__getstate__()* is picklable (see section *Pickling Class Instances* for details).

Attempts to pickle unpicklable objects will raise the *PicklingError* exception; when this happens, an unspecified number of bytes may have already been written to the underlying file. Trying to pickle a highly recursive data structure may exceed the maximum recursion depth, a *RecursionError* will be raised in this case. You can carefully raise this limit with *sys.setrecursionlimit()*.

Note that functions (built-in and user-defined) are pickled by "fully qualified" name reference, not by value.[2] This means that only the function name is pickled, along with the name of the module the function is defined in. Neither the function's code, nor any of its function attributes are pickled. Thus the defining module must be importable in the unpickling environment, and the module must contain the named object, otherwise an exception will be raised.[3]

Similarly, classes are pickled by named reference, so the same restrictions in the unpickling environment apply. Note that none of the class's code or data is pickled, so in the following example the class attribute `attr` is not restored in the unpickling environment:

```
class Foo:
    attr = 'A class attribute'

picklestring = pickle.dumps(Foo)
```

These restrictions are why picklable functions and classes must be defined in the top level of a module.

Similarly, when class instances are pickled, their class's code and data are not pickled along with them. Only the instance data are pickled. This is done on purpose, so you can fix bugs in a class or add methods to the class and still load objects that were created with an earlier version of the class. If you plan to have long-lived objects that will see many versions of a class, it may be worthwhile to put a version number in the objects so that suitable conversions can be made by the class's *__setstate__()* method.

12.1.5 Pickling Class Instances

In this section, we describe the general mechanisms available to you to define, customize, and control how class instances are pickled and unpickled.

In most cases, no additional code is needed to make instances picklable. By default, pickle will retrieve the class and the attributes of an instance via introspection. When a class instance is unpickled, its `__init__()` method is usually *not* invoked. The default behaviour first creates an uninitialized instance and then restores the saved attributes. The following code shows an implementation of this behaviour:

[2] This is why `lambda` functions cannot be pickled: all `lambda` functions share the same name: `<lambda>`.
[3] The exception raised will likely be an *ImportError* or an *AttributeError* but it could be something else.

```
def save(obj):
    return (obj.__class__, obj.__dict__)

def load(cls, attributes):
    obj = cls.__new__(cls)
    obj.__dict__.update(attributes)
    return obj
```

Classes can alter the default behaviour by providing one or several special methods:

`object.__getnewargs_ex__()`
: In protocols 2 and newer, classes that implements the *__getnewargs_ex__()* method can dictate the values passed to the `__new__()` method upon unpickling. The method must return a pair `(args, kwargs)` where *args* is a tuple of positional arguments and *kwargs* a dictionary of named arguments for constructing the object. Those will be passed to the `__new__()` method upon unpickling.

  You should implement this method if the `__new__()` method of your class requires keyword-only arguments. Otherwise, it is recommended for compatibility to implement *__getnewargs__()*.

  Changed in version 3.6: *__getnewargs_ex__()* is now used in protocols 2 and 3.

`object.__getnewargs__()`
: This method serves a similar purpose as *__getnewargs_ex__()*, but supports only positional arguments. It must return a tuple of arguments `args` which will be passed to the `__new__()` method upon unpickling.

  __getnewargs__() will not be called if *__getnewargs_ex__()* is defined.

  Changed in version 3.6: Before Python 3.6, *__getnewargs__()* was called instead of *__getnewargs_ex__()* in protocols 2 and 3.

`object.__getstate__()`
: Classes can further influence how their instances are pickled; if the class defines the method *__getstate__()*, it is called and the returned object is pickled as the contents for the instance, instead of the contents of the instance's dictionary. If the *__getstate__()* method is absent, the instance's *__dict__* is pickled as usual.

`object.__setstate__(`*state*`)`
: Upon unpickling, if the class defines *__setstate__()*, it is called with the unpickled state. In that case, there is no requirement for the state object to be a dictionary. Otherwise, the pickled state must be a dictionary and its items are assigned to the new instance's dictionary.

  Note: If *__getstate__()* returns a false value, the *__setstate__()* method will not be called upon unpickling.

Refer to the section *Handling Stateful Objects* for more information about how to use the methods *__getstate__()* and *__setstate__()*.

Note: At unpickling time, some methods like `__getattr__()`, `__getattribute__()`, or `__setattr__()` may be called upon the instance. In case those methods rely on some internal invariant being true, the type should implement *__getnewargs__()* or *__getnewargs_ex__()* to establish such an invariant; otherwise, neither `__new__()` nor `__init__()` will be called.

As we shall see, pickle does not use directly the methods described above. In fact, these methods are part of the copy protocol which implements the *__reduce__()* special method. The copy protocol provides a unified interface for retrieving the data necessary for pickling and copying objects.[4]

[4] The *copy* module uses this protocol for shallow and deep copying operations.

Although powerful, implementing *__reduce__()* directly in your classes is error prone. For this reason, class designers should use the high-level interface (i.e., *__getnewargs_ex__()*, *__getstate__()* and *__setstate__()*) whenever possible. We will show, however, cases where using *__reduce__()* is the only option or leads to more efficient pickling or both.

`object.__reduce__()`

The interface is currently defined as follows. The *__reduce__()* method takes no argument and shall return either a string or preferably a tuple (the returned object is often referred to as the "reduce value").

If a string is returned, the string should be interpreted as the name of a global variable. It should be the object's local name relative to its module; the pickle module searches the module namespace to determine the object's module. This behaviour is typically useful for singletons.

When a tuple is returned, it must be between two and five items long. Optional items can either be omitted, or `None` can be provided as their value. The semantics of each item are in order:

- A callable object that will be called to create the initial version of the object.
- A tuple of arguments for the callable object. An empty tuple must be given if the callable does not accept any argument.
- Optionally, the object's state, which will be passed to the object's *__setstate__()* method as previously described. If the object has no such method then, the value must be a dictionary and it will be added to the object's *__dict__* attribute.
- Optionally, an iterator (and not a sequence) yielding successive items. These items will be appended to the object either using `obj.append(item)` or, in batch, using `obj.extend(list_of_items)`. This is primarily used for list subclasses, but may be used by other classes as long as they have `append()` and `extend()` methods with the appropriate signature. (Whether `append()` or `extend()` is used depends on which pickle protocol version is used as well as the number of items to append, so both must be supported.)
- Optionally, an iterator (not a sequence) yielding successive key-value pairs. These items will be stored to the object using `obj[key] = value`. This is primarily used for dictionary subclasses, but may be used by other classes as long as they implement `__setitem__()`.

`object.__reduce_ex__`(*protocol*)

Alternatively, a *__reduce_ex__()* method may be defined. The only difference is this method should take a single integer argument, the protocol version. When defined, pickle will prefer it over the *__reduce__()* method. In addition, *__reduce__()* automatically becomes a synonym for the extended version. The main use for this method is to provide backwards-compatible reduce values for older Python releases.

Persistence of External Objects

For the benefit of object persistence, the *pickle* module supports the notion of a reference to an object outside the pickled data stream. Such objects are referenced by a persistent ID, which should be either a string of alphanumeric characters (for protocol 0)[5] or just an arbitrary object (for any newer protocol).

The resolution of such persistent IDs is not defined by the *pickle* module; it will delegate this resolution to the user defined methods on the pickler and unpickler, *persistent_id()* and *persistent_load()* respectively.

To pickle objects that have an external persistent id, the pickler must have a custom *persistent_id()* method that takes an object as an argument and returns either `None` or the persistent id for that object. When `None` is returned, the pickler simply pickles the object as normal. When a persistent ID string is

[5] The limitation on alphanumeric characters is due to the fact the persistent IDs, in protocol 0, are delimited by the newline character. Therefore if any kind of newline characters occurs in persistent IDs, the resulting pickle will become unreadable.

returned, the pickler will pickle that object, along with a marker so that the unpickler will recognize it as a persistent ID.

To unpickle external objects, the unpickler must have a custom *persistent_load()* method that takes a persistent ID object and returns the referenced object.

Here is a comprehensive example presenting how persistent ID can be used to pickle external objects by reference.

```
# Simple example presenting how persistent ID can be used to pickle
# external objects by reference.

import pickle
import sqlite3
from collections import namedtuple

# Simple class representing a record in our database.
MemoRecord = namedtuple("MemoRecord", "key, task")

class DBPickler(pickle.Pickler):

    def persistent_id(self, obj):
        # Instead of pickling MemoRecord as a regular class instance, we emit a
        # persistent ID.
        if isinstance(obj, MemoRecord):
            # Here, our persistent ID is simply a tuple, containing a tag and a
            # key, which refers to a specific record in the database.
            return ("MemoRecord", obj.key)
        else:
            # If obj does not have a persistent ID, return None. This means obj
            # needs to be pickled as usual.
            return None


class DBUnpickler(pickle.Unpickler):

    def __init__(self, file, connection):
        super().__init__(file)
        self.connection = connection

    def persistent_load(self, pid):
        # This method is invoked whenever a persistent ID is encountered.
        # Here, pid is the tuple returned by DBPickler.
        cursor = self.connection.cursor()
        type_tag, key_id = pid
        if type_tag == "MemoRecord":
            # Fetch the referenced record from the database and return it.
            cursor.execute("SELECT * FROM memos WHERE key=?", (str(key_id),))
            key, task = cursor.fetchone()
            return MemoRecord(key, task)
        else:
            # Always raises an error if you cannot return the correct object.
            # Otherwise, the unpickler will think None is the object referenced
            # by the persistent ID.
            raise pickle.UnpicklingError("unsupported persistent object")


def main():
    import io
```

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```
    import pprint

    # Initialize and populate our database.
    conn = sqlite3.connect(":memory:")
    cursor = conn.cursor()
    cursor.execute("CREATE TABLE memos(key INTEGER PRIMARY KEY, task TEXT)")
    tasks = (
        'give food to fish',
        'prepare group meeting',
        'fight with a zebra',
        )
    for task in tasks:
        cursor.execute("INSERT INTO memos VALUES(NULL, ?)", (task,))

    # Fetch the records to be pickled.
    cursor.execute("SELECT * FROM memos")
    memos = [MemoRecord(key, task) for key, task in cursor]
    # Save the records using our custom DBPickler.
    file = io.BytesIO()
    DBPickler(file).dump(memos)

    print("Pickled records:")
    pprint.pprint(memos)

    # Update a record, just for good measure.
    cursor.execute("UPDATE memos SET task='learn italian' WHERE key=1")

    # Load the records from the pickle data stream.
    file.seek(0)
    memos = DBUnpickler(file, conn).load()

    print("Unpickled records:")
    pprint.pprint(memos)


if __name__ == '__main__':
    main()
```

Dispatch Tables

If one wants to customize pickling of some classes without disturbing any other code which depends on pickling, then one can create a pickler with a private dispatch table.

The global dispatch table managed by the *copyreg* module is available as `copyreg.dispatch_table`. Therefore, one may choose to use a modified copy of `copyreg.dispatch_table` as a private dispatch table.

For example

```
f = io.BytesIO()
p = pickle.Pickler(f)
p.dispatch_table = copyreg.dispatch_table.copy()
p.dispatch_table[SomeClass] = reduce_SomeClass
```

creates an instance of *pickle.Pickler* with a private dispatch table which handles the `SomeClass` class specially. Alternatively, the code

```
class MyPickler(pickle.Pickler):
    dispatch_table = copyreg.dispatch_table.copy()
    dispatch_table[SomeClass] = reduce_SomeClass
f = io.BytesIO()
p = MyPickler(f)
```

does the same, but all instances of `MyPickler` will by default share the same dispatch table. The equivalent code using the *copyreg* module is

```
copyreg.pickle(SomeClass, reduce_SomeClass)
f = io.BytesIO()
p = pickle.Pickler(f)
```

Handling Stateful Objects

Here's an example that shows how to modify pickling behavior for a class. The `TextReader` class opens a text file, and returns the line number and line contents each time its `readline()` method is called. If a `TextReader` instance is pickled, all attributes *except* the file object member are saved. When the instance is unpickled, the file is reopened, and reading resumes from the last location. The *__setstate__()* and *__getstate__()* methods are used to implement this behavior.

```
class TextReader:
    """Print and number lines in a text file."""

    def __init__(self, filename):
        self.filename = filename
        self.file = open(filename)
        self.lineno = 0

    def readline(self):
        self.lineno += 1
        line = self.file.readline()
        if not line:
            return None
        if line.endswith('\n'):
            line = line[:-1]
        return "%i: %s" % (self.lineno, line)

    def __getstate__(self):
        # Copy the object's state from self.__dict__ which contains
        # all our instance attributes. Always use the dict.copy()
        # method to avoid modifying the original state.
        state = self.__dict__.copy()
        # Remove the unpicklable entries.
        del state['file']
        return state

    def __setstate__(self, state):
        # Restore instance attributes (i.e., filename and lineno).
        self.__dict__.update(state)
        # Restore the previously opened file's state. To do so, we need to
        # reopen it and read from it until the line count is restored.
        file = open(self.filename)
        for _ in range(self.lineno):
            file.readline()
```

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```
        # Finally, save the file.
        self.file = file
```

A sample usage might be something like this:

```
>>> reader = TextReader("hello.txt")
>>> reader.readline()
'1: Hello world!'
>>> reader.readline()
'2: I am line number two.'
>>> new_reader = pickle.loads(pickle.dumps(reader))
>>> new_reader.readline()
'3: Goodbye!'
```

12.1.6 Restricting Globals

By default, unpickling will import any class or function that it finds in the pickle data. For many applications, this behaviour is unacceptable as it permits the unpickler to import and invoke arbitrary code. Just consider what this hand-crafted pickle data stream does when loaded:

```
>>> import pickle
>>> pickle.loads(b"cos\nsystem\n(S'echo hello world'\ntR.")
hello world
0
```

In this example, the unpickler imports the *os.system()* function and then apply the string argument "echo hello world". Although this example is inoffensive, it is not difficult to imagine one that could damage your system.

For this reason, you may want to control what gets unpickled by customizing *Unpickler.find_class()*. Unlike its name suggests, *Unpickler.find_class()* is called whenever a global (i.e., a class or a function) is requested. Thus it is possible to either completely forbid globals or restrict them to a safe subset.

Here is an example of an unpickler allowing only few safe classes from the *builtins* module to be loaded:

```
import builtins
import io
import pickle

safe_builtins = {
    'range',
    'complex',
    'set',
    'frozenset',
    'slice',
}

class RestrictedUnpickler(pickle.Unpickler):

    def find_class(self, module, name):
        # Only allow safe classes from builtins.
        if module == "builtins" and name in safe_builtins:
            return getattr(builtins, name)
        # Forbid everything else.
        raise pickle.UnpicklingError("global '%s.%s' is forbidden" %
```

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```
                                    (module, name))

def restricted_loads(s):
    """Helper function analogous to pickle.loads()."""
    return RestrictedUnpickler(io.BytesIO(s)).load()
```

A sample usage of our unpickler working has intended:

```
>>> restricted_loads(pickle.dumps([1, 2, range(15)]))
[1, 2, range(0, 15)]
>>> restricted_loads(b"cos\nsystem\n(S'echo hello world'\ntR.")
Traceback (most recent call last):
  ...
pickle.UnpicklingError: global 'os.system' is forbidden
>>> restricted_loads(b'cbuiltins\neval\n'
...                  b'(S\'getattr(__import__("os"), "system")'
...                  b'("echo hello world")\'\ntR.')
Traceback (most recent call last):
  ...
pickle.UnpicklingError: global 'builtins.eval' is forbidden
```

As our examples shows, you have to be careful with what you allow to be unpickled. Therefore if security is a concern, you may want to consider alternatives such as the marshalling API in *xmlrpc.client* or third-party solutions.

12.1.7 Performance

Recent versions of the pickle protocol (from protocol 2 and upwards) feature efficient binary encodings for several common features and built-in types. Also, the *pickle* module has a transparent optimizer written in C.

12.1.8 Examples

For the simplest code, use the *dump()* and *load()* functions.

```
import pickle

# An arbitrary collection of objects supported by pickle.
data = {
    'a': [1, 2.0, 3, 4+6j],
    'b': ("character string", b"byte string"),
    'c': {None, True, False}
}

with open('data.pickle', 'wb') as f:
    # Pickle the 'data' dictionary using the highest protocol available.
    pickle.dump(data, f, pickle.HIGHEST_PROTOCOL)
```

The following example reads the resulting pickled data.

```
import pickle

with open('data.pickle', 'rb') as f:
    # The protocol version used is detected automatically, so we do not
```

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```
    # have to specify it.
    data = pickle.load(f)
```

See also:

Module *copyreg* Pickle interface constructor registration for extension types.

Module *pickletools* Tools for working with and analyzing pickled data.

Module *shelve* Indexed databases of objects; uses *pickle*.

Module *copy* Shallow and deep object copying.

Module *marshal* High-performance serialization of built-in types.

12.2 copyreg — Register pickle support functions

Source code: Lib/copyreg.py

The *copyreg* module offers a way to define functions used while pickling specific objects. The *pickle* and *copy* modules use those functions when pickling/copying those objects. The module provides configuration information about object constructors which are not classes. Such constructors may be factory functions or class instances.

copyreg.**constructor**(*object*)
: Declares *object* to be a valid constructor. If *object* is not callable (and hence not valid as a constructor), raises *TypeError*.

copyreg.**pickle**(*type*, *function*, *constructor=None*)
: Declares that *function* should be used as a "reduction" function for objects of type *type*. *function* should return either a string or a tuple containing two or three elements.

  The optional *constructor* parameter, if provided, is a callable object which can be used to reconstruct the object when called with the tuple of arguments returned by *function* at pickling time. *TypeError* will be raised if *object* is a class or *constructor* is not callable.

  See the *pickle* module for more details on the interface expected of *function* and *constructor*. Note that the *dispatch_table* attribute of a pickler object or subclass of *pickle.Pickler* can also be used for declaring reduction functions.

12.2.1 Example

The example below would like to show how to register a pickle function and how it will be used:

```
>>> import copyreg, copy, pickle
>>> class C(object):
...     def __init__(self, a):
...         self.a = a
...
>>> def pickle_c(c):
...     print("pickling a C instance...")
...     return C, (c.a,)
...
>>> copyreg.pickle(C, pickle_c)
>>> c = C(1)
```

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```
>>> d = copy.copy(c)
pickling a C instance...
>>> p = pickle.dumps(c)
pickling a C instance...
```

12.3 shelve — Python object persistence

Source code: Lib/shelve.py

A "shelf" is a persistent, dictionary-like object. The difference with "dbm" databases is that the values (not the keys!) in a shelf can be essentially arbitrary Python objects — anything that the *pickle* module can handle. This includes most class instances, recursive data types, and objects containing lots of shared sub-objects. The keys are ordinary strings.

shelve.open(*filename*, *flag='c'*, *protocol=None*, *writeback=False*)

Open a persistent dictionary. The filename specified is the base filename for the underlying database. As a side-effect, an extension may be added to the filename and more than one file may be created. By default, the underlying database file is opened for reading and writing. The optional *flag* parameter has the same interpretation as the *flag* parameter of *dbm.open()*.

By default, version 3 pickles are used to serialize values. The version of the pickle protocol can be specified with the *protocol* parameter.

Because of Python semantics, a shelf cannot know when a mutable persistent-dictionary entry is modified. By default modified objects are written *only* when assigned to the shelf (see *Example*). If the optional *writeback* parameter is set to `True`, all entries accessed are also cached in memory, and written back on *sync()* and *close()*; this can make it handier to mutate mutable entries in the persistent dictionary, but, if many entries are accessed, it can consume vast amounts of memory for the cache, and it can make the close operation very slow since all accessed entries are written back (there is no way to determine which accessed entries are mutable, nor which ones were actually mutated).

Note: Do not rely on the shelf being closed automatically; always call *close()* explicitly when you don't need it any more, or use *shelve.open()* as a context manager:

```
with shelve.open('spam') as db:
    db['eggs'] = 'eggs'
```

Warning: Because the *shelve* module is backed by *pickle*, it is insecure to load a shelf from an untrusted source. Like with pickle, loading a shelf can execute arbitrary code.

Shelf objects support all methods supported by dictionaries. This eases the transition from dictionary based scripts to those requiring persistent storage.

Two additional methods are supported:

Shelf.sync()

Write back all entries in the cache if the shelf was opened with *writeback* set to *True*. Also empty the cache and synchronize the persistent dictionary on disk, if feasible. This is called automatically when the shelf is closed with *close()*.

`Shelf.close()`
Synchronize and close the persistent *dict* object. Operations on a closed shelf will fail with a *ValueError*.

See also:

Persistent dictionary recipe with widely supported storage formats and having the speed of native dictionaries.

12.3.1 Restrictions

- The choice of which database package will be used (such as *dbm.ndbm* or *dbm.gnu*) depends on which interface is available. Therefore it is not safe to open the database directly using *dbm*. The database is also (unfortunately) subject to the limitations of *dbm*, if it is used — this means that (the pickled representation of) the objects stored in the database should be fairly small, and in rare cases key collisions may cause the database to refuse updates.
- The *shelve* module does not support *concurrent* read/write access to shelved objects. (Multiple simultaneous read accesses are safe.) When a program has a shelf open for writing, no other program should have it open for reading or writing. Unix file locking can be used to solve this, but this differs across Unix versions and requires knowledge about the database implementation used.

`class shelve.Shelf(`*dict*, *protocol=None*, *writeback=False*, *keyencoding='utf-8'*`)`
A subclass of *collections.abc.MutableMapping* which stores pickled values in the *dict* object.

By default, version 3 pickles are used to serialize values. The version of the pickle protocol can be specified with the *protocol* parameter. See the *pickle* documentation for a discussion of the pickle protocols.

If the *writeback* parameter is `True`, the object will hold a cache of all entries accessed and write them back to the *dict* at sync and close times. This allows natural operations on mutable entries, but can consume much more memory and make sync and close take a long time.

The *keyencoding* parameter is the encoding used to encode keys before they are used with the underlying dict.

A *Shelf* object can also be used as a context manager, in which case it will be automatically closed when the `with` block ends.

Changed in version 3.2: Added the *keyencoding* parameter; previously, keys were always encoded in UTF-8.

Changed in version 3.4: Added context manager support.

`class shelve.BsdDbShelf(`*dict*, *protocol=None*, *writeback=False*, *keyencoding='utf-8'*`)`
A subclass of *Shelf* which exposes `first()`, `next()`, `previous()`, `last()` and `set_location()` which are available in the third-party `bsddb` module from pybsddb but not in other database modules. The *dict* object passed to the constructor must support those methods. This is generally accomplished by calling one of `bsddb.hashopen()`, `bsddb.btopen()` or `bsddb.rnopen()`. The optional *protocol*, *writeback*, and *keyencoding* parameters have the same interpretation as for the *Shelf* class.

`class shelve.DbfilenameShelf(`*filename*, *flag='c'*, *protocol=None*, *writeback=False*`)`
A subclass of *Shelf* which accepts a *filename* instead of a dict-like object. The underlying file will be opened using *dbm.open()*. By default, the file will be created and opened for both read and write. The optional *flag* parameter has the same interpretation as for the *open()* function. The optional *protocol* and *writeback* parameters have the same interpretation as for the *Shelf* class.

12.3.2 Example

To summarize the interface (`key` is a string, `data` is an arbitrary object):

```
import shelve

d = shelve.open(filename)  # open -- file may get suffix added by low-level
                           # library

d[key] = data              # store data at key (overwrites old data if
                           # using an existing key)
data = d[key]              # retrieve a COPY of data at key (raise KeyError
                           # if no such key)
del d[key]                 # delete data stored at key (raises KeyError
                           # if no such key)

flag = key in d            # true if the key exists
klist = list(d.keys())     # a list of all existing keys (slow!)

# as d was opened WITHOUT writeback=True, beware:
d['xx'] = [0, 1, 2]        # this works as expected, but...
d['xx'].append(3)          # *this doesn't!* -- d['xx'] is STILL [0, 1, 2]!

# having opened d without writeback=True, you need to code carefully:
temp = d['xx']             # extracts the copy
temp.append(5)             # mutates the copy
d['xx'] = temp             # stores the copy right back, to persist it

# or, d=shelve.open(filename,writeback=True) would let you just code
# d['xx'].append(5) and have it work as expected, BUT it would also
# consume more memory and make the d.close() operation slower.

d.close()                  # close it
```

See also:

Module *dbm* Generic interface to `dbm`-style databases.

Module *pickle* Object serialization used by *shelve*.

12.4 `marshal` — Internal Python object serialization

This module contains functions that can read and write Python values in a binary format. The format is specific to Python, but independent of machine architecture issues (e.g., you can write a Python value to a file on a PC, transport the file to a Sun, and read it back there). Details of the format are undocumented on purpose; it may change between Python versions (although it rarely does).[1]

This is not a general "persistence" module. For general persistence and transfer of Python objects through RPC calls, see the modules *pickle* and *shelve*. The *marshal* module exists mainly to support reading and writing the "pseudo-compiled" code for Python modules of `.pyc` files. Therefore, the Python maintainers reserve the right to modify the marshal format in backward incompatible ways should the need arise. If you're serializing and de-serializing Python objects, use the *pickle* module instead – the performance is

[1] The name of this module stems from a bit of terminology used by the designers of Modula-3 (amongst others), who use the term "marshalling" for shipping of data around in a self-contained form. Strictly speaking, "to marshal" means to convert some data from internal to external form (in an RPC buffer for instance) and "unmarshalling" for the reverse process.

comparable, version independence is guaranteed, and pickle supports a substantially wider range of objects than marshal.

Warning: The *marshal* module is not intended to be secure against erroneous or maliciously constructed data. Never unmarshal data received from an untrusted or unauthenticated source.

Not all Python object types are supported; in general, only objects whose value is independent from a particular invocation of Python can be written and read by this module. The following types are supported: booleans, integers, floating point numbers, complex numbers, strings, bytes, bytearrays, tuples, lists, sets, frozensets, dictionaries, and code objects, where it should be understood that tuples, lists, sets, frozensets and dictionaries are only supported as long as the values contained therein are themselves supported. The singletons *None*, *Ellipsis* and *StopIteration* can also be marshalled and unmarshalled. For format *version* lower than 3, recursive lists, sets and dictionaries cannot be written (see below).

There are functions that read/write files as well as functions operating on bytes-like objects.

The module defines these functions:

`marshal.dump`(*value*, *file*[, *version*])
Write the value on the open file. The value must be a supported type. The file must be a writeable *binary file*.

If the value has (or contains an object that has) an unsupported type, a *ValueError* exception is raised — but garbage data will also be written to the file. The object will not be properly read back by *load()*.

The *version* argument indicates the data format that `dump` should use (see below).

`marshal.load`(*file*)
Read one value from the open file and return it. If no valid value is read (e.g. because the data has a different Python version's incompatible marshal format), raise *EOFError*, *ValueError* or *TypeError*. The file must be a readable *binary file*.

Note: If an object containing an unsupported type was marshalled with *dump()*, *load()* will substitute `None` for the unmarshallable type.

`marshal.dumps`(*value*[, *version*])
Return the bytes object that would be written to a file by `dump(value, file)`. The value must be a supported type. Raise a *ValueError* exception if value has (or contains an object that has) an unsupported type.

The *version* argument indicates the data format that `dumps` should use (see below).

`marshal.loads`(*bytes*)
Convert the *bytes-like object* to a value. If no valid value is found, raise *EOFError*, *ValueError* or *TypeError*. Extra bytes in the input are ignored.

In addition, the following constants are defined:

`marshal.version`
Indicates the format that the module uses. Version 0 is the historical format, version 1 shares interned strings and version 2 uses a binary format for floating point numbers. Version 3 adds support for object instancing and recursion. The current version is 4.

12.5 dbm — Interfaces to Unix "databases"

Source code: Lib/dbm/__init__.py

---

dbm is a generic interface to variants of the DBM database — *dbm.gnu* or *dbm.ndbm*. If none of these modules is installed, the slow-but-simple implementation in module *dbm.dumb* will be used. There is a third party interface to the Oracle Berkeley DB.

exception dbm.error

A tuple containing the exceptions that can be raised by each of the supported modules, with a unique exception also named *dbm.error* as the first item — the latter is used when *dbm.error* is raised.

dbm.whichdb(*filename*)

This function attempts to guess which of the several simple database modules available — *dbm.gnu*, *dbm.ndbm* or *dbm.dumb* — should be used to open a given file.

Returns one of the following values: `None` if the file can't be opened because it's unreadable or doesn't exist; the empty string (`''`) if the file's format can't be guessed; or a string containing the required module name, such as `'dbm.ndbm'` or `'dbm.gnu'`.

dbm.open(*file*, *flag='r'*, *mode=0o666*)

Open the database file *file* and return a corresponding object.

If the database file already exists, the *whichdb()* function is used to determine its type and the appropriate module is used; if it does not exist, the first module listed above that can be imported is used.

The optional *flag* argument can be:

Value	Meaning
`'r'`	Open existing database for reading only (default)
`'w'`	Open existing database for reading and writing
`'c'`	Open database for reading and writing, creating it if it doesn't exist
`'n'`	Always create a new, empty database, open for reading and writing

The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal `0o666` (and will be modified by the prevailing umask).

The object returned by *open()* supports the same basic functionality as dictionaries; keys and their corresponding values can be stored, retrieved, and deleted, and the `in` operator and the `keys()` method are available, as well as `get()` and `setdefault()`.

Changed in version 3.2: `get()` and `setdefault()` are now available in all database modules.

Key and values are always stored as bytes. This means that when strings are used they are implicitly converted to the default encoding before being stored.

These objects also support being used in a `with` statement, which will automatically close them when done.

Changed in version 3.4: Added native support for the context management protocol to the objects returned by *open()*.

The following example records some hostnames and a corresponding title, and then prints out the contents of the database:

```
import dbm

# Open database, creating it if necessary.
```

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```
with dbm.open('cache', 'c') as db:

    # Record some values
    db[b'hello'] = b'there'
    db['www.python.org'] = 'Python Website'
    db['www.cnn.com'] = 'Cable News Network'

    # Note that the keys are considered bytes now.
    assert db[b'www.python.org'] == b'Python Website'
    # Notice how the value is now in bytes.
    assert db['www.cnn.com'] == b'Cable News Network'

    # Often-used methods of the dict interface work too.
    print(db.get('python.org', b'not present'))

    # Storing a non-string key or value will raise an exception (most
    # likely a TypeError).
    db['www.yahoo.com'] = 4

# db is automatically closed when leaving the with statement.
```

See also:

Module *shelve* Persistence module which stores non-string data.

The individual submodules are described in the following sections.

12.5.1 dbm.gnu — GNU's reinterpretation of dbm

Source code: Lib/dbm/gnu.py

This module is quite similar to the *dbm* module, but uses the GNU library `gdbm` instead to provide some additional functionality. Please note that the file formats created by *dbm.gnu* and *dbm.ndbm* are incompatible.

The *dbm.gnu* module provides an interface to the GNU DBM library. `dbm.gnu.gdbm` objects behave like mappings (dictionaries), except that keys and values are always converted to bytes before storing. Printing a `gdbm` object doesn't print the keys and values, and the `items()` and `values()` methods are not supported.

exception dbm.gnu.error

Raised on *dbm.gnu*-specific errors, such as I/O errors. *KeyError* is raised for general mapping errors like specifying an incorrect key.

dbm.gnu.open(*filename*[, *flag*[, *mode*]])

Open a `gdbm` database and return a `gdbm` object. The *filename* argument is the name of the database file.

The optional *flag* argument can be:

Value	Meaning
`'r'`	Open existing database for reading only (default)
`'w'`	Open existing database for reading and writing
`'c'`	Open database for reading and writing, creating it if it doesn't exist
`'n'`	Always create a new, empty database, open for reading and writing

The following additional characters may be appended to the flag to control how the database is opened:

Value	Meaning
`'f'`	Open the database in fast mode. Writes to the database will not be synchronized.
`'s'`	Synchronized mode. This will cause changes to the database to be immediately written to the file.
`'u'`	Do not lock database.

Not all flags are valid for all versions of `gdbm`. The module constant `open_flags` is a string of supported flag characters. The exception *error* is raised if an invalid flag is specified.

The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal `0o666`.

In addition to the dictionary-like methods, `gdbm` objects have the following methods:

`gdbm.firstkey()`
It's possible to loop over every key in the database using this method and the *nextkey()* method. The traversal is ordered by `gdbm`'s internal hash values, and won't be sorted by the key values. This method returns the starting key.

`gdbm.nextkey(`*key*`)`
Returns the key that follows *key* in the traversal. The following code prints every key in the database `db`, without having to create a list in memory that contains them all:

```
k = db.firstkey()
while k != None:
    print(k)
    k = db.nextkey(k)
```

`gdbm.reorganize()`
If you have carried out a lot of deletions and would like to shrink the space used by the `gdbm` file, this routine will reorganize the database. `gdbm` objects will not shorten the length of a database file except by using this reorganization; otherwise, deleted file space will be kept and reused as new (key, value) pairs are added.

`gdbm.sync()`
When the database has been opened in fast mode, this method forces any unwritten data to be written to the disk.

`gdbm.close()`
Close the `gdbm` database.

12.5.2 `dbm.ndbm` — Interface based on ndbm

Source code: Lib/dbm/ndbm.py

The *dbm.ndbm* module provides an interface to the Unix "(n)dbm" library. Dbm objects behave like mappings (dictionaries), except that keys and values are always stored as bytes. Printing a `dbm` object doesn't print the keys and values, and the `items()` and `values()` methods are not supported.

This module can be used with the "classic" ndbm interface or the GNU GDBM compatibility interface. On Unix, the **configure** script will attempt to locate the appropriate header file to simplify building this module.

`exception dbm.ndbm.error`
Raised on *dbm.ndbm*-specific errors, such as I/O errors. *KeyError* is raised for general mapping errors like specifying an incorrect key.

dbm.ndbm.library
: Name of the ndbm implementation library used.

dbm.ndbm.open(*filename*[, *flag*[, *mode*]])
: Open a dbm database and return a ndbm object. The *filename* argument is the name of the database file (without the .dir or .pag extensions).

  The optional *flag* argument must be one of these values:

Value	Meaning
'r'	Open existing database for reading only (default)
'w'	Open existing database for reading and writing
'c'	Open database for reading and writing, creating it if it doesn't exist
'n'	Always create a new, empty database, open for reading and writing

  The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal 0o666 (and will be modified by the prevailing umask).

  In addition to the dictionary-like methods, ndbm objects provide the following method:

  ndbm.close()
  : Close the ndbm database.

12.5.3 dbm.dumb — Portable DBM implementation

Source code: Lib/dbm/dumb.py

Note: The *dbm.dumb* module is intended as a last resort fallback for the *dbm* module when a more robust module is not available. The *dbm.dumb* module is not written for speed and is not nearly as heavily used as the other database modules.

The *dbm.dumb* module provides a persistent dictionary-like interface which is written entirely in Python. Unlike other modules such as *dbm.gnu* no external library is required. As with other persistent mappings, the keys and values are always stored as bytes.

The module defines the following:

exception dbm.dumb.error
: Raised on *dbm.dumb*-specific errors, such as I/O errors. *KeyError* is raised for general mapping errors like specifying an incorrect key.

dbm.dumb.open(*filename*[, *flag*[, *mode*]])
: Open a dumbdbm database and return a dumbdbm object. The *filename* argument is the basename of the database file (without any specific extensions). When a dumbdbm database is created, files with .dat and .dir extensions are created.

  The optional *flag* argument supports only the semantics of 'c' and 'n' values. Other values will default to database being always opened for update, and will be created if it does not exist.

  The optional *mode* argument is the Unix mode of the file, used only when the database has to be created. It defaults to octal 0o666 (and will be modified by the prevailing umask).

  Warning: It is possible to crash the Python interpreter when loading a database with a sufficiently large/complex entry due to stack depth limitations in Python's AST compiler.

Changed in version 3.5: *open()* always creates a new database when the flag has the value `'n'`.

Deprecated since version 3.6, will be removed in version 3.8: Creating database in `'r'` and `'w'` modes. Modifying database in `'r'` mode.

In addition to the methods provided by the *collections.abc.MutableMapping* class, `dumbdbm` objects provide the following methods:

`dumbdbm.sync()`
Synchronize the on-disk directory and data files. This method is called by the `Shelve.sync()` method.

`dumbdbm.close()`
Close the `dumbdbm` database.

12.6 `sqlite3` — DB-API 2.0 interface for SQLite databases

Source code: Lib/sqlite3/

SQLite is a C library that provides a lightweight disk-based database that doesn't require a separate server process and allows accessing the database using a nonstandard variant of the SQL query language. Some applications can use SQLite for internal data storage. It's also possible to prototype an application using SQLite and then port the code to a larger database such as PostgreSQL or Oracle.

The sqlite3 module was written by Gerhard Häring. It provides a SQL interface compliant with the DB-API 2.0 specification described by **PEP 249**.

To use the module, you must first create a *Connection* object that represents the database. Here the data will be stored in the `example.db` file:

```
import sqlite3
conn = sqlite3.connect('example.db')
```

You can also supply the special name `:memory:` to create a database in RAM.

Once you have a *Connection*, you can create a *Cursor* object and call its *execute()* method to perform SQL commands:

```
c = conn.cursor()

# Create table
c.execute('''CREATE TABLE stocks
             (date text, trans text, symbol text, qty real, price real)''')

# Insert a row of data
c.execute("INSERT INTO stocks VALUES ('2006-01-05','BUY','RHAT',100,35.14)")

# Save (commit) the changes
conn.commit()

# We can also close the connection if we are done with it.
# Just be sure any changes have been committed or they will be lost.
conn.close()
```

The data you've saved is persistent and is available in subsequent sessions:

```
import sqlite3
conn = sqlite3.connect('example.db')
c = conn.cursor()
```

Usually your SQL operations will need to use values from Python variables. You shouldn't assemble your query using Python's string operations because doing so is insecure; it makes your program vulnerable to an SQL injection attack (see https://xkcd.com/327/ for humorous example of what can go wrong).

Instead, use the DB-API's parameter substitution. Put `?` as a placeholder wherever you want to use a value, and then provide a tuple of values as the second argument to the cursor's *execute()* method. (Other database modules may use a different placeholder, such as `%s` or `:1`.) For example:

```
# Never do this -- insecure!
symbol = 'RHAT'
c.execute("SELECT * FROM stocks WHERE symbol = '%s'" % symbol)

# Do this instead
t = ('RHAT',)
c.execute('SELECT * FROM stocks WHERE symbol=?', t)
print(c.fetchone())

# Larger example that inserts many records at a time
purchases = [('2006-03-28', 'BUY', 'IBM', 1000, 45.00),
             ('2006-04-05', 'BUY', 'MSFT', 1000, 72.00),
             ('2006-04-06', 'SELL', 'IBM', 500, 53.00),
            ]
c.executemany('INSERT INTO stocks VALUES (?,?,?,?,?)', purchases)
```

To retrieve data after executing a SELECT statement, you can either treat the cursor as an *iterator*, call the cursor's *fetchone()* method to retrieve a single matching row, or call *fetchall()* to get a list of the matching rows.

This example uses the iterator form:

```
>>> for row in c.execute('SELECT * FROM stocks ORDER BY price'):
        print(row)

('2006-01-05', 'BUY', 'RHAT', 100, 35.14)
('2006-03-28', 'BUY', 'IBM', 1000, 45.0)
('2006-04-06', 'SELL', 'IBM', 500, 53.0)
('2006-04-05', 'BUY', 'MSFT', 1000, 72.0)
```

See also:

https://github.com/ghaering/pysqlite The pysqlite web page – sqlite3 is developed externally under the name "pysqlite".

https://www.sqlite.org The SQLite web page; the documentation describes the syntax and the available data types for the supported SQL dialect.

https://www.w3schools.com/sql/ Tutorial, reference and examples for learning SQL syntax.

PEP 249 - Database API Specification 2.0 PEP written by Marc-André Lemburg.

12.6.1 Module functions and constants

`sqlite3.version`
The version number of this module, as a string. This is not the version of the SQLite library.

sqlite3.**version_info**
The version number of this module, as a tuple of integers. This is not the version of the SQLite library.

sqlite3.**sqlite_version**
The version number of the run-time SQLite library, as a string.

sqlite3.**sqlite_version_info**
The version number of the run-time SQLite library, as a tuple of integers.

sqlite3.**PARSE_DECLTYPES**
This constant is meant to be used with the *detect_types* parameter of the *connect()* function.

Setting it makes the *sqlite3* module parse the declared type for each column it returns. It will parse out the first word of the declared type, i. e. for "integer primary key", it will parse out "integer", or for "number(10)" it will parse out "number". Then for that column, it will look into the converters dictionary and use the converter function registered for that type there.

sqlite3.**PARSE_COLNAMES**
This constant is meant to be used with the *detect_types* parameter of the *connect()* function.

Setting this makes the SQLite interface parse the column name for each column it returns. It will look for a string formed [mytype] in there, and then decide that 'mytype' is the type of the column. It will try to find an entry of 'mytype' in the converters dictionary and then use the converter function found there to return the value. The column name found in *Cursor.description* is only the first word of the column name, i. e. if you use something like `'as "x [datetime]"'` in your SQL, then we will parse out everything until the first blank for the column name: the column name would simply be "x".

sqlite3.**connect**(*database*[, *timeout*, *detect_types*, *isolation_level*, *check_same_thread*, *factory*, *cached_statements*, *uri*])
Opens a connection to the SQLite database file *database*. By default returns a *Connection* object, unless a custom *factory* is given.

database is a *path-like object* giving the pathname (absolute or relative to the current working directory) of the database file to be opened. You can use `":memory:"` to open a database connection to a database that resides in RAM instead of on disk.

When a database is accessed by multiple connections, and one of the processes modifies the database, the SQLite database is locked until that transaction is committed. The *timeout* parameter specifies how long the connection should wait for the lock to go away until raising an exception. The default for the timeout parameter is 5.0 (five seconds).

For the *isolation_level* parameter, please see the *isolation_level* property of *Connection* objects.

SQLite natively supports only the types TEXT, INTEGER, REAL, BLOB and NULL. If you want to use other types you must add support for them yourself. The *detect_types* parameter and the using custom **converters** registered with the module-level *register_converter()* function allow you to easily do that.

detect_types defaults to 0 (i. e. off, no type detection), you can set it to any combination of *PARSE_DECLTYPES* and *PARSE_COLNAMES* to turn type detection on.

By default, *check_same_thread* is *True* and only the creating thread may use the connection. If set *False*, the returned connection may be shared across multiple threads. When using multiple threads with the same connection writing operations should be serialized by the user to avoid data corruption.

By default, the *sqlite3* module uses its *Connection* class for the connect call. You can, however, subclass the *Connection* class and make *connect()* use your class instead by providing your class for the *factory* parameter.

Consult the section *SQLite and Python types* of this manual for details.

The *sqlite3* module internally uses a statement cache to avoid SQL parsing overhead. If you want to explicitly set the number of statements that are cached for the connection, you can set the *cached_statements* parameter. The currently implemented default is to cache 100 statements.

If *uri* is true, *database* is interpreted as a URI. This allows you to specify options. For example, to open a database in read-only mode you can use:

```
db = sqlite3.connect('file:path/to/database?mode=ro', uri=True)
```

More information about this feature, including a list of recognized options, can be found in the SQLite URI documentation.

Changed in version 3.4: Added the *uri* parameter.

Changed in version 3.7: *database* can now also be a *path-like object*, not only a string.

sqlite3.register_converter(*typename*, *callable*)
Registers a callable to convert a bytestring from the database into a custom Python type. The callable will be invoked for all database values that are of the type *typename*. Confer the parameter *detect_types* of the *connect()* function for how the type detection works. Note that *typename* and the name of the type in your query are matched in case-insensitive manner.

sqlite3.register_adapter(*type*, *callable*)
Registers a callable to convert the custom Python type *type* into one of SQLite's supported types. The callable *callable* accepts as single parameter the Python value, and must return a value of the following types: int, float, str or bytes.

sqlite3.complete_statement(*sql*)
Returns *True* if the string *sql* contains one or more complete SQL statements terminated by semicolons. It does not verify that the SQL is syntactically correct, only that there are no unclosed string literals and the statement is terminated by a semicolon.

This can be used to build a shell for SQLite, as in the following example:

```
# A minimal SQLite shell for experiments

import sqlite3

con = sqlite3.connect(":memory:")
con.isolation_level = None
cur = con.cursor()

buffer = ""

print("Enter your SQL commands to execute in sqlite3.")
print("Enter a blank line to exit.")

while True:
    line = input()
    if line == "":
        break
    buffer += line
    if sqlite3.complete_statement(buffer):
        try:
            buffer = buffer.strip()
            cur.execute(buffer)

            if buffer.lstrip().upper().startswith("SELECT"):
                print(cur.fetchall())
        except sqlite3.Error as e:
```

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```
            print("An error occurred:", e.args[0])
        buffer = ""

con.close()
```

sqlite3.**enable_callback_tracebacks**(*flag*)
By default you will not get any tracebacks in user-defined functions, aggregates, converters, authorizer callbacks etc. If you want to debug them, you can call this function with *flag* set to `True`. Afterwards, you will get tracebacks from callbacks on `sys.stderr`. Use *False* to disable the feature again.

12.6.2 Connection Objects

class sqlite3.**Connection**
A SQLite database connection has the following attributes and methods:

isolation_level
Get or set the current isolation level. *None* for autocommit mode or one of "DEFERRED", "IMMEDIATE" or "EXCLUSIVE". See section *Controlling Transactions* for a more detailed explanation.

in_transaction
True if a transaction is active (there are uncommitted changes), *False* otherwise. Read-only attribute.

New in version 3.2.

cursor(*factory=Cursor*)
The cursor method accepts a single optional parameter *factory*. If supplied, this must be a callable returning an instance of *Cursor* or its subclasses.

commit()
This method commits the current transaction. If you don't call this method, anything you did since the last call to `commit()` is not visible from other database connections. If you wonder why you don't see the data you've written to the database, please check you didn't forget to call this method.

rollback()
This method rolls back any changes to the database since the last call to *commit()*.

close()
This closes the database connection. Note that this does not automatically call *commit()*. If you just close your database connection without calling *commit()* first, your changes will be lost!

execute(*sql*[, *parameters*])
This is a nonstandard shortcut that creates a cursor object by calling the *cursor()* method, calls the cursor's *execute()* method with the *parameters* given, and returns the cursor.

executemany(*sql*[, *parameters*])
This is a nonstandard shortcut that creates a cursor object by calling the *cursor()* method, calls the cursor's *executemany()* method with the *parameters* given, and returns the cursor.

executescript(*sql_script*)
This is a nonstandard shortcut that creates a cursor object by calling the *cursor()* method, calls the cursor's *executescript()* method with the given *sql_script*, and returns the cursor.

create_function(*name*, *num_params*, *func*)
Creates a user-defined function that you can later use from within SQL statements under the function name *name*. *num_params* is the number of parameters the function accepts (if *num_params*

is -1, the function may take any number of arguments), and *func* is a Python callable that is called as the SQL function.

The function can return any of the types supported by SQLite: bytes, str, int, float and `None`.

Example:

```
import sqlite3
import hashlib

def md5sum(t):
    return hashlib.md5(t).hexdigest()

con = sqlite3.connect(":memory:")
con.create_function("md5", 1, md5sum)
cur = con.cursor()
cur.execute("select md5(?)", (b"foo",))
print(cur.fetchone()[0])
```

create_aggregate(*name*, *num_params*, *aggregate_class*)

Creates a user-defined aggregate function.

The aggregate class must implement a `step` method, which accepts the number of parameters *num_params* (if *num_params* is -1, the function may take any number of arguments), and a `finalize` method which will return the final result of the aggregate.

The `finalize` method can return any of the types supported by SQLite: bytes, str, int, float and `None`.

Example:

```
import sqlite3

class MySum:
    def __init__(self):
        self.count = 0

    def step(self, value):
        self.count += value

    def finalize(self):
        return self.count

con = sqlite3.connect(":memory:")
con.create_aggregate("mysum", 1, MySum)
cur = con.cursor()
cur.execute("create table test(i)")
cur.execute("insert into test(i) values (1)")
cur.execute("insert into test(i) values (2)")
cur.execute("select mysum(i) from test")
print(cur.fetchone()[0])
```

create_collation(*name*, *callable*)

Creates a collation with the specified *name* and *callable*. The callable will be passed two string arguments. It should return -1 if the first is ordered lower than the second, 0 if they are ordered equal and 1 if the first is ordered higher than the second. Note that this controls sorting (ORDER BY in SQL) so your comparisons don't affect other SQL operations.

Note that the callable will get its parameters as Python bytestrings, which will normally be encoded in UTF-8.

The following example shows a custom collation that sorts "the wrong way":

```
import sqlite3

def collate_reverse(string1, string2):
    if string1 == string2:
        return 0
    elif string1 < string2:
        return 1
    else:
        return -1

con = sqlite3.connect(":memory:")
con.create_collation("reverse", collate_reverse)

cur = con.cursor()
cur.execute("create table test(x)")
cur.executemany("insert into test(x) values (?)", [("a",), ("b",)])
cur.execute("select x from test order by x collate reverse")
for row in cur:
    print(row)
con.close()
```

To remove a collation, call `create_collation` with `None` as callable:

```
con.create_collation("reverse", None)
```

interrupt()
You can call this method from a different thread to abort any queries that might be executing on the connection. The query will then abort and the caller will get an exception.

set_authorizer(*authorizer_callback*)
This routine registers a callback. The callback is invoked for each attempt to access a column of a table in the database. The callback should return `SQLITE_OK` if access is allowed, `SQLITE_DENY` if the entire SQL statement should be aborted with an error and `SQLITE_IGNORE` if the column should be treated as a NULL value. These constants are available in the *sqlite3* module.

The first argument to the callback signifies what kind of operation is to be authorized. The second and third argument will be arguments or *None* depending on the first argument. The 4th argument is the name of the database ("main", "temp", etc.) if applicable. The 5th argument is the name of the inner-most trigger or view that is responsible for the access attempt or *None* if this access attempt is directly from input SQL code.

Please consult the SQLite documentation about the possible values for the first argument and the meaning of the second and third argument depending on the first one. All necessary constants are available in the *sqlite3* module.

set_progress_handler(*handler*, *n*)
This routine registers a callback. The callback is invoked for every *n* instructions of the SQLite virtual machine. This is useful if you want to get called from SQLite during long-running operations, for example to update a GUI.

If you want to clear any previously installed progress handler, call the method with *None* for *handler*.

Returning a non-zero value from the handler function will terminate the currently executing query and cause it to raise an *OperationalError* exception.

set_trace_callback(*trace_callback*)
Registers *trace_callback* to be called for each SQL statement that is actually executed by the

SQLite backend.

The only argument passed to the callback is the statement (as string) that is being executed. The return value of the callback is ignored. Note that the backend does not only run statements passed to the *Cursor.execute()* methods. Other sources include the transaction management of the Python module and the execution of triggers defined in the current database.

Passing *None* as *trace_callback* will disable the trace callback.

New in version 3.3.

enable_load_extension(*enabled*)

This routine allows/disallows the SQLite engine to load SQLite extensions from shared libraries. SQLite extensions can define new functions, aggregates or whole new virtual table implementations. One well-known extension is the fulltext-search extension distributed with SQLite.

Loadable extensions are disabled by default. See[1].

New in version 3.2.

```
import sqlite3

con = sqlite3.connect(":memory:")

# enable extension loading
con.enable_load_extension(True)

# Load the fulltext search extension
con.execute("select load_extension('./fts3.so')")

# alternatively you can load the extension using an API call:
# con.load_extension("./fts3.so")

# disable extension loading again
con.enable_load_extension(False)

# example from SQLite wiki
con.execute("create virtual table recipe using fts3(name, ingredients)")
con.executescript("""
    insert into recipe (name, ingredients) values ('broccoli stew', 'broccoli peppers␣
↪cheese tomatoes');
    insert into recipe (name, ingredients) values ('pumpkin stew', 'pumpkin onions␣
↪garlic celery');
    insert into recipe (name, ingredients) values ('broccoli pie', 'broccoli cheese␣
↪onions flour');
    insert into recipe (name, ingredients) values ('pumpkin pie', 'pumpkin sugar flour␣
↪butter');
    """)
for row in con.execute("select rowid, name, ingredients from recipe where name match 'pie
↪'"):
    print(row)
```

load_extension(*path*)

This routine loads a SQLite extension from a shared library. You have to enable extension loading with *enable_load_extension()* before you can use this routine.

Loadable extensions are disabled by default. See[1].

[1] The sqlite3 module is not built with loadable extension support by default, because some platforms (notably Mac OS X) have SQLite libraries which are compiled without this feature. To get loadable extension support, you must pass –enable-loadable-sqlite-extensions to configure.

New in version 3.2.

row_factory

You can change this attribute to a callable that accepts the cursor and the original row as a tuple and will return the real result row. This way, you can implement more advanced ways of returning results, such as returning an object that can also access columns by name.

Example:

```
import sqlite3

def dict_factory(cursor, row):
    d = {}
    for idx, col in enumerate(cursor.description):
        d[col[0]] = row[idx]
    return d

con = sqlite3.connect(":memory:")
con.row_factory = dict_factory
cur = con.cursor()
cur.execute("select 1 as a")
print(cur.fetchone()["a"])
```

If returning a tuple doesn't suffice and you want name-based access to columns, you should consider setting *row_factory* to the highly-optimized *sqlite3.Row* type. *Row* provides both index-based and case-insensitive name-based access to columns with almost no memory overhead. It will probably be better than your own custom dictionary-based approach or even a db_row based solution.

text_factory

Using this attribute you can control what objects are returned for the TEXT data type. By default, this attribute is set to *str* and the *sqlite3* module will return Unicode objects for TEXT. If you want to return bytestrings instead, you can set it to *bytes*.

You can also set it to any other callable that accepts a single bytestring parameter and returns the resulting object.

See the following example code for illustration:

```
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()

AUSTRIA = "\xd6sterreich"

# by default, rows are returned as Unicode
cur.execute("select ?", (AUSTRIA,))
row = cur.fetchone()
assert row[0] == AUSTRIA

# but we can make sqlite3 always return bytestrings ...
con.text_factory = bytes
cur.execute("select ?", (AUSTRIA,))
row = cur.fetchone()
assert type(row[0]) is bytes
# the bytestrings will be encoded in UTF-8, unless you stored garbage in the
# database ...
assert row[0] == AUSTRIA.encode("utf-8")
```

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```
# we can also implement a custom text_factory ...
# here we implement one that appends "foo" to all strings
con.text_factory = lambda x: x.decode("utf-8") + "foo"
cur.execute("select ?", ("bar",))
row = cur.fetchone()
assert row[0] == "barfoo"
```

total_changes
Returns the total number of database rows that have been modified, inserted, or deleted since the database connection was opened.

iterdump()
Returns an iterator to dump the database in an SQL text format. Useful when saving an in-memory database for later restoration. This function provides the same capabilities as the `.dump` command in the **sqlite3** shell.

Example:

```
# Convert file existing_db.db to SQL dump file dump.sql
import sqlite3

con = sqlite3.connect('existing_db.db')
with open('dump.sql', 'w') as f:
    for line in con.iterdump():
        f.write('%s\n' % line)
```

backup(*target*, ***, *pages=0*, *progress=None*, *name="main"*, *sleep=0.250*)
This method makes a backup of a SQLite database even while it's being accessed by other clients, or concurrently by the same connection. The copy will be written into the mandatory argument *target*, that must be another *Connection* instance.

By default, or when *pages* is either `0` or a negative integer, the entire database is copied in a single step; otherwise the method performs a loop copying up to *pages* pages at a time.

If *progress* is specified, it must either be `None` or a callable object that will be executed at each iteration with three integer arguments, respectively the *status* of the last iteration, the *remaining* number of pages still to be copied and the *total* number of pages.

The *name* argument specifies the database name that will be copied: it must be a string containing either `"main"`, the default, to indicate the main database, `"temp"` to indicate the temporary database or the name specified after the `AS` keyword in an `ATTACH DATABASE` statement for an attached database.

The *sleep* argument specifies the number of seconds to sleep by between successive attempts to backup remaining pages, can be specified either as an integer or a floating point value.

Example 1, copy an existing database into another:

```
import sqlite3

def progress(status, remaining, total):
    print(f'Copied {total-remaining} of {total} pages...')

con = sqlite3.connect('existing_db.db')
with sqlite3.connect('backup.db') as bck:
    con.backup(bck, pages=1, progress=progress)
```

Example 2, copy an existing database into a transient copy:

```
import sqlite3

source = sqlite3.connect('existing_db.db')
dest = sqlite3.connect(':memory:')
source.backup(dest)
```

Availability: SQLite 3.6.11 or higher

New in version 3.7.

12.6.3 Cursor Objects

class sqlite3.Cursor

A *Cursor* instance has the following attributes and methods.

execute(*sql*[, *parameters*])

Executes an SQL statement. The SQL statement may be parameterized (i. e. placeholders instead of SQL literals). The *sqlite3* module supports two kinds of placeholders: question marks (qmark style) and named placeholders (named style).

Here's an example of both styles:

```
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.execute("create table people (name_last, age)")

who = "Yeltsin"
age = 72

# This is the qmark style:
cur.execute("insert into people values (?, ?)", (who, age))

# And this is the named style:
cur.execute("select * from people where name_last=:who and age=:age", {"who": who, "age
↪": age})

print(cur.fetchone())
```

execute() will only execute a single SQL statement. If you try to execute more than one statement with it, it will raise a *Warning*. Use *executescript()* if you want to execute multiple SQL statements with one call.

executemany(*sql*, *seq_of_parameters*)

Executes an SQL command against all parameter sequences or mappings found in the sequence *seq_of_parameters*. The *sqlite3* module also allows using an *iterator* yielding parameters instead of a sequence.

```
import sqlite3

class IterChars:
    def __init__(self):
        self.count = ord('a')

    def __iter__(self):
        return self
```

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```
    def __next__(self):
        if self.count > ord('z'):
            raise StopIteration
        self.count += 1
        return (chr(self.count - 1),) # this is a 1-tuple

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.execute("create table characters(c)")

theIter = IterChars()
cur.executemany("insert into characters(c) values (?)", theIter)

cur.execute("select c from characters")
print(cur.fetchall())
```

Here's a shorter example using a *generator*:

```
import sqlite3
import string

def char_generator():
    for c in string.ascii_lowercase:
        yield (c,)

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.execute("create table characters(c)")

cur.executemany("insert into characters(c) values (?)", char_generator())

cur.execute("select c from characters")
print(cur.fetchall())
```

executescript(*sql_script*)

This is a nonstandard convenience method for executing multiple SQL statements at once. It issues a `COMMIT` statement first, then executes the SQL script it gets as a parameter.

sql_script can be an instance of *str*.

Example:

```
import sqlite3

con = sqlite3.connect(":memory:")
cur = con.cursor()
cur.executescript("""
    create table person(
        firstname,
        lastname,
        age
    );

    create table book(
        title,
        author,
```

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```
        published
    );

    insert into book(title, author, published)
    values (
        'Dirk Gently''s Holistic Detective Agency',
        'Douglas Adams',
        1987
    );
    """)
```

fetchone()
Fetches the next row of a query result set, returning a single sequence, or *None* when no more data is available.

fetchmany(*size=cursor.arraysize*)
Fetches the next set of rows of a query result, returning a list. An empty list is returned when no more rows are available.

The number of rows to fetch per call is specified by the *size* parameter. If it is not given, the cursor's arraysize determines the number of rows to be fetched. The method should try to fetch as many rows as indicated by the size parameter. If this is not possible due to the specified number of rows not being available, fewer rows may be returned.

Note there are performance considerations involved with the *size* parameter. For optimal performance, it is usually best to use the arraysize attribute. If the *size* parameter is used, then it is best for it to retain the same value from one *fetchmany()* call to the next.

fetchall()
Fetches all (remaining) rows of a query result, returning a list. Note that the cursor's arraysize attribute can affect the performance of this operation. An empty list is returned when no rows are available.

close()
Close the cursor now (rather than whenever `__del__` is called).

The cursor will be unusable from this point forward; a *ProgrammingError* exception will be raised if any operation is attempted with the cursor.

rowcount
Although the *Cursor* class of the *sqlite3* module implements this attribute, the database engine's own support for the determination of "rows affected"/"rows selected" is quirky.

For *executemany()* statements, the number of modifications are summed up into *rowcount*.

As required by the Python DB API Spec, the *rowcount* attribute "is -1 in case no `executeXX()` has been performed on the cursor or the rowcount of the last operation is not determinable by the interface". This includes `SELECT` statements because we cannot determine the number of rows a query produced until all rows were fetched.

With SQLite versions before 3.6.5, *rowcount* is set to 0 if you make a `DELETE FROM table` without any condition.

lastrowid
This read-only attribute provides the rowid of the last modified row. It is only set if you issued an `INSERT` or a `REPLACE` statement using the *execute()* method. For operations other than `INSERT` or `REPLACE` or when *executemany()* is called, *lastrowid* is set to *None*.

If the `INSERT` or `REPLACE` statement failed to insert the previous successful rowid is returned.

Changed in version 3.6: Added support for the `REPLACE` statement.

arraysize
Read/write attribute that controls the number of rows returned by *fetchmany()*. The default value is 1 which means a single row would be fetched per call.

description
This read-only attribute provides the column names of the last query. To remain compatible with the Python DB API, it returns a 7-tuple for each column where the last six items of each tuple are *None*.

It is set for SELECT statements without any matching rows as well.

connection
This read-only attribute provides the SQLite database *Connection* used by the *Cursor* object. A *Cursor* object created by calling *con.cursor()* will have a *connection* attribute that refers to *con*:

```
>>> con = sqlite3.connect(":memory:")
>>> cur = con.cursor()
>>> cur.connection == con
True
```

12.6.4 Row Objects

class sqlite3.Row
A *Row* instance serves as a highly optimized *row_factory* for *Connection* objects. It tries to mimic a tuple in most of its features.

It supports mapping access by column name and index, iteration, representation, equality testing and *len()*.

If two *Row* objects have exactly the same columns and their members are equal, they compare equal.

keys()
This method returns a list of column names. Immediately after a query, it is the first member of each tuple in *Cursor.description*.

Changed in version 3.5: Added support of slicing.

Let's assume we initialize a table as in the example given above:

```
conn = sqlite3.connect(":memory:")
c = conn.cursor()
c.execute('''create table stocks
(date text, trans text, symbol text,
 qty real, price real)''')
c.execute("""insert into stocks
          values ('2006-01-05','BUY','RHAT',100,35.14)""")
conn.commit()
c.close()
```

Now we plug *Row* in:

```
>>> conn.row_factory = sqlite3.Row
>>> c = conn.cursor()
>>> c.execute('select * from stocks')
<sqlite3.Cursor object at 0x7f4e7dd8fa80>
>>> r = c.fetchone()
>>> type(r)
<class 'sqlite3.Row'>
```

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```
>>> tuple(r)
('2006-01-05', 'BUY', 'RHAT', 100.0, 35.14)
>>> len(r)
5
>>> r[2]
'RHAT'
>>> r.keys()
['date', 'trans', 'symbol', 'qty', 'price']
>>> r['qty']
100.0
>>> for member in r:
...     print(member)
...
2006-01-05
BUY
RHAT
100.0
35.14
```

12.6.5 Exceptions

exception sqlite3.Warning
A subclass of *Exception*.

exception sqlite3.Error
The base class of the other exceptions in this module. It is a subclass of *Exception*.

exception sqlite3.DatabaseError
Exception raised for errors that are related to the database.

exception sqlite3.IntegrityError
Exception raised when the relational integrity of the database is affected, e.g. a foreign key check fails. It is a subclass of *DatabaseError*.

exception sqlite3.ProgrammingError
Exception raised for programming errors, e.g. table not found or already exists, syntax error in the SQL statement, wrong number of parameters specified, etc. It is a subclass of *DatabaseError*.

exception sqlite3.OperationalError
Exception raised for errors that are related to the database's operation and not necessarily under the control of the programmer, e.g. an unexpected disconnect occurs, the data source name is not found, a transaction could not be processed, etc. It is a subclass of *DatabaseError*.

12.6.6 SQLite and Python types

Introduction

SQLite natively supports the following types: `NULL`, `INTEGER`, `REAL`, `TEXT`, `BLOB`.

The following Python types can thus be sent to SQLite without any problem:

Python type	SQLite type
None	NULL
int	INTEGER
float	REAL
str	TEXT
bytes	BLOB

This is how SQLite types are converted to Python types by default:

SQLite type	Python type
NULL	*None*
INTEGER	*int*
REAL	*float*
TEXT	depends on *text_factory*, *str* by default
BLOB	*bytes*

The type system of the *sqlite3* module is extensible in two ways: you can store additional Python types in a SQLite database via object adaptation, and you can let the *sqlite3* module convert SQLite types to different Python types via converters.

Using adapters to store additional Python types in SQLite databases

As described before, SQLite supports only a limited set of types natively. To use other Python types with SQLite, you must **adapt** them to one of the sqlite3 module's supported types for SQLite: one of NoneType, int, float, str, bytes.

There are two ways to enable the *sqlite3* module to adapt a custom Python type to one of the supported ones.

Letting your object adapt itself

This is a good approach if you write the class yourself. Let's suppose you have a class like this:

```
class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y
```

Now you want to store the point in a single SQLite column. First you'll have to choose one of the supported types first to be used for representing the point. Let's just use str and separate the coordinates using a semicolon. Then you need to give your class a method `__conform__(self, protocol)` which must return the converted value. The parameter *protocol* will be `PrepareProtocol`.

```
import sqlite3

class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y

    def __conform__(self, protocol):
        if protocol is sqlite3.PrepareProtocol:
            return "%f;%f" % (self.x, self.y)
```

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```
con = sqlite3.connect(":memory:")
cur = con.cursor()

p = Point(4.0, -3.2)
cur.execute("select ?", (p,))
print(cur.fetchone()[0])
```

Registering an adapter callable

The other possibility is to create a function that converts the type to the string representation and register the function with *register_adapter()*.

```
import sqlite3

class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y

def adapt_point(point):
    return "%f;%f" % (point.x, point.y)

sqlite3.register_adapter(Point, adapt_point)

con = sqlite3.connect(":memory:")
cur = con.cursor()

p = Point(4.0, -3.2)
cur.execute("select ?", (p,))
print(cur.fetchone()[0])
```

The *sqlite3* module has two default adapters for Python's built-in *datetime.date* and *datetime.datetime* types. Now let's suppose we want to store *datetime.datetime* objects not in ISO representation, but as a Unix timestamp.

```
import sqlite3
import datetime
import time

def adapt_datetime(ts):
    return time.mktime(ts.timetuple())

sqlite3.register_adapter(datetime.datetime, adapt_datetime)

con = sqlite3.connect(":memory:")
cur = con.cursor()

now = datetime.datetime.now()
cur.execute("select ?", (now,))
print(cur.fetchone()[0])
```

Converting SQLite values to custom Python types

Writing an adapter lets you send custom Python types to SQLite. But to make it really useful we need to make the Python to SQLite to Python roundtrip work.

Enter converters.

Let's go back to the `Point` class. We stored the x and y coordinates separated via semicolons as strings in SQLite.

First, we'll define a converter function that accepts the string as a parameter and constructs a `Point` object from it.

Note: Converter functions **always** get called with a *bytes* object, no matter under which data type you sent the value to SQLite.

```
def convert_point(s):
    x, y = map(float, s.split(b";"))
    return Point(x, y)
```

Now you need to make the *sqlite3* module know that what you select from the database is actually a point. There are two ways of doing this:

- Implicitly via the declared type
- Explicitly via the column name

Both ways are described in section *Module functions and constants*, in the entries for the constants *PARSE_DECLTYPES* and *PARSE_COLNAMES*.

The following example illustrates both approaches.

```
import sqlite3

class Point:
    def __init__(self, x, y):
        self.x, self.y = x, y

    def __repr__(self):
        return "(%f;%f)" % (self.x, self.y)

def adapt_point(point):
    return ("%f;%f" % (point.x, point.y)).encode('ascii')

def convert_point(s):
    x, y = list(map(float, s.split(b";")))
    return Point(x, y)

# Register the adapter
sqlite3.register_adapter(Point, adapt_point)

# Register the converter
sqlite3.register_converter("point", convert_point)

p = Point(4.0, -3.2)

#########################
# 1) Using declared types
con = sqlite3.connect(":memory:", detect_types=sqlite3.PARSE_DECLTYPES)
cur = con.cursor()
cur.execute("create table test(p point)")

cur.execute("insert into test(p) values (?)", (p,))
cur.execute("select p from test")
```

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```
print("with declared types:", cur.fetchone()[0])
cur.close()
con.close()

#######################
# 1) Using column names
con = sqlite3.connect(":memory:", detect_types=sqlite3.PARSE_COLNAMES)
cur = con.cursor()
cur.execute("create table test(p)")

cur.execute("insert into test(p) values (?)", (p,))
cur.execute('select p as "p [point]" from test')
print("with column names:", cur.fetchone()[0])
cur.close()
con.close()
```

Default adapters and converters

There are default adapters for the date and datetime types in the datetime module. They will be sent as ISO dates/ISO timestamps to SQLite.

The default converters are registered under the name "date" for *datetime.date* and under the name "timestamp" for *datetime.datetime*.

This way, you can use date/timestamps from Python without any additional fiddling in most cases. The format of the adapters is also compatible with the experimental SQLite date/time functions.

The following example demonstrates this.

```
import sqlite3
import datetime

con = sqlite3.connect(":memory:", detect_types=sqlite3.PARSE_DECLTYPES|sqlite3.PARSE_COLNAMES)
cur = con.cursor()
cur.execute("create table test(d date, ts timestamp)")

today = datetime.date.today()
now = datetime.datetime.now()

cur.execute("insert into test(d, ts) values (?, ?)", (today, now))
cur.execute("select d, ts from test")
row = cur.fetchone()
print(today, "=>", row[0], type(row[0]))
print(now, "=>", row[1], type(row[1]))

cur.execute('select current_date as "d [date]", current_timestamp as "ts [timestamp]"')
row = cur.fetchone()
print("current_date", row[0], type(row[0]))
print("current_timestamp", row[1], type(row[1]))
```

If a timestamp stored in SQLite has a fractional part longer than 6 numbers, its value will be truncated to microsecond precision by the timestamp converter.

12.6.7 Controlling Transactions

By default, the *sqlite3* module opens transactions implicitly before a Data Modification Language (DML) statement (i.e. INSERT/UPDATE/DELETE/REPLACE).

You can control which kind of BEGIN statements sqlite3 implicitly executes (or none at all) via the *isolation_level* parameter to the *connect()* call, or via the isolation_level property of connections.

If you want **autocommit mode**, then set isolation_level to None.

Otherwise leave it at its default, which will result in a plain "BEGIN" statement, or set it to one of SQLite's supported isolation levels: "DEFERRED", "IMMEDIATE" or "EXCLUSIVE".

The current transaction state is exposed through the *Connection.in_transaction* attribute of the connection object.

Changed in version 3.6: *sqlite3* used to implicitly commit an open transaction before DDL statements. This is no longer the case.

12.6.8 Using sqlite3 efficiently

Using shortcut methods

Using the nonstandard execute(), executemany() and executescript() methods of the *Connection* object, your code can be written more concisely because you don't have to create the (often superfluous) *Cursor* objects explicitly. Instead, the *Cursor* objects are created implicitly and these shortcut methods return the cursor objects. This way, you can execute a SELECT statement and iterate over it directly using only a single call on the *Connection* object.

```
import sqlite3

persons = [
    ("Hugo", "Boss"),
    ("Calvin", "Klein")
    ]

con = sqlite3.connect(":memory:")

# Create the table
con.execute("create table person(firstname, lastname)")

# Fill the table
con.executemany("insert into person(firstname, lastname) values (?, ?)", persons)

# Print the table contents
for row in con.execute("select firstname, lastname from person"):
    print(row)

print("I just deleted", con.execute("delete from person").rowcount, "rows")
```

Accessing columns by name instead of by index

One useful feature of the *sqlite3* module is the built-in *sqlite3.Row* class designed to be used as a row factory.

Rows wrapped with this class can be accessed both by index (like tuples) and case-insensitively by name:

```
import sqlite3

con = sqlite3.connect(":memory:")
con.row_factory = sqlite3.Row

cur = con.cursor()
cur.execute("select 'John' as name, 42 as age")
for row in cur:
    assert row[0] == row["name"]
    assert row["name"] == row["nAmE"]
    assert row[1] == row["age"]
    assert row[1] == row["AgE"]
```

Using the connection as a context manager

Connection objects can be used as context managers that automatically commit or rollback transactions. In the event of an exception, the transaction is rolled back; otherwise, the transaction is committed:

```
import sqlite3

con = sqlite3.connect(":memory:")
con.execute("create table person (id integer primary key, firstname varchar unique)")

# Successful, con.commit() is called automatically afterwards
with con:
    con.execute("insert into person(firstname) values (?)", ("Joe",))

# con.rollback() is called after the with block finishes with an exception, the
# exception is still raised and must be caught
try:
    with con:
        con.execute("insert into person(firstname) values (?)", ("Joe",))
except sqlite3.IntegrityError:
    print("couldn't add Joe twice")
```

12.6.9 Common issues

Multithreading

Older SQLite versions had issues with sharing connections between threads. That's why the Python module disallows sharing connections and cursors between threads. If you still try to do so, you will get an exception at runtime.

The only exception is calling the *interrupt()* method, which only makes sense to call from a different thread.

CHAPTER

THIRTEEN

DATA COMPRESSION AND ARCHIVING

The modules described in this chapter support data compression with the zlib, gzip, bzip2 and lzma algorithms, and the creation of ZIP- and tar-format archives. See also *Archiving operations* provided by the *shutil* module.

13.1 zlib — Compression compatible with gzip

For applications that require data compression, the functions in this module allow compression and decompression, using the zlib library. The zlib library has its own home page at http://www.zlib.net. There are known incompatibilities between the Python module and versions of the zlib library earlier than 1.1.3; 1.1.3 has a security vulnerability, so we recommend using 1.1.4 or later.

zlib's functions have many options and often need to be used in a particular order. This documentation doesn't attempt to cover all of the permutations; consult the zlib manual at http://www.zlib.net/manual.html for authoritative information.

For reading and writing `.gz` files see the *gzip* module.

The available exception and functions in this module are:

exception zlib.error
Exception raised on compression and decompression errors.

zlib.adler32(*data*[, *value*])
Computes an Adler-32 checksum of *data*. (An Adler-32 checksum is almost as reliable as a CRC32 but can be computed much more quickly.) The result is an unsigned 32-bit integer. If *value* is present, it is used as the starting value of the checksum; otherwise, a default value of 1 is used. Passing in *value* allows computing a running checksum over the concatenation of several inputs. The algorithm is not cryptographically strong, and should not be used for authentication or digital signatures. Since the algorithm is designed for use as a checksum algorithm, it is not suitable for use as a general hash algorithm.

Changed in version 3.0: Always returns an unsigned value. To generate the same numeric value across all Python versions and platforms, use `adler32(data) & 0xffffffff`.

zlib.compress(*data*, *level=-1*)
Compresses the bytes in *data*, returning a bytes object containing compressed data. *level* is an integer from `0` to `9` or `-1` controlling the level of compression; `1` (Z_BEST_SPEED) is fastest and produces the least compression, `9` (Z_BEST_COMPRESSION) is slowest and produces the most. `0` (Z_NO_COMPRESSION) is no compression. The default value is `-1` (Z_DEFAULT_COMPRESSION). Z_DEFAULT_COMPRESSION represents a default compromise between speed and compression (currently equivalent to level 6). Raises the *error* exception if any error occurs.

Changed in version 3.6: *level* can now be used as a keyword parameter.

zlib.compressobj(*level=-1*, *method=DEFLATED*, *wbits=MAX_WBITS*, *memLevel=DEF_MEM_LEVEL*, *strategy=Z_DEFAULT_STRATEGY*[, *zdict*])

Returns a compression object, to be used for compressing data streams that won't fit into memory at once.

level is the compression level – an integer from `0` to `9` or `-1`. A value of `1` (Z_BEST_SPEED) is fastest and produces the least compression, while a value of `9` (Z_BEST_COMPRESSION) is slowest and produces the most. `0` (Z_NO_COMPRESSION) is no compression. The default value is `-1` (Z_DEFAULT_COMPRESSION). Z_DEFAULT_COMPRESSION represents a default compromise between speed and compression (currently equivalent to level 6).

method is the compression algorithm. Currently, the only supported value is `DEFLATED`.

The *wbits* argument controls the size of the history buffer (or the "window size") used when compressing data, and whether a header and trailer is included in the output. It can take several ranges of values, defaulting to `15` (MAX_WBITS):

- +9 to +15: The base-two logarithm of the window size, which therefore ranges between 512 and 32768. Larger values produce better compression at the expense of greater memory usage. The resulting output will include a zlib-specific header and trailer.
- −9 to −15: Uses the absolute value of *wbits* as the window size logarithm, while producing a raw output stream with no header or trailing checksum.
- +25 to +31 = 16 + (9 to 15): Uses the low 4 bits of the value as the window size logarithm, while including a basic **gzip** header and trailing checksum in the output.

The *memLevel* argument controls the amount of memory used for the internal compression state. Valid values range from `1` to `9`. Higher values use more memory, but are faster and produce smaller output.

strategy is used to tune the compression algorithm. Possible values are `Z_DEFAULT_STRATEGY`, `Z_FILTERED`, `Z_HUFFMAN_ONLY`, `Z_RLE` (zlib 1.2.0.1) and `Z_FIXED` (zlib 1.2.2.2).

zdict is a predefined compression dictionary. This is a sequence of bytes (such as a *bytes* object) containing subsequences that are expected to occur frequently in the data that is to be compressed. Those subsequences that are expected to be most common should come at the end of the dictionary.

Changed in version 3.3: Added the *zdict* parameter and keyword argument support.

zlib.crc32(*data*[, *value*])

Computes a CRC (Cyclic Redundancy Check) checksum of *data*. The result is an unsigned 32-bit integer. If *value* is present, it is used as the starting value of the checksum; otherwise, a default value of 0 is used. Passing in *value* allows computing a running checksum over the concatenation of several inputs. The algorithm is not cryptographically strong, and should not be used for authentication or digital signatures. Since the algorithm is designed for use as a checksum algorithm, it is not suitable for use as a general hash algorithm.

Changed in version 3.0: Always returns an unsigned value. To generate the same numeric value across all Python versions and platforms, use `crc32(data) & 0xffffffff`.

zlib.decompress(*data*, *wbits=MAX_WBITS*, *bufsize=DEF_BUF_SIZE*)

Decompresses the bytes in *data*, returning a bytes object containing the uncompressed data. The *wbits* parameter depends on the format of *data*, and is discussed further below. If *bufsize* is given, it is used as the initial size of the output buffer. Raises the *error* exception if any error occurs.

The *wbits* parameter controls the size of the history buffer (or "window size"), and what header and trailer format is expected. It is similar to the parameter for *compressobj()*, but accepts more ranges of values:

- +8 to +15: The base-two logarithm of the window size. The input must include a zlib header and trailer.
- 0: Automatically determine the window size from the zlib header. Only supported since zlib 1.2.3.5.
- −8 to −15: Uses the absolute value of *wbits* as the window size logarithm. The input must be a raw stream with no header or trailer.
- +24 to +31 = 16 + (8 to 15): Uses the low 4 bits of the value as the window size logarithm. The input must include a gzip header and trailer.
- +40 to +47 = 32 + (8 to 15): Uses the low 4 bits of the value as the window size logarithm, and automatically accepts either the zlib or gzip format.

When decompressing a stream, the window size must not be smaller than the size originally used to compress the stream; using a too-small value may result in an *error* exception. The default *wbits* value corresponds to the largest window size and requires a zlib header and trailer to be included.

bufsize is the initial size of the buffer used to hold decompressed data. If more space is required, the buffer size will be increased as needed, so you don't have to get this value exactly right; tuning it will only save a few calls to `malloc()`.

Changed in version 3.6: *wbits* and *bufsize* can be used as keyword arguments.

`zlib.decompressobj`(*wbits=MAX_WBITS*[, *zdict*])
Returns a decompression object, to be used for decompressing data streams that won't fit into memory at once.

The *wbits* parameter controls the size of the history buffer (or the "window size"), and what header and trailer format is expected. It has the same meaning as *described for decompress()*.

The *zdict* parameter specifies a predefined compression dictionary. If provided, this must be the same dictionary as was used by the compressor that produced the data that is to be decompressed.

Note: If *zdict* is a mutable object (such as a *bytearray*), you must not modify its contents between the call to *decompressobj()* and the first call to the decompressor's `decompress()` method.

Changed in version 3.3: Added the *zdict* parameter.

Compression objects support the following methods:

`Compress.compress`(*data*)
Compress *data*, returning a bytes object containing compressed data for at least part of the data in *data*. This data should be concatenated to the output produced by any preceding calls to the *compress()* method. Some input may be kept in internal buffers for later processing.

`Compress.flush`([*mode*])
All pending input is processed, and a bytes object containing the remaining compressed output is returned. *mode* can be selected from the constants `Z_NO_FLUSH`, `Z_PARTIAL_FLUSH`, `Z_SYNC_FLUSH`, `Z_FULL_FLUSH`, `Z_BLOCK` (zlib 1.2.3.4), or `Z_FINISH`, defaulting to `Z_FINISH`. Except `Z_FINISH`, all constants allow compressing further bytestrings of data, while `Z_FINISH` finishes the compressed stream and prevents compressing any more data. After calling *flush()* with *mode* set to `Z_FINISH`, the *compress()* method cannot be called again; the only realistic action is to delete the object.

`Compress.copy`()
Returns a copy of the compression object. This can be used to efficiently compress a set of data that share a common initial prefix.

Decompression objects support the following methods and attributes:

Decompress.**unused_data**
A bytes object which contains any bytes past the end of the compressed data. That is, this remains `b""` until the last byte that contains compression data is available. If the whole bytestring turned out to contain compressed data, this is `b""`, an empty bytes object.

Decompress.**unconsumed_tail**
A bytes object that contains any data that was not consumed by the last *decompress()* call because it exceeded the limit for the uncompressed data buffer. This data has not yet been seen by the zlib machinery, so you must feed it (possibly with further data concatenated to it) back to a subsequent *decompress()* method call in order to get correct output.

Decompress.**eof**
A boolean indicating whether the end of the compressed data stream has been reached.

This makes it possible to distinguish between a properly-formed compressed stream, and an incomplete or truncated one.

New in version 3.3.

Decompress.**decompress**(*data*, *max_length=0*)
Decompress *data*, returning a bytes object containing the uncompressed data corresponding to at least part of the data in *string*. This data should be concatenated to the output produced by any preceding calls to the *decompress()* method. Some of the input data may be preserved in internal buffers for later processing.

If the optional parameter *max_length* is non-zero then the return value will be no longer than *max_length*. This may mean that not all of the compressed input can be processed; and unconsumed data will be stored in the attribute *unconsumed_tail*. This bytestring must be passed to a subsequent call to *decompress()* if decompression is to continue. If *max_length* is zero then the whole input is decompressed, and *unconsumed_tail* is empty.

Changed in version 3.6: *max_length* can be used as a keyword argument.

Decompress.**flush**([*length*])
All pending input is processed, and a bytes object containing the remaining uncompressed output is returned. After calling *flush()*, the *decompress()* method cannot be called again; the only realistic action is to delete the object.

The optional parameter *length* sets the initial size of the output buffer.

Decompress.**copy**()
Returns a copy of the decompression object. This can be used to save the state of the decompressor midway through the data stream in order to speed up random seeks into the stream at a future point.

Information about the version of the zlib library in use is available through the following constants:

zlib.**ZLIB_VERSION**
The version string of the zlib library that was used for building the module. This may be different from the zlib library actually used at runtime, which is available as *ZLIB_RUNTIME_VERSION*.

zlib.**ZLIB_RUNTIME_VERSION**
The version string of the zlib library actually loaded by the interpreter.

New in version 3.3.

See also:

Module *gzip* Reading and writing **gzip**-format files.

http://www.zlib.net The zlib library home page.

http://www.zlib.net/manual.html The zlib manual explains the semantics and usage of the library's many functions.

13.2 gzip — Support for gzip files

Source code: Lib/gzip.py

This module provides a simple interface to compress and decompress files just like the GNU programs **gzip** and **gunzip** would.

The data compression is provided by the *zlib* module.

The *gzip* module provides the *GzipFile* class, as well as the *open()*, *compress()* and *decompress()* convenience functions. The *GzipFile* class reads and writes **gzip**-format files, automatically compressing or decompressing the data so that it looks like an ordinary *file object*.

Note that additional file formats which can be decompressed by the **gzip** and **gunzip** programs, such as those produced by **compress** and **pack**, are not supported by this module.

The module defines the following items:

gzip.open(*filename*, *mode='rb'*, *compresslevel=9*, *encoding=None*, *errors=None*, *newline=None*)
Open a gzip-compressed file in binary or text mode, returning a *file object*.

The *filename* argument can be an actual filename (a *str* or *bytes* object), or an existing file object to read from or write to.

The *mode* argument can be any of `'r'`, `'rb'`, `'a'`, `'ab'`, `'w'`, `'wb'`, `'x'` or `'xb'` for binary mode, or `'rt'`, `'at'`, `'wt'`, or `'xt'` for text mode. The default is `'rb'`.

The *compresslevel* argument is an integer from 0 to 9, as for the *GzipFile* constructor.

For binary mode, this function is equivalent to the *GzipFile* constructor: `GzipFile(filename, mode, compresslevel)`. In this case, the *encoding*, *errors* and *newline* arguments must not be provided.

For text mode, a *GzipFile* object is created, and wrapped in an *io.TextIOWrapper* instance with the specified encoding, error handling behavior, and line ending(s).

Changed in version 3.3: Added support for *filename* being a file object, support for text mode, and the *encoding*, *errors* and *newline* arguments.

Changed in version 3.4: Added support for the `'x'`, `'xb'` and `'xt'` modes.

Changed in version 3.6: Accepts a *path-like object*.

class gzip.GzipFile(*filename=None*, *mode=None*, *compresslevel=9*, *fileobj=None*, *mtime=None*)
Constructor for the *GzipFile* class, which simulates most of the methods of a *file object*, with the exception of the `truncate()` method. At least one of *fileobj* and *filename* must be given a non-trivial value.

The new class instance is based on *fileobj*, which can be a regular file, an *io.BytesIO* object, or any other object which simulates a file. It defaults to `None`, in which case *filename* is opened to provide a file object.

When *fileobj* is not `None`, the *filename* argument is only used to be included in the **gzip** file header, which may include the original filename of the uncompressed file. It defaults to the filename of *fileobj*, if discernible; otherwise, it defaults to the empty string, and in this case the original filename is not included in the header.

The *mode* argument can be any of `'r'`, `'rb'`, `'a'`, `'ab'`, `'w'`, `'wb'`, `'x'`, or `'xb'`, depending on whether the file will be read or written. The default is the mode of *fileobj* if discernible; otherwise, the default is `'rb'`.

Note that the file is always opened in binary mode. To open a compressed file in text mode, use *open()* (or wrap your *GzipFile* with an *io.TextIOWrapper*).

The *compresslevel* argument is an integer from `0` to `9` controlling the level of compression; `1` is fastest and produces the least compression, and `9` is slowest and produces the most compression. `0` is no compression. The default is `9`.

The *mtime* argument is an optional numeric timestamp to be written to the last modification time field in the stream when compressing. It should only be provided in compression mode. If omitted or `None`, the current time is used. See the *mtime* attribute for more details.

Calling a *GzipFile* object's `close()` method does not close *fileobj*, since you might wish to append more material after the compressed data. This also allows you to pass an *io.BytesIO* object opened for writing as *fileobj*, and retrieve the resulting memory buffer using the *io.BytesIO* object's *getvalue()* method.

GzipFile supports the *io.BufferedIOBase* interface, including iteration and the `with` statement. Only the `truncate()` method isn't implemented.

GzipFile also provides the following method and attribute:

peek(*n*)
Read *n* uncompressed bytes without advancing the file position. At most one single read on the compressed stream is done to satisfy the call. The number of bytes returned may be more or less than requested.

Note: While calling *peek()* does not change the file position of the *GzipFile*, it may change the position of the underlying file object (e.g. if the *GzipFile* was constructed with the *fileobj* parameter).

New in version 3.2.

mtime
When decompressing, the value of the last modification time field in the most recently read header may be read from this attribute, as an integer. The initial value before reading any headers is `None`.

All **gzip** compressed streams are required to contain this timestamp field. Some programs, such as **gunzip**, make use of the timestamp. The format is the same as the return value of *time.time()* and the *st_mtime* attribute of the object returned by *os.stat()*.

Changed in version 3.1: Support for the `with` statement was added, along with the *mtime* constructor argument and *mtime* attribute.

Changed in version 3.2: Support for zero-padded and unseekable files was added.

Changed in version 3.3: The *io.BufferedIOBase.read1()* method is now implemented.

Changed in version 3.4: Added support for the `'x'` and `'xb'` modes.

Changed in version 3.5: Added support for writing arbitrary *bytes-like objects*. The *read()* method now accepts an argument of `None`.

Changed in version 3.6: Accepts a *path-like object*.

gzip.compress(*data*, *compresslevel=9*)
Compress the *data*, returning a *bytes* object containing the compressed data. *compresslevel* has the same meaning as in the *GzipFile* constructor above.

New in version 3.2.

gzip.decompress(*data*)
Decompress the *data*, returning a *bytes* object containing the uncompressed data.

New in version 3.2.

13.2.1 Examples of usage

Example of how to read a compressed file:

```
import gzip
with gzip.open('/home/joe/file.txt.gz', 'rb') as f:
    file_content = f.read()
```

Example of how to create a compressed GZIP file:

```
import gzip
content = b"Lots of content here"
with gzip.open('/home/joe/file.txt.gz', 'wb') as f:
    f.write(content)
```

Example of how to GZIP compress an existing file:

```
import gzip
import shutil
with open('/home/joe/file.txt', 'rb') as f_in:
    with gzip.open('/home/joe/file.txt.gz', 'wb') as f_out:
        shutil.copyfileobj(f_in, f_out)
```

Example of how to GZIP compress a binary string:

```
import gzip
s_in = b"Lots of content here"
s_out = gzip.compress(s_in)
```

See also:

Module *zlib* The basic data compression module needed to support the **gzip** file format.

13.3 bz2 — Support for bzip2 compression

Source code: Lib/bz2.py

This module provides a comprehensive interface for compressing and decompressing data using the bzip2 compression algorithm.

The *bz2* module contains:

- The *open()* function and *BZ2File* class for reading and writing compressed files.
- The *BZ2Compressor* and *BZ2Decompressor* classes for incremental (de)compression.
- The *compress()* and *decompress()* functions for one-shot (de)compression.

All of the classes in this module may safely be accessed from multiple threads.

13.3.1 (De)compression of files

bz2.open(*filename*, *mode='r'*, *compresslevel=9*, *encoding=None*, *errors=None*, *newline=None*)
Open a bzip2-compressed file in binary or text mode, returning a *file object*.

As with the constructor for *BZ2File*, the *filename* argument can be an actual filename (a *str* or *bytes* object), or an existing file object to read from or write to.

The *mode* argument can be any of `'r'`, `'rb'`, `'w'`, `'wb'`, `'x'`, `'xb'`, `'a'` or `'ab'` for binary mode, or `'rt'`, `'wt'`, `'xt'`, or `'at'` for text mode. The default is `'rb'`.

The *compresslevel* argument is an integer from 1 to 9, as for the *BZ2File* constructor.

For binary mode, this function is equivalent to the *BZ2File* constructor: `BZ2File(filename, mode, compresslevel=compresslevel)`. In this case, the *encoding*, *errors* and *newline* arguments must not be provided.

For text mode, a *BZ2File* object is created, and wrapped in an *io.TextIOWrapper* instance with the specified encoding, error handling behavior, and line ending(s).

New in version 3.3.

Changed in version 3.4: The `'x'` (exclusive creation) mode was added.

Changed in version 3.6: Accepts a *path-like object*.

class bz2.BZ2File(*filename*, *mode='r'*, *buffering=None*, *compresslevel=9*)

Open a bzip2-compressed file in binary mode.

If *filename* is a *str* or *bytes* object, open the named file directly. Otherwise, *filename* should be a *file object*, which will be used to read or write the compressed data.

The *mode* argument can be either `'r'` for reading (default), `'w'` for overwriting, `'x'` for exclusive creation, or `'a'` for appending. These can equivalently be given as `'rb'`, `'wb'`, `'xb'` and `'ab'` respectively.

If *filename* is a file object (rather than an actual file name), a mode of `'w'` does not truncate the file, and is instead equivalent to `'a'`.

The *buffering* argument is ignored. Its use is deprecated.

If *mode* is `'w'` or `'a'`, *compresslevel* can be a number between `1` and `9` specifying the level of compression: `1` produces the least compression, and `9` (default) produces the most compression.

If *mode* is `'r'`, the input file may be the concatenation of multiple compressed streams.

BZ2File provides all of the members specified by the *io.BufferedIOBase*, except for `detach()` and `truncate()`. Iteration and the `with` statement are supported.

BZ2File also provides the following method:

peek(*[n]*)

Return buffered data without advancing the file position. At least one byte of data will be returned (unless at EOF). The exact number of bytes returned is unspecified.

Note: While calling *peek()* does not change the file position of the *BZ2File*, it may change the position of the underlying file object (e.g. if the *BZ2File* was constructed by passing a file object for *filename*).

New in version 3.3.

Changed in version 3.1: Support for the `with` statement was added.

Changed in version 3.3: The `fileno()`, `readable()`, `seekable()`, `writable()`, `read1()` and `readinto()` methods were added.

Changed in version 3.3: Support was added for *filename* being a *file object* instead of an actual filename.

Changed in version 3.3: The `'a'` (append) mode was added, along with support for reading multi-stream files.

Changed in version 3.4: The `'x'` (exclusive creation) mode was added.

Changed in version 3.5: The *read()* method now accepts an argument of `None`.

Changed in version 3.6: Accepts a *path-like object*.

13.3.2 Incremental (de)compression

`class bz2.BZ2Compressor(`*compresslevel=9*`)`

Create a new compressor object. This object may be used to compress data incrementally. For one-shot compression, use the *compress()* function instead.

compresslevel, if given, must be a number between `1` and `9`. The default is `9`.

`compress(`*data*`)`

Provide data to the compressor object. Returns a chunk of compressed data if possible, or an empty byte string otherwise.

When you have finished providing data to the compressor, call the *flush()* method to finish the compression process.

`flush()`

Finish the compression process. Returns the compressed data left in internal buffers.

The compressor object may not be used after this method has been called.

`class bz2.BZ2Decompressor`

Create a new decompressor object. This object may be used to decompress data incrementally. For one-shot compression, use the *decompress()* function instead.

Note: This class does not transparently handle inputs containing multiple compressed streams, unlike *decompress()* and *BZ2File*. If you need to decompress a multi-stream input with *BZ2Decompressor*, you must use a new decompressor for each stream.

`decompress(`*data*, *max_length=-1*`)`

Decompress *data* (a *bytes-like object*), returning uncompressed data as bytes. Some of *data* may be buffered internally, for use in later calls to *decompress()*. The returned data should be concatenated with the output of any previous calls to *decompress()*.

If *max_length* is nonnegative, returns at most *max_length* bytes of decompressed data. If this limit is reached and further output can be produced, the *needs_input* attribute will be set to `False`. In this case, the next call to *decompress()* may provide *data* as `b''` to obtain more of the output.

If all of the input data was decompressed and returned (either because this was less than *max_length* bytes, or because *max_length* was negative), the *needs_input* attribute will be set to `True`.

Attempting to decompress data after the end of stream is reached raises an *EOFError*. Any data found after the end of the stream is ignored and saved in the *unused_data* attribute.

Changed in version 3.5: Added the *max_length* parameter.

`eof`

`True` if the end-of-stream marker has been reached.

New in version 3.3.

`unused_data`

Data found after the end of the compressed stream.

If this attribute is accessed before the end of the stream has been reached, its value will be `b''`.

needs_input
`False` if the *decompress()* method can provide more decompressed data before requiring new uncompressed input.

New in version 3.5.

13.3.3 One-shot (de)compression

bz2.compress(*data*, *compresslevel=9*)
Compress *data*.

compresslevel, if given, must be a number between `1` and `9`. The default is `9`.

For incremental compression, use a *BZ2Compressor* instead.

bz2.decompress(*data*)
Decompress *data*.

If *data* is the concatenation of multiple compressed streams, decompress all of the streams.

For incremental decompression, use a *BZ2Decompressor* instead.

Changed in version 3.3: Support for multi-stream inputs was added.

13.4 `lzma` — Compression using the LZMA algorithm

New in version 3.3.

Source code: Lib/lzma.py

This module provides classes and convenience functions for compressing and decompressing data using the LZMA compression algorithm. Also included is a file interface supporting the `.xz` and legacy `.lzma` file formats used by the **xz** utility, as well as raw compressed streams.

The interface provided by this module is very similar to that of the *bz2* module. However, note that *LZMAFile* is *not* thread-safe, unlike *bz2.BZ2File*, so if you need to use a single *LZMAFile* instance from multiple threads, it is necessary to protect it with a lock.

exception lzma.LZMAError
This exception is raised when an error occurs during compression or decompression, or while initializing the compressor/decompressor state.

13.4.1 Reading and writing compressed files

lzma.open(*filename*, *mode="rb"*, ***, *format=None*, *check=-1*, *preset=None*, *filters=None*, *encoding=None*, *errors=None*, *newline=None*)
Open an LZMA-compressed file in binary or text mode, returning a *file object*.

The *filename* argument can be either an actual file name (given as a *str*, *bytes* or *path-like* object), in which case the named file is opened, or it can be an existing file object to read from or write to.

The *mode* argument can be any of `"r"`, `"rb"`, `"w"`, `"wb"`, `"x"`, `"xb"`, `"a"` or `"ab"` for binary mode, or `"rt"`, `"wt"`, `"xt"`, or `"at"` for text mode. The default is `"rb"`.

When opening a file for reading, the *format* and *filters* arguments have the same meanings as for *LZMADecompressor*. In this case, the *check* and *preset* arguments should not be used.

When opening a file for writing, the *format*, *check*, *preset* and *filters* arguments have the same meanings as for *LZMACompressor*.

For binary mode, this function is equivalent to the *LZMAFile* constructor: `LZMAFile(filename, mode, ...)`. In this case, the *encoding*, *errors* and *newline* arguments must not be provided.

For text mode, a *LZMAFile* object is created, and wrapped in an *io.TextIOWrapper* instance with the specified encoding, error handling behavior, and line ending(s).

Changed in version 3.4: Added support for the `"x"`, `"xb"` and `"xt"` modes.

Changed in version 3.6: Accepts a *path-like object*.

class lzma.LZMAFile(*filename=None*, *mode="r"*, ***, *format=None*, *check=-1*, *preset=None*, *filters=None*)

Open an LZMA-compressed file in binary mode.

An *LZMAFile* can wrap an already-open *file object*, or operate directly on a named file. The *filename* argument specifies either the file object to wrap, or the name of the file to open (as a *str*, *bytes* or *path-like* object). When wrapping an existing file object, the wrapped file will not be closed when the *LZMAFile* is closed.

The *mode* argument can be either `"r"` for reading (default), `"w"` for overwriting, `"x"` for exclusive creation, or `"a"` for appending. These can equivalently be given as `"rb"`, `"wb"`, `"xb"` and `"ab"` respectively.

If *filename* is a file object (rather than an actual file name), a mode of `"w"` does not truncate the file, and is instead equivalent to `"a"`.

When opening a file for reading, the input file may be the concatenation of multiple separate compressed streams. These are transparently decoded as a single logical stream.

When opening a file for reading, the *format* and *filters* arguments have the same meanings as for *LZMADecompressor*. In this case, the *check* and *preset* arguments should not be used.

When opening a file for writing, the *format*, *check*, *preset* and *filters* arguments have the same meanings as for *LZMACompressor*.

LZMAFile supports all the members specified by *io.BufferedIOBase*, except for `detach()` and `truncate()`. Iteration and the `with` statement are supported.

The following method is also provided:

peek(*size=-1*)

Return buffered data without advancing the file position. At least one byte of data will be returned, unless EOF has been reached. The exact number of bytes returned is unspecified (the *size* argument is ignored).

Note: While calling *peek()* does not change the file position of the *LZMAFile*, it may change the position of the underlying file object (e.g. if the *LZMAFile* was constructed by passing a file object for *filename*).

Changed in version 3.4: Added support for the `"x"` and `"xb"` modes.

Changed in version 3.5: The *read()* method now accepts an argument of `None`.

Changed in version 3.6: Accepts a *path-like object*.

13.4.2 Compressing and decompressing data in memory

class lzma.LZMACompressor(*format=FORMAT_XZ*, *check=-1*, *preset=None*, *filters=None*)

Create a compressor object, which can be used to compress data incrementally.

For a more convenient way of compressing a single chunk of data, see *compress()*.

The *format* argument specifies what container format should be used. Possible values are:

- **FORMAT_XZ: The .xz container format.** This is the default format.
- **FORMAT_ALONE: The legacy .lzma container format.** This format is more limited than .xz – it does not support integrity checks or multiple filters.
- **FORMAT_RAW: A raw data stream, not using any container format.** This format specifier does not support integrity checks, and requires that you always specify a custom filter chain (for both compression and decompression). Additionally, data compressed in this manner cannot be decompressed using FORMAT_AUTO (see *LZMADecompressor*).

The *check* argument specifies the type of integrity check to include in the compressed data. This check is used when decompressing, to ensure that the data has not been corrupted. Possible values are:

- CHECK_NONE: No integrity check. This is the default (and the only acceptable value) for FORMAT_ALONE and FORMAT_RAW.
- CHECK_CRC32: 32-bit Cyclic Redundancy Check.
- CHECK_CRC64: 64-bit Cyclic Redundancy Check. This is the default for FORMAT_XZ.
- CHECK_SHA256: 256-bit Secure Hash Algorithm.

If the specified check is not supported, an *LZMAError* is raised.

The compression settings can be specified either as a preset compression level (with the *preset* argument), or in detail as a custom filter chain (with the *filters* argument).

The *preset* argument (if provided) should be an integer between 0 and 9 (inclusive), optionally OR-ed with the constant PRESET_EXTREME. If neither *preset* nor *filters* are given, the default behavior is to use PRESET_DEFAULT (preset level 6). Higher presets produce smaller output, but make the compression process slower.

Note: In addition to being more CPU-intensive, compression with higher presets also requires much more memory (and produces output that needs more memory to decompress). With preset 9 for example, the overhead for an *LZMACompressor* object can be as high as 800 MiB. For this reason, it is generally best to stick with the default preset.

The *filters* argument (if provided) should be a filter chain specifier. See *Specifying custom filter chains* for details.

compress(*data*)
Compress *data* (a *bytes* object), returning a *bytes* object containing compressed data for at least part of the input. Some of *data* may be buffered internally, for use in later calls to *compress()* and *flush()*. The returned data should be concatenated with the output of any previous calls to *compress()*.

flush()
Finish the compression process, returning a *bytes* object containing any data stored in the compressor's internal buffers.

The compressor cannot be used after this method has been called.

class lzma.LZMADecompressor(*format=FORMAT_AUTO*, *memlimit=None*, *filters=None*)
Create a decompressor object, which can be used to decompress data incrementally.

For a more convenient way of decompressing an entire compressed stream at once, see *decompress()*.

The *format* argument specifies the container format that should be used. The default is FORMAT_AUTO, which can decompress both .xz and .lzma files. Other possible values are FORMAT_XZ, FORMAT_ALONE, and FORMAT_RAW.

The *memlimit* argument specifies a limit (in bytes) on the amount of memory that the decompressor can use. When this argument is used, decompression will fail with an *LZMAError* if it is not possible to decompress the input within the given memory limit.

The *filters* argument specifies the filter chain that was used to create the stream being decompressed. This argument is required if *format* is `FORMAT_RAW`, but should not be used for other formats. See *Specifying custom filter chains* for more information about filter chains.

Note: This class does not transparently handle inputs containing multiple compressed streams, unlike *decompress()* and *LZMAFile*. To decompress a multi-stream input with *LZMADecompressor*, you must create a new decompressor for each stream.

---

decompress(*data*, *max_length=-1*)

Decompress *data* (a *bytes-like object*), returning uncompressed data as bytes. Some of *data* may be buffered internally, for use in later calls to *decompress()*. The returned data should be concatenated with the output of any previous calls to *decompress()*.

If *max_length* is nonnegative, returns at most *max_length* bytes of decompressed data. If this limit is reached and further output can be produced, the *needs_input* attribute will be set to `False`. In this case, the next call to *decompress()* may provide *data* as `b''` to obtain more of the output.

If all of the input data was decompressed and returned (either because this was less than *max_length* bytes, or because *max_length* was negative), the *needs_input* attribute will be set to `True`.

Attempting to decompress data after the end of stream is reached raises an *EOFError*. Any data found after the end of the stream is ignored and saved in the *unused_data* attribute.

Changed in version 3.5: Added the *max_length* parameter.

check

The ID of the integrity check used by the input stream. This may be `CHECK_UNKNOWN` until enough of the input has been decoded to determine what integrity check it uses.

eof

`True` if the end-of-stream marker has been reached.

unused_data

Data found after the end of the compressed stream.

Before the end of the stream is reached, this will be `b""`.

needs_input

`False` if the *decompress()* method can provide more decompressed data before requiring new uncompressed input.

New in version 3.5.

lzma.**compress**(*data*, *format=FORMAT_XZ*, *check=-1*, *preset=None*, *filters=None*)

Compress *data* (a *bytes* object), returning the compressed data as a *bytes* object.

See *LZMACompressor* above for a description of the *format*, *check*, *preset* and *filters* arguments.

lzma.**decompress**(*data*, *format=FORMAT_AUTO*, *memlimit=None*, *filters=None*)

Decompress *data* (a *bytes* object), returning the uncompressed data as a *bytes* object.

If *data* is the concatenation of multiple distinct compressed streams, decompress all of these streams, and return the concatenation of the results.

See *LZMADecompressor* above for a description of the *format*, *memlimit* and *filters* arguments.

13.4.3 Miscellaneous

`lzma.is_check_supported(`*check*`)`
Returns true if the given integrity check is supported on this system.

`CHECK_NONE` and `CHECK_CRC32` are always supported. `CHECK_CRC64` and `CHECK_SHA256` may be unavailable if you are using a version of `liblzma` that was compiled with a limited feature set.

13.4.4 Specifying custom filter chains

A filter chain specifier is a sequence of dictionaries, where each dictionary contains the ID and options for a single filter. Each dictionary must contain the key `"id"`, and may contain additional keys to specify filter-dependent options. Valid filter IDs are as follows:

- **Compression filters:**
  - `FILTER_LZMA1` (for use with `FORMAT_ALONE`)
  - `FILTER_LZMA2` (for use with `FORMAT_XZ` and `FORMAT_RAW`)
- **Delta filter:**
  - `FILTER_DELTA`
- **Branch-Call-Jump (BCJ) filters:**
  - `FILTER_X86`
  - `FILTER_IA64`
  - `FILTER_ARM`
  - `FILTER_ARMTHUMB`
  - `FILTER_POWERPC`
  - `FILTER_SPARC`

A filter chain can consist of up to 4 filters, and cannot be empty. The last filter in the chain must be a compression filter, and any other filters must be delta or BCJ filters.

Compression filters support the following options (specified as additional entries in the dictionary representing the filter):

- `preset`: A compression preset to use as a source of default values for options that are not specified explicitly.
- `dict_size`: Dictionary size in bytes. This should be between 4 KiB and 1.5 GiB (inclusive).
- `lc`: Number of literal context bits.
- `lp`: Number of literal position bits. The sum `lc + lp` must be at most 4.
- `pb`: Number of position bits; must be at most 4.
- `mode`: `MODE_FAST` or `MODE_NORMAL`.
- `nice_len`: What should be considered a "nice length" for a match. This should be 273 or less.
- `mf`: What match finder to use – `MF_HC3`, `MF_HC4`, `MF_BT2`, `MF_BT3`, or `MF_BT4`.
- `depth`: Maximum search depth used by match finder. 0 (default) means to select automatically based on other filter options.

The delta filter stores the differences between bytes, producing more repetitive input for the compressor in certain circumstances. It supports one option, `dist`. This indicates the distance between bytes to be subtracted. The default is 1, i.e. take the differences between adjacent bytes.

The BCJ filters are intended to be applied to machine code. They convert relative branches, calls and jumps in the code to use absolute addressing, with the aim of increasing the redundancy that can be exploited by the compressor. These filters support one option, `start_offset`. This specifies the address that should be mapped to the beginning of the input data. The default is 0.

13.4.5 Examples

Reading in a compressed file:

```
import lzma
with lzma.open("file.xz") as f:
    file_content = f.read()
```

Creating a compressed file:

```
import lzma
data = b"Insert Data Here"
with lzma.open("file.xz", "w") as f:
    f.write(data)
```

Compressing data in memory:

```
import lzma
data_in = b"Insert Data Here"
data_out = lzma.compress(data_in)
```

Incremental compression:

```
import lzma
lzc = lzma.LZMACompressor()
out1 = lzc.compress(b"Some data\n")
out2 = lzc.compress(b"Another piece of data\n")
out3 = lzc.compress(b"Even more data\n")
out4 = lzc.flush()
# Concatenate all the partial results:
result = b"".join([out1, out2, out3, out4])
```

Writing compressed data to an already-open file:

```
import lzma
with open("file.xz", "wb") as f:
    f.write(b"This data will not be compressed\n")
    with lzma.open(f, "w") as lzf:
        lzf.write(b"This *will* be compressed\n")
    f.write(b"Not compressed\n")
```

Creating a compressed file using a custom filter chain:

```
import lzma
my_filters = [
    {"id": lzma.FILTER_DELTA, "dist": 5},
    {"id": lzma.FILTER_LZMA2, "preset": 7 | lzma.PRESET_EXTREME},
]
with lzma.open("file.xz", "w", filters=my_filters) as f:
    f.write(b"blah blah blah")
```

13.5 zipfile — Work with ZIP archives

Source code: Lib/zipfile.py

The ZIP file format is a common archive and compression standard. This module provides tools to create, read, write, append, and list a ZIP file. Any advanced use of this module will require an understanding of the format, as defined in PKZIP Application Note.

This module does not currently handle multi-disk ZIP files. It can handle ZIP files that use the ZIP64 extensions (that is ZIP files that are more than 4 GiB in size). It supports decryption of encrypted files in ZIP archives, but it currently cannot create an encrypted file. Decryption is extremely slow as it is implemented in native Python rather than C.

The module defines the following items:

exception zipfile.BadZipFile
The error raised for bad ZIP files.

New in version 3.2.

exception zipfile.BadZipfile
Alias of *BadZipFile*, for compatibility with older Python versions.

Deprecated since version 3.2.

exception zipfile.LargeZipFile
The error raised when a ZIP file would require ZIP64 functionality but that has not been enabled.

class zipfile.ZipFile
The class for reading and writing ZIP files. See section *ZipFile Objects* for constructor details.

class zipfile.PyZipFile
Class for creating ZIP archives containing Python libraries.

class zipfile.ZipInfo(*filename='NoName'*, *date_time=(1980, 1, 1, 0, 0, 0)*)
Class used to represent information about a member of an archive. Instances of this class are returned by the *getinfo()* and *infolist()* methods of *ZipFile* objects. Most users of the *zipfile* module will not need to create these, but only use those created by this module. *filename* should be the full name of the archive member, and *date_time* should be a tuple containing six fields which describe the time of the last modification to the file; the fields are described in section *ZipInfo Objects*.

zipfile.is_zipfile(*filename*)
Returns `True` if *filename* is a valid ZIP file based on its magic number, otherwise returns `False`. *filename* may be a file or file-like object too.

Changed in version 3.1: Support for file and file-like objects.

zipfile.ZIP_STORED
The numeric constant for an uncompressed archive member.

zipfile.ZIP_DEFLATED
The numeric constant for the usual ZIP compression method. This requires the *zlib* module.

zipfile.ZIP_BZIP2
The numeric constant for the BZIP2 compression method. This requires the *bz2* module.

New in version 3.3.

zipfile.ZIP_LZMA
The numeric constant for the LZMA compression method. This requires the *lzma* module.

New in version 3.3.

Note: The ZIP file format specification has included support for bzip2 compression since 2001, and for LZMA compression since 2006. However, some tools (including older Python releases) do not support these compression methods, and may either refuse to process the ZIP file altogether, or fail to extract individual files.

See also:

PKZIP Application Note Documentation on the ZIP file format by Phil Katz, the creator of the format and algorithms used.

Info-ZIP Home Page Information about the Info-ZIP project's ZIP archive programs and development libraries.

13.5.1 ZipFile Objects

class zipfile.ZipFile(*file*, *mode='r'*, *compression=ZIP_STORED*, *allowZip64=True*, *compresslevel=None*)

Open a ZIP file, where *file* can be a path to a file (a string), a file-like object or a *path-like object*.

The *mode* parameter should be `'r'` to read an existing file, `'w'` to truncate and write a new file, `'a'` to append to an existing file, or `'x'` to exclusively create and write a new file. If *mode* is `'x'` and *file* refers to an existing file, a *FileExistsError* will be raised. If *mode* is `'a'` and *file* refers to an existing ZIP file, then additional files are added to it. If *file* does not refer to a ZIP file, then a new ZIP archive is appended to the file. This is meant for adding a ZIP archive to another file (such as `python.exe`). If *mode* is `'a'` and the file does not exist at all, it is created. If *mode* is `'r'` or `'a'`, the file should be seekable.

compression is the ZIP compression method to use when writing the archive, and should be *ZIP_STORED*, *ZIP_DEFLATED*, *ZIP_BZIP2* or *ZIP_LZMA*; unrecognized values will cause *NotImplementedError* to be raised. If *ZIP_DEFLATED*, *ZIP_BZIP2* or *ZIP_LZMA* is specified but the corresponding module (*zlib*, *bz2* or *lzma*) is not available, *RuntimeError* is raised. The default is *ZIP_STORED*.

If *allowZip64* is `True` (the default) zipfile will create ZIP files that use the ZIP64 extensions when the zipfile is larger than 4 GiB. If it is `false` *zipfile* will raise an exception when the ZIP file would require ZIP64 extensions.

The *compresslevel* parameter controls the compression level to use when writing files to the archive. When using *ZIP_STORED* or *ZIP_LZMA* it has no effect. When using *ZIP_DEFLATED* integers `0` through `9` are accepted (see *zlib* for more information). When using *ZIP_BZIP2* integers `1` through `9` are accepted (see *bz2* for more information).

If the file is created with mode `'w'`, `'x'` or `'a'` and then *closed* without adding any files to the archive, the appropriate ZIP structures for an empty archive will be written to the file.

ZipFile is also a context manager and therefore supports the `with` statement. In the example, *myzip* is closed after the `with` statement's suite is finished—even if an exception occurs:

```
with ZipFile('spam.zip', 'w') as myzip:
    myzip.write('eggs.txt')
```

New in version 3.2: Added the ability to use *ZipFile* as a context manager.

Changed in version 3.3: Added support for *bzip2* and *lzma* compression.

Changed in version 3.4: ZIP64 extensions are enabled by default.

Changed in version 3.5: Added support for writing to unseekable streams. Added support for the `'x'` mode.

Changed in version 3.6: Previously, a plain *RuntimeError* was raised for unrecognized compression values.

Changed in version 3.6.2: The *file* parameter accepts a *path-like object*.

Changed in version 3.7: Add the *compresslevel* parameter.

ZipFile.close()
Close the archive file. You must call *close()* before exiting your program or essential records will not be written.

ZipFile.getinfo(*name*)
Return a *ZipInfo* object with information about the archive member *name*. Calling *getinfo()* for a name not currently contained in the archive will raise a *KeyError*.

ZipFile.infolist()
Return a list containing a *ZipInfo* object for each member of the archive. The objects are in the same order as their entries in the actual ZIP file on disk if an existing archive was opened.

ZipFile.namelist()
Return a list of archive members by name.

ZipFile.open(*name*, *mode='r'*, *pwd=None*, ***, *force_zip64=False*)
Access a member of the archive as a binary file-like object. *name* can be either the name of a file within the archive or a *ZipInfo* object. The *mode* parameter, if included, must be `'r'` (the default) or `'w'`. *pwd* is the password used to decrypt encrypted ZIP files.

open() is also a context manager and therefore supports the `with` statement:

```
with ZipFile('spam.zip') as myzip:
    with myzip.open('eggs.txt') as myfile:
        print(myfile.read())
```

With *mode* `'r'` the file-like object (`ZipExtFile`) is read-only and provides the following methods: *read()*, *readline()*, *readlines()*, *seek()*, *tell()*, `__iter__()`, *__next__()*. These objects can operate independently of the ZipFile.

With `mode='w'`, a writable file handle is returned, which supports the *write()* method. While a writable file handle is open, attempting to read or write other files in the ZIP file will raise a *ValueError*.

When writing a file, if the file size is not known in advance but may exceed 2 GiB, pass `force_zip64=True` to ensure that the header format is capable of supporting large files. If the file size is known in advance, construct a *ZipInfo* object with *file_size* set, and use that as the *name* parameter.

Note: The *open()*, *read()* and *extract()* methods can take a filename or a *ZipInfo* object. You will appreciate this when trying to read a ZIP file that contains members with duplicate names.

Changed in version 3.6: Removed support of `mode='U'`. Use *io.TextIOWrapper* for reading compressed text files in *universal newlines* mode.

Changed in version 3.6: *open()* can now be used to write files into the archive with the `mode='w'` option.

Changed in version 3.6: Calling *open()* on a closed ZipFile will raise a *ValueError*. Previously, a *RuntimeError* was raised.

ZipFile.extract(*member*, *path=None*, *pwd=None*)
Extract a member from the archive to the current working directory; *member* must be its full name or a *ZipInfo* object. Its file information is extracted as accurately as possible. *path* specifies a different

directory to extract to. *member* can be a filename or a *ZipInfo* object. *pwd* is the password used for encrypted files.

Returns the normalized path created (a directory or new file).

Note: If a member filename is an absolute path, a drive/UNC sharepoint and leading (back)slashes will be stripped, e.g.: `///foo/bar` becomes `foo/bar` on Unix, and `C:\foo\bar` becomes `foo\bar` on Windows. And all `".."` components in a member filename will be removed, e.g.: `../../foo../../ba..r` becomes `foo../ba..r`. On Windows illegal characters (`:`, `<`, `>`, `|`, `"`, `?`, and `*`) replaced by underscore (`_`).

Changed in version 3.6: Calling *extract()* on a closed ZipFile will raise a *ValueError*. Previously, a *RuntimeError* was raised.

Changed in version 3.6.2: The *path* parameter accepts a *path-like object*.

ZipFile.extractall(*path=None*, *members=None*, *pwd=None*)

Extract all members from the archive to the current working directory. *path* specifies a different directory to extract to. *members* is optional and must be a subset of the list returned by *namelist()*. *pwd* is the password used for encrypted files.

> **Warning:** Never extract archives from untrusted sources without prior inspection. It is possible that files are created outside of *path*, e.g. members that have absolute filenames starting with `"/"` or filenames with two dots `".."`. This module attempts to prevent that. See *extract()* note.

Changed in version 3.6: Calling *extractall()* on a closed ZipFile will raise a *ValueError*. Previously, a *RuntimeError* was raised.

Changed in version 3.6.2: The *path* parameter accepts a *path-like object*.

ZipFile.printdir()

Print a table of contents for the archive to `sys.stdout`.

ZipFile.setpassword(*pwd*)

Set *pwd* as default password to extract encrypted files.

ZipFile.read(*name*, *pwd=None*)

Return the bytes of the file *name* in the archive. *name* is the name of the file in the archive, or a *ZipInfo* object. The archive must be open for read or append. *pwd* is the password used for encrypted files and, if specified, it will override the default password set with *setpassword()*. Calling *read()* on a ZipFile that uses a compression method other than *ZIP_STORED*, *ZIP_DEFLATED*, *ZIP_BZIP2* or *ZIP_LZMA* will raise a *NotImplementedError*. An error will also be raised if the corresponding compression module is not available.

Changed in version 3.6: Calling *read()* on a closed ZipFile will raise a *ValueError*. Previously, a *RuntimeError* was raised.

ZipFile.testzip()

Read all the files in the archive and check their CRC's and file headers. Return the name of the first bad file, or else return `None`.

Changed in version 3.6: Calling `testfile()` on a closed ZipFile will raise a *ValueError*. Previously, a *RuntimeError* was raised.

ZipFile.write(*filename*, *arcname=None*, *compress_type=None*, *compresslevel=None*)

Write the file named *filename* to the archive, giving it the archive name *arcname* (by default, this will be the same as *filename*, but without a drive letter and with leading path separators removed). If given, *compress_type* overrides the value given for the *compression* parameter to the constructor for

the new entry. Similarly, *compresslevel* will override the constructor if given. The archive must be open with mode `'w'`, `'x'` or `'a'`.

Note: There is no official file name encoding for ZIP files. If you have unicode file names, you must convert them to byte strings in your desired encoding before passing them to *write()*. WinZip interprets all file names as encoded in CP437, also known as DOS Latin.

Note: Archive names should be relative to the archive root, that is, they should not start with a path separator.

Note: If `arcname` (or `filename`, if `arcname` is not given) contains a null byte, the name of the file in the archive will be truncated at the null byte.

Changed in version 3.6: Calling *write()* on a ZipFile created with mode `'r'` or a closed ZipFile will raise a *ValueError*. Previously, a *RuntimeError* was raised.

`ZipFile.writestr`(*zinfo_or_arcname*, *data*, *compress_type=None*, *compresslevel=None*)

Write the string *data* to the archive; *zinfo_or_arcname* is either the file name it will be given in the archive, or a *ZipInfo* instance. If it's an instance, at least the filename, date, and time must be given. If it's a name, the date and time is set to the current date and time. The archive must be opened with mode `'w'`, `'x'` or `'a'`.

If given, *compress_type* overrides the value given for the *compression* parameter to the constructor for the new entry, or in the *zinfo_or_arcname* (if that is a *ZipInfo* instance). Similarly, *compresslevel* will override the constructor if given.

Note: When passing a *ZipInfo* instance as the *zinfo_or_arcname* parameter, the compression method used will be that specified in the *compress_type* member of the given *ZipInfo* instance. By default, the *ZipInfo* constructor sets this member to *ZIP_STORED*.

Changed in version 3.2: The *compress_type* argument.

Changed in version 3.6: Calling *writestr()* on a ZipFile created with mode `'r'` or a closed ZipFile will raise a *ValueError*. Previously, a *RuntimeError* was raised.

The following data attributes are also available:

`ZipFile.filename`

Name of the ZIP file.

`ZipFile.debug`

The level of debug output to use. This may be set from `0` (the default, no output) to `3` (the most output). Debugging information is written to `sys.stdout`.

`ZipFile.comment`

The comment text associated with the ZIP file. If assigning a comment to a *ZipFile* instance created with mode `'w'`, `'x'` or `'a'`, this should be a string no longer than 65535 bytes. Comments longer than this will be truncated in the written archive when *close()* is called.

13.5.2 PyZipFile Objects

The *PyZipFile* constructor takes the same parameters as the *ZipFile* constructor, and one additional parameter, *optimize*.

class zipfile.PyZipFile(*file*, *mode='r'*, *compression=ZIP_STORED*, *allowZip64=True*, *optimize=-1*)

New in version 3.2: The *optimize* parameter.

Changed in version 3.4: ZIP64 extensions are enabled by default.

Instances have one method in addition to those of *ZipFile* objects:

writepy(*pathname*, *basename=''*, *filterfunc=None*)

Search for files `*.py` and add the corresponding file to the archive.

If the *optimize* parameter to *PyZipFile* was not given or `-1`, the corresponding file is a `*.pyc` file, compiling if necessary.

If the *optimize* parameter to *PyZipFile* was `0`, `1` or `2`, only files with that optimization level (see *compile()*) are added to the archive, compiling if necessary.

If *pathname* is a file, the filename must end with `.py`, and just the (corresponding `*.pyc`) file is added at the top level (no path information). If *pathname* is a file that does not end with `.py`, a *RuntimeError* will be raised. If it is a directory, and the directory is not a package directory, then all the files `*.pyc` are added at the top level. If the directory is a package directory, then all `*.pyc` are added under the package name as a file path, and if any subdirectories are package directories, all of these are added recursively in sorted order.

basename is intended for internal use only.

filterfunc, if given, must be a function taking a single string argument. It will be passed each path (including each individual full file path) before it is added to the archive. If *filterfunc* returns a false value, the path will not be added, and if it is a directory its contents will be ignored. For example, if our test files are all either in `test` directories or start with the string `test_`, we can use a *filterfunc* to exclude them:

```
>>> zf = PyZipFile('myprog.zip')
>>> def notests(s):
...     fn = os.path.basename(s)
...     return (not (fn == 'test' or fn.startswith('test_')))
>>> zf.writepy('myprog', filterfunc=notests)
```

The *writepy()* method makes archives with file names like this:

```
string.pyc                  # Top level name
test/__init__.pyc           # Package directory
test/testall.pyc            # Module test.testall
test/bogus/__init__.pyc     # Subpackage directory
test/bogus/myfile.pyc       # Submodule test.bogus.myfile
```

New in version 3.4: The *filterfunc* parameter.

Changed in version 3.6.2: The *pathname* parameter accepts a *path-like object*.

Changed in version 3.7: Recursion sorts directory entries.

13.5.3 ZipInfo Objects

Instances of the *ZipInfo* class are returned by the *getinfo()* and *infolist()* methods of *ZipFile* objects. Each object stores information about a single member of the ZIP archive.

There is one classmethod to make a *ZipInfo* instance for a filesystem file:

classmethod ZipInfo.from_file(*filename*, *arcname=None*)

Construct a *ZipInfo* instance for a file on the filesystem, in preparation for adding it to a zip file.

filename should be the path to a file or directory on the filesystem.

If *arcname* is specified, it is used as the name within the archive. If *arcname* is not specified, the name will be the same as *filename*, but with any drive letter and leading path separators removed.

New in version 3.6.

Changed in version 3.6.2: The *filename* parameter accepts a *path-like object*.

Instances have the following methods and attributes:

`ZipInfo.is_dir()`
Return `True` if this archive member is a directory.

This uses the entry's name: directories should always end with `/`.

New in version 3.6.

`ZipInfo.filename`
Name of the file in the archive.

`ZipInfo.date_time`
The time and date of the last modification to the archive member. This is a tuple of six values:

Index	Value
0	Year (>= 1980)
1	Month (one-based)
2	Day of month (one-based)
3	Hours (zero-based)
4	Minutes (zero-based)
5	Seconds (zero-based)

Note: The ZIP file format does not support timestamps before 1980.

`ZipInfo.compress_type`
Type of compression for the archive member.

`ZipInfo.comment`
Comment for the individual archive member.

`ZipInfo.extra`
Expansion field data. The PKZIP Application Note contains some comments on the internal structure of the data contained in this string.

`ZipInfo.create_system`
System which created ZIP archive.

`ZipInfo.create_version`
PKZIP version which created ZIP archive.

`ZipInfo.extract_version`
PKZIP version needed to extract archive.

`ZipInfo.reserved`
Must be zero.

`ZipInfo.flag_bits`
ZIP flag bits.

`ZipInfo.volume`
Volume number of file header.

ZipInfo.**internal_attr**
Internal attributes.

ZipInfo.**external_attr**
External file attributes.

ZipInfo.**header_offset**
Byte offset to the file header.

ZipInfo.**CRC**
CRC-32 of the uncompressed file.

ZipInfo.**compress_size**
Size of the compressed data.

ZipInfo.**file_size**
Size of the uncompressed file.

13.5.4 Command-Line Interface

The *zipfile* module provides a simple command-line interface to interact with ZIP archives.

If you want to create a new ZIP archive, specify its name after the `-c` option and then list the filename(s) that should be included:

```
$ python -m zipfile -c monty.zip spam.txt eggs.txt
```

Passing a directory is also acceptable:

```
$ python -m zipfile -c monty.zip life-of-brian_1979/
```

If you want to extract a ZIP archive into the specified directory, use the `-e` option:

```
$ python -m zipfile -e monty.zip target-dir/
```

For a list of the files in a ZIP archive, use the `-l` option:

```
$ python -m zipfile -l monty.zip
```

Command-line options

-l <zipfile>
--list <zipfile>
List files in a zipfile.

-c <zipfile> <source1> ... <sourceN>
--create <zipfile> <source1> ... <sourceN>
Create zipfile from source files.

-e <zipfile> <output_dir>
--extract <zipfile> <output_dir>
Extract zipfile into target directory.

-t <zipfile>
--test <zipfile>
Test whether the zipfile is valid or not.

13.6 tarfile — Read and write tar archive files

Source code: Lib/tarfile.py

The *tarfile* module makes it possible to read and write tar archives, including those using gzip, bz2 and lzma compression. Use the *zipfile* module to read or write `.zip` files, or the higher-level functions in *shutil*.

Some facts and figures:

- reads and writes *gzip*, *bz2* and *lzma* compressed archives if the respective modules are available.
- read/write support for the POSIX.1-1988 (ustar) format.
- read/write support for the GNU tar format including *longname* and *longlink* extensions, read-only support for all variants of the *sparse* extension including restoration of sparse files.
- read/write support for the POSIX.1-2001 (pax) format.
- handles directories, regular files, hardlinks, symbolic links, fifos, character devices and block devices and is able to acquire and restore file information like timestamp, access permissions and owner.

Changed in version 3.3: Added support for *lzma* compression.

`tarfile.open`(*name=None*, *mode='r'*, *fileobj=None*, *bufsize=10240*, ***kwargs*)

Return a *TarFile* object for the pathname *name*. For detailed information on *TarFile* objects and the keyword arguments that are allowed, see *TarFile Objects*.

mode has to be a string of the form `'filemode[:compression]'`, it defaults to `'r'`. Here is a full list of mode combinations:

mode	action
`'r'` or `'r:*'`	Open for reading with transparent compression (recommended).
`'r:'`	Open for reading exclusively without compression.
`'r:gz'`	Open for reading with gzip compression.
`'r:bz2'`	Open for reading with bzip2 compression.
`'r:xz'`	Open for reading with lzma compression.
`'x'` or `'x:'`	Create a tarfile exclusively without compression. Raise an *FileExistsError* exception if it already exists.
`'x:gz'`	Create a tarfile with gzip compression. Raise an *FileExistsError* exception if it already exists.
`'x:bz2'`	Create a tarfile with bzip2 compression. Raise an *FileExistsError* exception if it already exists.
`'x:xz'`	Create a tarfile with lzma compression. Raise an *FileExistsError* exception if it already exists.
`'a'` or `'a:'`	Open for appending with no compression. The file is created if it does not exist.
`'w'` or `'w:'`	Open for uncompressed writing.
`'w:gz'`	Open for gzip compressed writing.
`'w:bz2'`	Open for bzip2 compressed writing.
`'w:xz'`	Open for lzma compressed writing.

Note that `'a:gz'`, `'a:bz2'` or `'a:xz'` is not possible. If *mode* is not suitable to open a certain (compressed) file for reading, *ReadError* is raised. Use *mode* `'r'` to avoid this. If a compression method is not supported, *CompressionError* is raised.

If *fileobj* is specified, it is used as an alternative to a *file object* opened in binary mode for *name*. It is supposed to be at position 0.

For modes `'w:gz'`, `'r:gz'`, `'w:bz2'`, `'r:bz2'`, `'x:gz'`, `'x:bz2'`, *tarfile.open()* accepts the keyword argument *compresslevel* (default `9`) to specify the compression level of the file.

For special purposes, there is a second format for *mode*: `'filemode|[compression]'`. *tarfile.open()* will return a *TarFile* object that processes its data as a stream of blocks. No random seeking will be done on the file. If given, *fileobj* may be any object that has a `read()` or `write()` method (depending on the *mode*). *bufsize* specifies the blocksize and defaults to `20 * 512` bytes. Use this variant in combination with e.g. `sys.stdin`, a socket *file object* or a tape device. However, such a *TarFile* object is limited in that it does not allow random access, see *Examples*. The currently possible modes:

Mode	Action
`'r|*'`	Open a *stream* of tar blocks for reading with transparent compression.
`'r|'`	Open a *stream* of uncompressed tar blocks for reading.
`'r|gz'`	Open a gzip compressed *stream* for reading.
`'r|bz2'`	Open a bzip2 compressed *stream* for reading.
`'r|xz'`	Open an lzma compressed *stream* for reading.
`'w|'`	Open an uncompressed *stream* for writing.
`'w|gz'`	Open a gzip compressed *stream* for writing.
`'w|bz2'`	Open a bzip2 compressed *stream* for writing.
`'w|xz'`	Open an lzma compressed *stream* for writing.

Changed in version 3.5: The `'x'` (exclusive creation) mode was added.

Changed in version 3.6: The *name* parameter accepts a *path-like object*.

class tarfile.TarFile
Class for reading and writing tar archives. Do not use this class directly: use *tarfile.open()* instead. See *TarFile Objects*.

tarfile.is_tarfile(*name*)
Return *True* if *name* is a tar archive file, that the *tarfile* module can read.

The *tarfile* module defines the following exceptions:

exception tarfile.TarError
Base class for all *tarfile* exceptions.

exception tarfile.ReadError
Is raised when a tar archive is opened, that either cannot be handled by the *tarfile* module or is somehow invalid.

exception tarfile.CompressionError
Is raised when a compression method is not supported or when the data cannot be decoded properly.

exception tarfile.StreamError
Is raised for the limitations that are typical for stream-like *TarFile* objects.

exception tarfile.ExtractError
Is raised for *non-fatal* errors when using *TarFile.extract()*, but only if `TarFile.errorlevel== 2`.

exception tarfile.HeaderError
Is raised by *TarInfo.frombuf()* if the buffer it gets is invalid.

The following constants are available at the module level:

tarfile.ENCODING
The default character encoding: `'utf-8'` on Windows, the value returned by *sys.getfilesystemencoding()* otherwise.

Each of the following constants defines a tar archive format that the *tarfile* module is able to create. See section *Supported tar formats* for details.

`tarfile.USTAR_FORMAT`
POSIX.1-1988 (ustar) format.

`tarfile.GNU_FORMAT`
GNU tar format.

`tarfile.PAX_FORMAT`
POSIX.1-2001 (pax) format.

`tarfile.DEFAULT_FORMAT`
The default format for creating archives. This is currently *GNU_FORMAT*.

See also:

Module *zipfile* Documentation of the *zipfile* standard module.

Archiving operations Documentation of the higher-level archiving facilities provided by the standard *shutil* module.

GNU tar manual, Basic Tar Format Documentation for tar archive files, including GNU tar extensions.

13.6.1 TarFile Objects

The *TarFile* object provides an interface to a tar archive. A tar archive is a sequence of blocks. An archive member (a stored file) is made up of a header block followed by data blocks. It is possible to store a file in a tar archive several times. Each archive member is represented by a *TarInfo* object, see *TarInfo Objects* for details.

A *TarFile* object can be used as a context manager in a `with` statement. It will automatically be closed when the block is completed. Please note that in the event of an exception an archive opened for writing will not be finalized; only the internally used file object will be closed. See the *Examples* section for a use case.

New in version 3.2: Added support for the context management protocol.

`class tarfile.TarFile(`*name=None*, *mode='r'*, *fileobj=None*, *format=DEFAULT_FORMAT*, *tarinfo=TarInfo*, *dereference=False*, *ignore_zeros=False*, *encoding=ENCODING*, *errors='surrogateescape'*, *pax_headers=None*, *debug=0*, *errorlevel=0*`)`

All following arguments are optional and can be accessed as instance attributes as well.

name is the pathname of the archive. *name* may be a *path-like object*. It can be omitted if *fileobj* is given. In this case, the file object's `name` attribute is used if it exists.

mode is either `'r'` to read from an existing archive, `'a'` to append data to an existing file, `'w'` to create a new file overwriting an existing one, or `'x'` to create a new file only if it does not already exist.

If *fileobj* is given, it is used for reading or writing data. If it can be determined, *mode* is overridden by *fileobj*'s mode. *fileobj* will be used from position 0.

Note: *fileobj* is not closed, when *TarFile* is closed.

---

format controls the archive format. It must be one of the constants *USTAR_FORMAT*, *GNU_FORMAT* or *PAX_FORMAT* that are defined at module level.

The *tarinfo* argument can be used to replace the default *TarInfo* class with a different one.

If *dereference* is *False*, add symbolic and hard links to the archive. If it is *True*, add the content of the target files to the archive. This has no effect on systems that do not support symbolic links.

If *ignore_zeros* is *False*, treat an empty block as the end of the archive. If it is *True*, skip empty (and invalid) blocks and try to get as many members as possible. This is only useful for reading concatenated or damaged archives.

debug can be set from `0` (no debug messages) up to `3` (all debug messages). The messages are written to `sys.stderr`.

If *errorlevel* is `0`, all errors are ignored when using *TarFile.extract()*. Nevertheless, they appear as error messages in the debug output, when debugging is enabled. If `1`, all *fatal* errors are raised as *OSError* exceptions. If `2`, all *non-fatal* errors are raised as *TarError* exceptions as well.

The *encoding* and *errors* arguments define the character encoding to be used for reading or writing the archive and how conversion errors are going to be handled. The default settings will work for most users. See section *Unicode issues* for in-depth information.

The *pax_headers* argument is an optional dictionary of strings which will be added as a pax global header if *format* is *PAX_FORMAT*.

Changed in version 3.2: Use `'surrogateescape'` as the default for the *errors* argument.

Changed in version 3.5: The `'x'` (exclusive creation) mode was added.

Changed in version 3.6: The *name* parameter accepts a *path-like object*.

classmethod `TarFile.open`(...)
Alternative constructor. The *tarfile.open()* function is actually a shortcut to this classmethod.

`TarFile.getmember`(*name*)
Return a *TarInfo* object for member *name*. If *name* can not be found in the archive, *KeyError* is raised.

Note: If a member occurs more than once in the archive, its last occurrence is assumed to be the most up-to-date version.

`TarFile.getmembers`()
Return the members of the archive as a list of *TarInfo* objects. The list has the same order as the members in the archive.

`TarFile.getnames`()
Return the members as a list of their names. It has the same order as the list returned by *getmembers()*.

`TarFile.list`(*verbose=True*, ***, *members=None*)
Print a table of contents to `sys.stdout`. If *verbose* is *False*, only the names of the members are printed. If it is *True*, output similar to that of `ls -l` is produced. If optional *members* is given, it must be a subset of the list returned by *getmembers()*.

Changed in version 3.5: Added the *members* parameter.

`TarFile.next`()
Return the next member of the archive as a *TarInfo* object, when *TarFile* is opened for reading. Return *None* if there is no more available.

`TarFile.extractall`(*path="."*, *members=None*, ***, *numeric_owner=False*)
Extract all members from the archive to the current working directory or directory *path*. If optional *members* is given, it must be a subset of the list returned by *getmembers()*. Directory information like owner, modification time and permissions are set after all members have been extracted. This is done to work around two problems: A directory's modification time is reset each time a file is created in it. And, if a directory's permissions do not allow writing, extracting files to it will fail.

If *numeric_owner* is *True*, the uid and gid numbers from the tarfile are used to set the owner/group for the extracted files. Otherwise, the named values from the tarfile are used.

> **Warning:** Never extract archives from untrusted sources without prior inspection. It is possible that files are created outside of *path*, e.g. members that have absolute filenames starting with `"/"` or filenames with two dots `".."`.

Changed in version 3.5: Added the *numeric_owner* parameter.

Changed in version 3.6: The *path* parameter accepts a *path-like object*.

TarFile.extract(*member*, *path=""*, *set_attrs=True*, ***, *numeric_owner=False*)
Extract a member from the archive to the current working directory, using its full name. Its file information is extracted as accurately as possible. *member* may be a filename or a *TarInfo* object. You can specify a different directory using *path*. *path* may be a *path-like object*. File attributes (owner, mtime, mode) are set unless *set_attrs* is false.

If *numeric_owner* is *True*, the uid and gid numbers from the tarfile are used to set the owner/group for the extracted files. Otherwise, the named values from the tarfile are used.

Note: The *extract()* method does not take care of several extraction issues. In most cases you should consider using the *extractall()* method.

> **Warning:** See the warning for *extractall()*.

Changed in version 3.2: Added the *set_attrs* parameter.

Changed in version 3.5: Added the *numeric_owner* parameter.

Changed in version 3.6: The *path* parameter accepts a *path-like object*.

TarFile.extractfile(*member*)
Extract a member from the archive as a file object. *member* may be a filename or a *TarInfo* object. If *member* is a regular file or a link, an *io.BufferedReader* object is returned. Otherwise, *None* is returned.

Changed in version 3.3: Return an *io.BufferedReader* object.

TarFile.add(*name*, *arcname=None*, *recursive=True*, ***, *filter=None*)
Add the file *name* to the archive. *name* may be any type of file (directory, fifo, symbolic link, etc.). If given, *arcname* specifies an alternative name for the file in the archive. Directories are added recursively by default. This can be avoided by setting *recursive* to *False*. Recursion adds entries in sorted order. If *filter* is given, it should be a function that takes a *TarInfo* object argument and returns the changed *TarInfo* object. If it instead returns *None* the *TarInfo* object will be excluded from the archive. See *Examples* for an example.

Changed in version 3.2: Added the *filter* parameter.

Changed in version 3.7: Recursion adds entries in sorted order.

TarFile.addfile(*tarinfo*, *fileobj=None*)
Add the *TarInfo* object *tarinfo* to the archive. If *fileobj* is given, it should be a *binary file*, and `tarinfo.size` bytes are read from it and added to the archive. You can create *TarInfo* objects directly, or by using *gettarinfo()*.

TarFile.gettarinfo(*name=None*, *arcname=None*, *fileobj=None*)
Create a *TarInfo* object from the result of *os.stat()* or equivalent on an existing file. The file is

either named by *name*, or specified as a *file object* *fileobj* with a file descriptor. *name* may be a *path-like object*. If given, *arcname* specifies an alternative name for the file in the archive, otherwise, the name is taken from *fileobj*'s *name* attribute, or the *name* argument. The name should be a text string.

You can modify some of the *TarInfo*'s attributes before you add it using *addfile()*. If the file object is not an ordinary file object positioned at the beginning of the file, attributes such as *size* may need modifying. This is the case for objects such as *GzipFile*. The *name* may also be modified, in which case *arcname* could be a dummy string.

Changed in version 3.6: The *name* parameter accepts a *path-like object*.

TarFile.close()
Close the *TarFile*. In write mode, two finishing zero blocks are appended to the archive.

TarFile.pax_headers
A dictionary containing key-value pairs of pax global headers.

13.6.2 TarInfo Objects

A *TarInfo* object represents one member in a *TarFile*. Aside from storing all required attributes of a file (like file type, size, time, permissions, owner etc.), it provides some useful methods to determine its type. It does *not* contain the file's data itself.

TarInfo objects are returned by *TarFile*'s methods **getmember()**, **getmembers()** and **gettarinfo()**.

class tarfile.TarInfo(*name=""*)
Create a *TarInfo* object.

classmethod TarInfo.frombuf(*buf*, *encoding*, *errors*)
Create and return a *TarInfo* object from string buffer *buf*.

Raises *HeaderError* if the buffer is invalid.

classmethod TarInfo.fromtarfile(*tarfile*)
Read the next member from the *TarFile* object *tarfile* and return it as a *TarInfo* object.

TarInfo.tobuf(*format=DEFAULT_FORMAT*, *encoding=ENCODING*, *errors='surrogateescape'*)
Create a string buffer from a *TarInfo* object. For information on the arguments see the constructor of the *TarFile* class.

Changed in version 3.2: Use **'surrogateescape'** as the default for the *errors* argument.

A **TarInfo** object has the following public data attributes:

TarInfo.name
Name of the archive member.

TarInfo.size
Size in bytes.

TarInfo.mtime
Time of last modification.

TarInfo.mode
Permission bits.

TarInfo.type
File type. *type* is usually one of these constants: **REGTYPE**, **AREGTYPE**, **LNKTYPE**, **SYMTYPE**, **DIRTYPE**, **FIFOTYPE**, **CONTTYPE**, **CHRTYPE**, **BLKTYPE**, **GNUTYPE_SPARSE**. To determine the type of a *TarInfo* object more conveniently, use the **is*()** methods below.

TarInfo.linkname
Name of the target file name, which is only present in *TarInfo* objects of type **LNKTYPE** and **SYMTYPE**.

TarInfo.uid
User ID of the user who originally stored this member.

TarInfo.gid
Group ID of the user who originally stored this member.

TarInfo.uname
User name.

TarInfo.gname
Group name.

TarInfo.pax_headers
A dictionary containing key-value pairs of an associated pax extended header.

A *TarInfo* object also provides some convenient query methods:

TarInfo.isfile()
Return *True* if the Tarinfo object is a regular file.

TarInfo.isreg()
Same as *isfile()*.

TarInfo.isdir()
Return *True* if it is a directory.

TarInfo.issym()
Return *True* if it is a symbolic link.

TarInfo.islnk()
Return *True* if it is a hard link.

TarInfo.ischr()
Return *True* if it is a character device.

TarInfo.isblk()
Return *True* if it is a block device.

TarInfo.isfifo()
Return *True* if it is a FIFO.

TarInfo.isdev()
Return *True* if it is one of character device, block device or FIFO.

13.6.3 Command-Line Interface

New in version 3.4.

The *tarfile* module provides a simple command-line interface to interact with tar archives.

If you want to create a new tar archive, specify its name after the `-c` option and then list the filename(s) that should be included:

```
$ python -m tarfile -c monty.tar  spam.txt eggs.txt
```

Passing a directory is also acceptable:

```
$ python -m tarfile -c monty.tar life-of-brian_1979/
```

If you want to extract a tar archive into the current directory, use the `-e` option:

```
$ python -m tarfile -e monty.tar
```

You can also extract a tar archive into a different directory by passing the directory's name:

```
$ python -m tarfile -e monty.tar  other-dir/
```

For a list of the files in a tar archive, use the `-l` option:

```
$ python -m tarfile -l monty.tar
```

Command-line options

-l <tarfile>
--list <tarfile>
List files in a tarfile.

-c <tarfile> <source1> ... <sourceN>
--create <tarfile> <source1> ... <sourceN>
Create tarfile from source files.

-e <tarfile> [<output_dir>]
--extract <tarfile> [<output_dir>]
Extract tarfile into the current directory if *output_dir* is not specified.

-t <tarfile>
--test <tarfile>
Test whether the tarfile is valid or not.

-v, --verbose
Verbose output.

13.6.4 Examples

How to extract an entire tar archive to the current working directory:

```
import tarfile
tar = tarfile.open("sample.tar.gz")
tar.extractall()
tar.close()
```

How to extract a subset of a tar archive with *TarFile.extractall()* using a generator function instead of a list:

```
import os
import tarfile

def py_files(members):
    for tarinfo in members:
        if os.path.splitext(tarinfo.name)[1] == ".py":
            yield tarinfo

tar = tarfile.open("sample.tar.gz")
tar.extractall(members=py_files(tar))
tar.close()
```

How to create an uncompressed tar archive from a list of filenames:

```
import tarfile
tar = tarfile.open("sample.tar", "w")
for name in ["foo", "bar", "quux"]:
```

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```
    tar.add(name)
tar.close()
```

The same example using the `with` statement:

```
import tarfile
with tarfile.open("sample.tar", "w") as tar:
    for name in ["foo", "bar", "quux"]:
        tar.add(name)
```

How to read a gzip compressed tar archive and display some member information:

```
import tarfile
tar = tarfile.open("sample.tar.gz", "r:gz")
for tarinfo in tar:
    print(tarinfo.name, "is", tarinfo.size, "bytes in size and is", end="")
    if tarinfo.isreg():
        print("a regular file.")
    elif tarinfo.isdir():
        print("a directory.")
    else:
        print("something else.")
tar.close()
```

How to create an archive and reset the user information using the *filter* parameter in *TarFile.add()*:

```
import tarfile
def reset(tarinfo):
    tarinfo.uid = tarinfo.gid = 0
    tarinfo.uname = tarinfo.gname = "root"
    return tarinfo
tar = tarfile.open("sample.tar.gz", "w:gz")
tar.add("foo", filter=reset)
tar.close()
```

13.6.5 Supported tar formats

There are three tar formats that can be created with the *tarfile* module:

- The POSIX.1-1988 ustar format (*USTAR_FORMAT*). It supports filenames up to a length of at best 256 characters and linknames up to 100 characters. The maximum file size is 8 GiB. This is an old and limited but widely supported format.
- The GNU tar format (*GNU_FORMAT*). It supports long filenames and linknames, files bigger than 8 GiB and sparse files. It is the de facto standard on GNU/Linux systems. *tarfile* fully supports the GNU tar extensions for long names, sparse file support is read-only.
- The POSIX.1-2001 pax format (*PAX_FORMAT*). It is the most flexible format with virtually no limits. It supports long filenames and linknames, large files and stores pathnames in a portable way. However, not all tar implementations today are able to handle pax archives properly.

  The *pax* format is an extension to the existing *ustar* format. It uses extra headers for information that cannot be stored otherwise. There are two flavours of pax headers: Extended headers only affect the subsequent file header, global headers are valid for the complete archive and affect all following files. All the data in a pax header is encoded in *UTF-8* for portability reasons.

There are some more variants of the tar format which can be read, but not created:

- The ancient V7 format. This is the first tar format from Unix Seventh Edition, storing only regular files and directories. Names must not be longer than 100 characters, there is no user/group name information. Some archives have miscalculated header checksums in case of fields with non-ASCII characters.
- The SunOS tar extended format. This format is a variant of the POSIX.1-2001 pax format, but is not compatible.

13.6.6 Unicode issues

The tar format was originally conceived to make backups on tape drives with the main focus on preserving file system information. Nowadays tar archives are commonly used for file distribution and exchanging archives over networks. One problem of the original format (which is the basis of all other formats) is that there is no concept of supporting different character encodings. For example, an ordinary tar archive created on a *UTF-8* system cannot be read correctly on a *Latin-1* system if it contains non-*ASCII* characters. Textual metadata (like filenames, linknames, user/group names) will appear damaged. Unfortunately, there is no way to autodetect the encoding of an archive. The pax format was designed to solve this problem. It stores non-ASCII metadata using the universal character encoding *UTF-8*.

The details of character conversion in *tarfile* are controlled by the *encoding* and *errors* keyword arguments of the *TarFile* class.

encoding defines the character encoding to use for the metadata in the archive. The default value is *sys.getfilesystemencoding()* or `'ascii'` as a fallback. Depending on whether the archive is read or written, the metadata must be either decoded or encoded. If *encoding* is not set appropriately, this conversion may fail.

The *errors* argument defines how characters are treated that cannot be converted. Possible values are listed in section *Error Handlers*. The default scheme is `'surrogateescape'` which Python also uses for its file system calls, see *File Names, Command Line Arguments, and Environment Variables*.

In case of *PAX_FORMAT* archives, *encoding* is generally not needed because all the metadata is stored using *UTF-8*. *encoding* is only used in the rare cases when binary pax headers are decoded or when strings with surrogate characters are stored.

CHAPTER

FOURTEEN

FILE FORMATS

The modules described in this chapter parse various miscellaneous file formats that aren't markup languages and are not related to e-mail.

14.1 csv — CSV File Reading and Writing

Source code: Lib/csv.py

The so-called CSV (Comma Separated Values) format is the most common import and export format for spreadsheets and databases. CSV format was used for many years prior to attempts to describe the format in a standardized way in **RFC 4180**. The lack of a well-defined standard means that subtle differences often exist in the data produced and consumed by different applications. These differences can make it annoying to process CSV files from multiple sources. Still, while the delimiters and quoting characters vary, the overall format is similar enough that it is possible to write a single module which can efficiently manipulate such data, hiding the details of reading and writing the data from the programmer.

The *csv* module implements classes to read and write tabular data in CSV format. It allows programmers to say, "write this data in the format preferred by Excel," or "read data from this file which was generated by Excel," without knowing the precise details of the CSV format used by Excel. Programmers can also describe the CSV formats understood by other applications or define their own special-purpose CSV formats.

The *csv* module's *reader* and *writer* objects read and write sequences. Programmers can also read and write data in dictionary form using the *DictReader* and *DictWriter* classes.

See also:

PEP 305 - CSV File API The Python Enhancement Proposal which proposed this addition to Python.

14.1.1 Module Contents

The *csv* module defines the following functions:

`csv.reader(`*csvfile*, *dialect='excel'*, ***fmtparams*`)`

Return a reader object which will iterate over lines in the given *csvfile*. *csvfile* can be any object which supports the *iterator* protocol and returns a string each time its `__next__()` method is called — *file objects* and list objects are both suitable. If *csvfile* is a file object, it should be opened with `newline=''`.[1] An optional *dialect* parameter can be given which is used to define a set of parameters specific to a particular CSV dialect. It may be an instance of a subclass of the *Dialect* class or one of the strings returned by the *list_dialects()* function. The other optional *fmtparams* keyword

[1] If `newline=''` is not specified, newlines embedded inside quoted fields will not be interpreted correctly, and on platforms that use `\r\n` linendings on write an extra `\r` will be added. It should always be safe to specify `newline=''`, since the csv module does its own (*universal*) newline handling.

arguments can be given to override individual formatting parameters in the current dialect. For full details about the dialect and formatting parameters, see section *Dialects and Formatting Parameters*.

Each row read from the csv file is returned as a list of strings. No automatic data type conversion is performed unless the `QUOTE_NONNUMERIC` format option is specified (in which case unquoted fields are transformed into floats).

A short usage example:

```
>>> import csv
>>> with open('eggs.csv', newline='') as csvfile:
...     spamreader = csv.reader(csvfile, delimiter=' ', quotechar='|')
...     for row in spamreader:
...         print(', '.join(row))
Spam, Spam, Spam, Spam, Spam, Baked Beans
Spam, Lovely Spam, Wonderful Spam
```

csv.writer(*csvfile*, *dialect='excel'*, ***fmtparams*)

Return a writer object responsible for converting the user's data into delimited strings on the given file-like object. *csvfile* can be any object with a `write()` method. If *csvfile* is a file object, it should be opened with `newline=''`[1]. An optional *dialect* parameter can be given which is used to define a set of parameters specific to a particular CSV dialect. It may be an instance of a subclass of the *Dialect* class or one of the strings returned by the *list_dialects()* function. The other optional *fmtparams* keyword arguments can be given to override individual formatting parameters in the current dialect. For full details about the dialect and formatting parameters, see section *Dialects and Formatting Parameters*. To make it as easy as possible to interface with modules which implement the DB API, the value *None* is written as the empty string. While this isn't a reversible transformation, it makes it easier to dump SQL NULL data values to CSV files without preprocessing the data returned from a `cursor.fetch*` call. All other non-string data are stringified with *str()* before being written.

A short usage example:

```
import csv
with open('eggs.csv', 'w', newline='') as csvfile:
    spamwriter = csv.writer(csvfile, delimiter=' ',
                            quotechar='|', quoting=csv.QUOTE_MINIMAL)
    spamwriter.writerow(['Spam'] * 5 + ['Baked Beans'])
    spamwriter.writerow(['Spam', 'Lovely Spam', 'Wonderful Spam'])
```

csv.register_dialect(*name*[, *dialect*[, ***fmtparams*]])

Associate *dialect* with *name*. *name* must be a string. The dialect can be specified either by passing a sub-class of *Dialect*, or by *fmtparams* keyword arguments, or both, with keyword arguments overriding parameters of the dialect. For full details about the dialect and formatting parameters, see section *Dialects and Formatting Parameters*.

csv.unregister_dialect(*name*)

Delete the dialect associated with *name* from the dialect registry. An *Error* is raised if *name* is not a registered dialect name.

csv.get_dialect(*name*)

Return the dialect associated with *name*. An *Error* is raised if *name* is not a registered dialect name. This function returns an immutable *Dialect*.

csv.list_dialects()

Return the names of all registered dialects.

csv.field_size_limit([*new_limit*])

Returns the current maximum field size allowed by the parser. If *new_limit* is given, this becomes the new limit.

The *csv* module defines the following classes:

class csv.DictReader(*f*, *fieldnames=None*, *restkey=None*, *restval=None*, *dialect='excel'*, **args*, ***kwds*)

Create an object that operates like a regular reader but maps the information in each row to an *OrderedDict* whose keys are given by the optional *fieldnames* parameter.

The *fieldnames* parameter is a *sequence*. If *fieldnames* is omitted, the values in the first row of file *f* will be used as the fieldnames. Regardless of how the fieldnames are determined, the ordered dictionary preserves their original ordering.

If a row has more fields than fieldnames, the remaining data is put in a list and stored with the fieldname specified by *restkey* (which defaults to `None`). If a non-blank row has fewer fields than fieldnames, the missing values are filled-in with `None`.

All other optional or keyword arguments are passed to the underlying *reader* instance.

Changed in version 3.6: Returned rows are now of type `OrderedDict`.

A short usage example:

```
>>> import csv
>>> with open('names.csv', newline='') as csvfile:
...     reader = csv.DictReader(csvfile)
...     for row in reader:
...         print(row['first_name'], row['last_name'])
...
Eric Idle
John Cleese

>>> print(row)
OrderedDict([('first_name', 'John'), ('last_name', 'Cleese')])
```

class csv.DictWriter(*f*, *fieldnames*, *restval=''*, *extrasaction='raise'*, *dialect='excel'*, **args*, ***kwds*)

Create an object which operates like a regular writer but maps dictionaries onto output rows. The *fieldnames* parameter is a *sequence* of keys that identify the order in which values in the dictionary passed to the `writerow()` method are written to file *f*. The optional *restval* parameter specifies the value to be written if the dictionary is missing a key in *fieldnames*. If the dictionary passed to the `writerow()` method contains a key not found in *fieldnames*, the optional *extrasaction* parameter indicates what action to take. If it is set to `'raise'`, the default value, a *ValueError* is raised. If it is set to `'ignore'`, extra values in the dictionary are ignored. Any other optional or keyword arguments are passed to the underlying *writer* instance.

Note that unlike the *DictReader* class, the *fieldnames* parameter of the *DictWriter* class is not optional.

A short usage example:

```
import csv

with open('names.csv', 'w', newline='') as csvfile:
    fieldnames = ['first_name', 'last_name']
    writer = csv.DictWriter(csvfile, fieldnames=fieldnames)

    writer.writeheader()
    writer.writerow({'first_name': 'Baked', 'last_name': 'Beans'})
    writer.writerow({'first_name': 'Lovely', 'last_name': 'Spam'})
    writer.writerow({'first_name': 'Wonderful', 'last_name': 'Spam'})
```

class csv.Dialect

The *Dialect* class is a container class relied on primarily for its attributes, which are used to define

the parameters for a specific *reader* or *writer* instance.

class csv.excel
The *excel* class defines the usual properties of an Excel-generated CSV file. It is registered with the dialect name 'excel'.

class csv.excel_tab
The *excel_tab* class defines the usual properties of an Excel-generated TAB-delimited file. It is registered with the dialect name 'excel-tab'.

class csv.unix_dialect
The *unix_dialect* class defines the usual properties of a CSV file generated on UNIX systems, i.e. using '\n' as line terminator and quoting all fields. It is registered with the dialect name 'unix'.

New in version 3.2.

class csv.Sniffer
The *Sniffer* class is used to deduce the format of a CSV file.

The *Sniffer* class provides two methods:

sniff(*sample*, *delimiters=None*)
Analyze the given *sample* and return a *Dialect* subclass reflecting the parameters found. If the optional *delimiters* parameter is given, it is interpreted as a string containing possible valid delimiter characters.

has_header(*sample*)
Analyze the sample text (presumed to be in CSV format) and return *True* if the first row appears to be a series of column headers.

An example for *Sniffer* use:

```
with open('example.csv', newline='') as csvfile:
    dialect = csv.Sniffer().sniff(csvfile.read(1024))
    csvfile.seek(0)
    reader = csv.reader(csvfile, dialect)
    # ... process CSV file contents here ...
```

The *csv* module defines the following constants:

csv.QUOTE_ALL
Instructs *writer* objects to quote all fields.

csv.QUOTE_MINIMAL
Instructs *writer* objects to only quote those fields which contain special characters such as *delimiter*, *quotechar* or any of the characters in *lineterminator*.

csv.QUOTE_NONNUMERIC
Instructs *writer* objects to quote all non-numeric fields.

Instructs the reader to convert all non-quoted fields to type *float*.

csv.QUOTE_NONE
Instructs *writer* objects to never quote fields. When the current *delimiter* occurs in output data it is preceded by the current *escapechar* character. If *escapechar* is not set, the writer will raise *Error* if any characters that require escaping are encountered.

Instructs *reader* to perform no special processing of quote characters.

The *csv* module defines the following exception:

exception csv.Error
Raised by any of the functions when an error is detected.

14.1.2 Dialects and Formatting Parameters

To make it easier to specify the format of input and output records, specific formatting parameters are grouped together into dialects. A dialect is a subclass of the *Dialect* class having a set of specific methods and a single `validate()` method. When creating *reader* or *writer* objects, the programmer can specify a string or a subclass of the *Dialect* class as the dialect parameter. In addition to, or instead of, the *dialect* parameter, the programmer can also specify individual formatting parameters, which have the same names as the attributes defined below for the *Dialect* class.

Dialects support the following attributes:

Dialect.delimiter
A one-character string used to separate fields. It defaults to `','`.

Dialect.doublequote
Controls how instances of *quotechar* appearing inside a field should themselves be quoted. When *True*, the character is doubled. When *False*, the *escapechar* is used as a prefix to the *quotechar*. It defaults to *True*.

On output, if *doublequote* is *False* and no *escapechar* is set, *Error* is raised if a *quotechar* is found in a field.

Dialect.escapechar
A one-character string used by the writer to escape the *delimiter* if *quoting* is set to *QUOTE_NONE* and the *quotechar* if *doublequote* is *False*. On reading, the *escapechar* removes any special meaning from the following character. It defaults to *None*, which disables escaping.

Dialect.lineterminator
The string used to terminate lines produced by the *writer*. It defaults to `'\r\n'`.

Note: The *reader* is hard-coded to recognise either `'\r'` or `'\n'` as end-of-line, and ignores *lineterminator*. This behavior may change in the future.

Dialect.quotechar
A one-character string used to quote fields containing special characters, such as the *delimiter* or *quotechar*, or which contain new-line characters. It defaults to `'"'`.

Dialect.quoting
Controls when quotes should be generated by the writer and recognised by the reader. It can take on any of the `QUOTE_*` constants (see section *Module Contents*) and defaults to *QUOTE_MINIMAL*.

Dialect.skipinitialspace
When *True*, whitespace immediately following the *delimiter* is ignored. The default is *False*.

Dialect.strict
When `True`, raise exception *Error* on bad CSV input. The default is `False`.

14.1.3 Reader Objects

Reader objects (*DictReader* instances and objects returned by the *reader()* function) have the following public methods:

csvreader.__next__()
Return the next row of the reader's iterable object as a list (if the object was returned from *reader()*) or a dict (if it is a *DictReader* instance), parsed according to the current dialect. Usually you should call this as `next(reader)`.

Reader objects have the following public attributes:

csvreader.dialect
A read-only description of the dialect in use by the parser.

csvreader.line_num
The number of lines read from the source iterator. This is not the same as the number of records returned, as records can span multiple lines.

DictReader objects have the following public attribute:

csvreader.fieldnames
If not passed as a parameter when creating the object, this attribute is initialized upon first access or when the first record is read from the file.

14.1.4 Writer Objects

`Writer` objects (*DictWriter* instances and objects returned by the *writer()* function) have the following public methods. A *row* must be an iterable of strings or numbers for `Writer` objects and a dictionary mapping fieldnames to strings or numbers (by passing them through *str()* first) for *DictWriter* objects. Note that complex numbers are written out surrounded by parens. This may cause some problems for other programs which read CSV files (assuming they support complex numbers at all).

csvwriter.writerow(*row*)
Write the *row* parameter to the writer's file object, formatted according to the current dialect.

Changed in version 3.5: Added support of arbitrary iterables.

csvwriter.writerows(*rows*)
Write all elements in *rows* (an iterable of *row* objects as described above) to the writer's file object, formatted according to the current dialect.

Writer objects have the following public attribute:

csvwriter.dialect
A read-only description of the dialect in use by the writer.

DictWriter objects have the following public method:

DictWriter.writeheader()
Write a row with the field names (as specified in the constructor).

New in version 3.2.

14.1.5 Examples

The simplest example of reading a CSV file:

```
import csv
with open('some.csv', newline='') as f:
    reader = csv.reader(f)
    for row in reader:
        print(row)
```

Reading a file with an alternate format:

```
import csv
with open('passwd', newline='') as f:
    reader = csv.reader(f, delimiter=':', quoting=csv.QUOTE_NONE)
    for row in reader:
        print(row)
```

The corresponding simplest possible writing example is:

```
import csv
with open('some.csv', 'w', newline='') as f:
    writer = csv.writer(f)
    writer.writerows(someiterable)
```

Since *open()* is used to open a CSV file for reading, the file will by default be decoded into unicode using the system default encoding (see *locale.getpreferredencoding()*). To decode a file using a different encoding, use the `encoding` argument of open:

```
import csv
with open('some.csv', newline='', encoding='utf-8') as f:
    reader = csv.reader(f)
    for row in reader:
        print(row)
```

The same applies to writing in something other than the system default encoding: specify the encoding argument when opening the output file.

Registering a new dialect:

```
import csv
csv.register_dialect('unixpwd', delimiter=':', quoting=csv.QUOTE_NONE)
with open('passwd', newline='') as f:
    reader = csv.reader(f, 'unixpwd')
```

A slightly more advanced use of the reader — catching and reporting errors:

```
import csv, sys
filename = 'some.csv'
with open(filename, newline='') as f:
    reader = csv.reader(f)
    try:
        for row in reader:
            print(row)
    except csv.Error as e:
        sys.exit('file {}, line {}: {}'.format(filename, reader.line_num, e))
```

And while the module doesn't directly support parsing strings, it can easily be done:

```
import csv
for row in csv.reader(['one,two,three']):
    print(row)
```

14.2 `configparser` — Configuration file parser

Source code: Lib/configparser.py

This module provides the *ConfigParser* class which implements a basic configuration language which provides a structure similar to what's found in Microsoft Windows INI files. You can use this to write Python programs which can be customized by end users easily.

Note: This library does *not* interpret or write the value-type prefixes used in the Windows Registry extended version of INI syntax.

See also:

Module *shlex* Support for creating Unix shell-like mini-languages which can be used as an alternate format for application configuration files.

Module *json* The json module implements a subset of JavaScript syntax which can also be used for this purpose.

14.2.1 Quick Start

Let's take a very basic configuration file that looks like this:

```
[DEFAULT]
ServerAliveInterval = 45
Compression = yes
CompressionLevel = 9
ForwardX11 = yes

[bitbucket.org]
User = hg

[topsecret.server.com]
Port = 50022
ForwardX11 = no
```

The structure of INI files is described *in the following section*. Essentially, the file consists of sections, each of which contains keys with values. *configparser* classes can read and write such files. Let's start by creating the above configuration file programmatically.

```
>>> import configparser
>>> config = configparser.ConfigParser()
>>> config['DEFAULT'] = {'ServerAliveInterval': '45',
...                      'Compression': 'yes',
...                      'CompressionLevel': '9'}
>>> config['bitbucket.org'] = {}
>>> config['bitbucket.org']['User'] = 'hg'
>>> config['topsecret.server.com'] = {}
>>> topsecret = config['topsecret.server.com']
>>> topsecret['Port'] = '50022'     # mutates the parser
>>> topsecret['ForwardX11'] = 'no'  # same here
>>> config['DEFAULT']['ForwardX11'] = 'yes'
>>> with open('example.ini', 'w') as configfile:
...   config.write(configfile)
...
```

As you can see, we can treat a config parser much like a dictionary. There are differences, *outlined later*, but the behavior is very close to what you would expect from a dictionary.

Now that we have created and saved a configuration file, let's read it back and explore the data it holds.

```
>>> config = configparser.ConfigParser()
>>> config.sections()
[]
```

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```
>>> config.read('example.ini')
['example.ini']
>>> config.sections()
['bitbucket.org', 'topsecret.server.com']
>>> 'bitbucket.org' in config
True
>>> 'bytebong.com' in config
False
>>> config['bitbucket.org']['User']
'hg'
>>> config['DEFAULT']['Compression']
'yes'
>>> topsecret = config['topsecret.server.com']
>>> topsecret['ForwardX11']
'no'
>>> topsecret['Port']
'50022'
>>> for key in config['bitbucket.org']:
...     print(key)
user
compressionlevel
serveraliveinterval
compression
forwardx11
>>> config['bitbucket.org']['ForwardX11']
'yes'
```

As we can see above, the API is pretty straightforward. The only bit of magic involves the `DEFAULT` section which provides default values for all other sections[1]. Note also that keys in sections are case-insensitive and stored in lowercase[1].

14.2.2 Supported Datatypes

Config parsers do not guess datatypes of values in configuration files, always storing them internally as strings. This means that if you need other datatypes, you should convert on your own:

```
>>> int(topsecret['Port'])
50022
>>> float(topsecret['CompressionLevel'])
9.0
```

Since this task is so common, config parsers provide a range of handy getter methods to handle integers, floats and booleans. The last one is the most interesting because simply passing the value to `bool()` would do no good since `bool('False')` is still `True`. This is why config parsers also provide *`getboolean()`*. This method is case-insensitive and recognizes Boolean values from `'yes'`/`'no'`, `'on'`/`'off'`, `'true'`/`'false'` and `'1'`/`'0'`[1]. For example:

```
>>> topsecret.getboolean('ForwardX11')
False
>>> config['bitbucket.org'].getboolean('ForwardX11')
True
>>> config.getboolean('bitbucket.org', 'Compression')
True
```

[1] Config parsers allow for heavy customization. If you are interested in changing the behaviour outlined by the footnote reference, consult the *Customizing Parser Behaviour* section.

Apart from *getboolean()*, config parsers also provide equivalent *getint()* and *getfloat()* methods. You can register your own converters and customize the provided ones.[1]

14.2.3 Fallback Values

As with a dictionary, you can use a section's `get()` method to provide fallback values:

```
>>> topsecret.get('Port')
'50022'
>>> topsecret.get('CompressionLevel')
'9'
>>> topsecret.get('Cipher')
>>> topsecret.get('Cipher', '3des-cbc')
'3des-cbc'
```

Please note that default values have precedence over fallback values. For instance, in our example the `'CompressionLevel'` key was specified only in the `'DEFAULT'` section. If we try to get it from the section `'topsecret.server.com'`, we will always get the default, even if we specify a fallback:

```
>>> topsecret.get('CompressionLevel', '3')
'9'
```

One more thing to be aware of is that the parser-level `get()` method provides a custom, more complex interface, maintained for backwards compatibility. When using this method, a fallback value can be provided via the `fallback` keyword-only argument:

```
>>> config.get('bitbucket.org', 'monster',
...            fallback='No such things as monsters')
'No such things as monsters'
```

The same `fallback` argument can be used with the *getint()*, *getfloat()* and *getboolean()* methods, for example:

```
>>> 'BatchMode' in topsecret
False
>>> topsecret.getboolean('BatchMode', fallback=True)
True
>>> config['DEFAULT']['BatchMode'] = 'no'
>>> topsecret.getboolean('BatchMode', fallback=True)
False
```

14.2.4 Supported INI File Structure

A configuration file consists of sections, each led by a `[section]` header, followed by key/value entries separated by a specific string (`=` or `:` by default[1]). By default, section names are case sensitive but keys are not[1]. Leading and trailing whitespace is removed from keys and values. Values can be omitted, in which case the key/value delimiter may also be left out. Values can also span multiple lines, as long as they are indented deeper than the first line of the value. Depending on the parser's mode, blank lines may be treated as parts of multiline values or ignored.

Configuration files may include comments, prefixed by specific characters (`#` and `;` by default[1]). Comments may appear on their own on an otherwise empty line, possibly indented.[1]

For example:

```
[Simple Values]
key=value
spaces in keys=allowed
spaces in values=allowed as well
spaces around the delimiter = obviously
you can also use : to delimit keys from values

[All Values Are Strings]
values like this: 1000000
or this: 3.14159265359
are they treated as numbers? : no
integers, floats and booleans are held as: strings
can use the API to get converted values directly: true

[Multiline Values]
chorus: I'm a lumberjack, and I'm okay
    I sleep all night and I work all day

[No Values]
key_without_value
empty string value here =

[You can use comments]
# like this
; or this

# By default only in an empty line.
# Inline comments can be harmful because they prevent users
# from using the delimiting characters as parts of values.
# That being said, this can be customized.

    [Sections Can Be Indented]
        can_values_be_as_well = True
        does_that_mean_anything_special = False
        purpose = formatting for readability
        multiline_values = are
            handled just fine as
            long as they are indented
            deeper than the first line
            of a value
        # Did I mention we can indent comments, too?
```

14.2.5 Interpolation of values

On top of the core functionality, *ConfigParser* supports interpolation. This means values can be preprocessed before returning them from `get()` calls.

class configparser.BasicInterpolation

The default implementation used by *ConfigParser*. It enables values to contain format strings which refer to other values in the same section, or values in the special default section[1]. Additional default values can be provided on initialization.

For example:

```
[Paths]
home_dir: /Users
```

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```
my_dir: %(home_dir)s/lumberjack
my_pictures: %(my_dir)s/Pictures
```

In the example above, *ConfigParser* with *interpolation* set to `BasicInterpolation()` would resolve `%(home_dir)s` to the value of `home_dir` (`/Users` in this case). `%(my_dir)s` in effect would resolve to `/Users/lumberjack`. All interpolations are done on demand so keys used in the chain of references do not have to be specified in any specific order in the configuration file.

With `interpolation` set to `None`, the parser would simply return `%(my_dir)s/Pictures` as the value of `my_pictures` and `%(home_dir)s/lumberjack` as the value of `my_dir`.

class configparser.ExtendedInterpolation

An alternative handler for interpolation which implements a more advanced syntax, used for instance in `zc.buildout`. Extended interpolation is using `${section:option}` to denote a value from a foreign section. Interpolation can span multiple levels. For convenience, if the `section:` part is omitted, interpolation defaults to the current section (and possibly the default values from the special section).

For example, the configuration specified above with basic interpolation, would look like this with extended interpolation:

```
[Paths]
home_dir: /Users
my_dir: ${home_dir}/lumberjack
my_pictures: ${my_dir}/Pictures
```

Values from other sections can be fetched as well:

```
[Common]
home_dir: /Users
library_dir: /Library
system_dir: /System
macports_dir: /opt/local

[Frameworks]
Python: 3.2
path: ${Common:system_dir}/Library/Frameworks/

[Arthur]
nickname: Two Sheds
last_name: Jackson
my_dir: ${Common:home_dir}/twosheds
my_pictures: ${my_dir}/Pictures
python_dir: ${Frameworks:path}/Python/Versions/${Frameworks:Python}
```

14.2.6 Mapping Protocol Access

New in version 3.2.

Mapping protocol access is a generic name for functionality that enables using custom objects as if they were dictionaries. In case of *configparser*, the mapping interface implementation is using the `parser['section']['option']` notation.

`parser['section']` in particular returns a proxy for the section's data in the parser. This means that the values are not copied but they are taken from the original parser on demand. What's even more important is that when values are changed on a section proxy, they are actually mutated in the original parser.

configparser objects behave as close to actual dictionaries as possible. The mapping interface is complete and adheres to the *MutableMapping* ABC. However, there are a few differences that should be taken into account:

- By default, all keys in sections are accessible in a case-insensitive manner[1]. E.g. `for option in parser["section"]` yields only `optionxform`'ed option key names. This means lowercased keys by default. At the same time, for a section that holds the key `'a'`, both expressions return `True`:

```
"a" in parser["section"]
"A" in parser["section"]
```

- All sections include `DEFAULTSECT` values as well which means that `.clear()` on a section may not leave the section visibly empty. This is because default values cannot be deleted from the section (because technically they are not there). If they are overridden in the section, deleting causes the default value to be visible again. Trying to delete a default value causes a `KeyError`.
- `DEFAULTSECT` cannot be removed from the parser:
  - trying to delete it raises `ValueError`,
  - `parser.clear()` leaves it intact,
  - `parser.popitem()` never returns it.
- `parser.get(section, option, **kwargs)` - the second argument is **not** a fallback value. Note however that the section-level `get()` methods are compatible both with the mapping protocol and the classic configparser API.
- `parser.items()` is compatible with the mapping protocol (returns a list of *section_name*, *section_proxy* pairs including the DEFAULTSECT). However, this method can also be invoked with arguments: `parser.items(section, raw, vars)`. The latter call returns a list of *option*, *value* pairs for a specified `section`, with all interpolations expanded (unless `raw=True` is provided).

The mapping protocol is implemented on top of the existing legacy API so that subclasses overriding the original interface still should have mappings working as expected.

14.2.7 Customizing Parser Behaviour

There are nearly as many INI format variants as there are applications using it. *configparser* goes a long way to provide support for the largest sensible set of INI styles available. The default functionality is mainly dictated by historical background and it's very likely that you will want to customize some of the features.

The most common way to change the way a specific config parser works is to use the `__init__()` options:

- *defaults*, default value: `None`

  This option accepts a dictionary of key-value pairs which will be initially put in the `DEFAULT` section. This makes for an elegant way to support concise configuration files that don't specify values which are the same as the documented default.

  Hint: if you want to specify default values for a specific section, use `read_dict()` before you read the actual file.

- *dict_type*, default value: *collections.OrderedDict*

  This option has a major impact on how the mapping protocol will behave and how the written configuration files look. With the default ordered dictionary, every section is stored in the order they were added to the parser. Same goes for options within sections.

  An alternative dictionary type can be used for example to sort sections and options on write-back. You can also use a regular dictionary for performance reasons.

Please note: there are ways to add a set of key-value pairs in a single operation. When you use a regular dictionary in those operations, the order of the keys may be random. For example:

```
>>> parser = configparser.ConfigParser()
>>> parser.read_dict({'section1': {'key1': 'value1',
...                                'key2': 'value2',
...                                'key3': 'value3'},
...                   'section2': {'keyA': 'valueA',
...                                'keyB': 'valueB',
...                                'keyC': 'valueC'},
...                   'section3': {'foo': 'x',
...                                'bar': 'y',
...                                'baz': 'z'}
... })
>>> parser.sections()
['section3', 'section2', 'section1']
>>> [option for option in parser['section3']]
['baz', 'foo', 'bar']
```

In these operations you need to use an ordered dictionary as well:

```
>>> from collections import OrderedDict
>>> parser = configparser.ConfigParser()
>>> parser.read_dict(
...   OrderedDict((
...     ('s1',
...      OrderedDict((
...        ('1', '2'),
...        ('3', '4'),
...        ('5', '6'),
...      ))
...     ),
...     ('s2',
...      OrderedDict((
...        ('a', 'b'),
...        ('c', 'd'),
...        ('e', 'f'),
...      ))
...     ),
...   ))
... )
>>> parser.sections()
['s1', 's2']
>>> [option for option in parser['s1']]
['1', '3', '5']
>>> [option for option in parser['s2'].values()]
['b', 'd', 'f']
```

- *allow_no_value*, default value: `False`

  Some configuration files are known to include settings without values, but which otherwise conform to the syntax supported by *configparser*. The *allow_no_value* parameter to the constructor can be used to indicate that such values should be accepted:

```
>>> import configparser

>>> sample_config = """
... [mysqld]
```

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```
...   user = mysql
...   pid-file = /var/run/mysqld/mysqld.pid
...   skip-external-locking
...   old_passwords = 1
...   skip-bdb
...   # we don't need ACID today
...   skip-innodb
... """
>>> config = configparser.ConfigParser(allow_no_value=True)
>>> config.read_string(sample_config)

>>> # Settings with values are treated as before:
>>> config["mysqld"]["user"]
'mysql'

>>> # Settings without values provide None:
>>> config["mysqld"]["skip-bdb"]

>>> # Settings which aren't specified still raise an error:
>>> config["mysqld"]["does-not-exist"]
Traceback (most recent call last):
  ...
KeyError: 'does-not-exist'
```

- *delimiters*, default value: `('=', ':')`

  Delimiters are substrings that delimit keys from values within a section. The first occurrence of a delimiting substring on a line is considered a delimiter. This means values (but not keys) can contain the delimiters.

  See also the *space_around_delimiters* argument to *ConfigParser.write()*.

- *comment_prefixes*, default value: `('#', ';')`

- *inline_comment_prefixes*, default value: `None`

  Comment prefixes are strings that indicate the start of a valid comment within a config file. *comment_prefixes* are used only on otherwise empty lines (optionally indented) whereas *inline_comment_prefixes* can be used after every valid value (e.g. section names, options and empty lines as well). By default inline comments are disabled and `'#'` and `';'` are used as prefixes for whole line comments.

  Changed in version 3.2: In previous versions of *configparser* behaviour matched `comment_prefixes=('#',';')` and `inline_comment_prefixes=(';',)`.

  Please note that config parsers don't support escaping of comment prefixes so using *inline_comment_prefixes* may prevent users from specifying option values with characters used as comment prefixes. When in doubt, avoid setting *inline_comment_prefixes*. In any circumstances, the only way of storing comment prefix characters at the beginning of a line in multiline values is to interpolate the prefix, for example:

```
>>> from configparser import ConfigParser, ExtendedInterpolation
>>> parser = ConfigParser(interpolation=ExtendedInterpolation())
>>> # the default BasicInterpolation could be used as well
>>> parser.read_string("""
... [DEFAULT]
... hash = #
...
... [hashes]
```

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```
... shebang =
...   ${hash}!/usr/bin/env python
...   ${hash} -*- coding: utf-8 -*-
...
... extensions =
...   enabled_extension
...   another_extension
...   #disabled_by_comment
...   yet_another_extension
...
... interpolation not necessary = if # is not at line start
... even in multiline values = line #1
...   line #2
...   line #3
... """)
>>> print(parser['hashes']['shebang'])

#!/usr/bin/env python
# -*- coding: utf-8 -*-
>>> print(parser['hashes']['extensions'])

enabled_extension
another_extension
yet_another_extension
>>> print(parser['hashes']['interpolation not necessary'])
if # is not at line start
>>> print(parser['hashes']['even in multiline values'])
line #1
line #2
line #3
```

- *strict*, default value: `True`

  When set to `True`, the parser will not allow for any section or option duplicates while reading from a single source (using `read_file()`, `read_string()` or `read_dict()`). It is recommended to use strict parsers in new applications.

  Changed in version 3.2: In previous versions of *configparser* behaviour matched `strict=False`.

- *empty_lines_in_values*, default value: `True`

  In config parsers, values can span multiple lines as long as they are indented more than the key that holds them. By default parsers also let empty lines to be parts of values. At the same time, keys can be arbitrarily indented themselves to improve readability. In consequence, when configuration files get big and complex, it is easy for the user to lose track of the file structure. Take for instance:

```
[Section]
key = multiline
  value with a gotcha

 this = is still a part of the multiline value of 'key'
```

  This can be especially problematic for the user to see if she's using a proportional font to edit the file. That is why when your application does not need values with empty lines, you should consider disallowing them. This will make empty lines split keys every time. In the example above, it would produce two keys, `key` and `this`.

- *default_section*, default value: `configparser.DEFAULTSECT` (that is: `"DEFAULT"`)

The convention of allowing a special section of default values for other sections or interpolation purposes is a powerful concept of this library, letting users create complex declarative configurations. This section is normally called `"DEFAULT"` but this can be customized to point to any other valid section name. Some typical values include: `"general"` or `"common"`. The name provided is used for recognizing default sections when reading from any source and is used when writing configuration back to a file. Its current value can be retrieved using the `parser_instance.default_section` attribute and may be modified at runtime (i.e. to convert files from one format to another).

- *interpolation*, default value: `configparser.BasicInterpolation`

  Interpolation behaviour may be customized by providing a custom handler through the *interpolation* argument. `None` can be used to turn off interpolation completely, `ExtendedInterpolation()` provides a more advanced variant inspired by `zc.buildout`. More on the subject in the *dedicated documentation section*. *`RawConfigParser`* has a default value of `None`.

- *converters*, default value: not set

  Config parsers provide option value getters that perform type conversion. By default *`getint()`*, *`getfloat()`*, and *`getboolean()`* are implemented. Should other getters be desirable, users may define them in a subclass or pass a dictionary where each key is a name of the converter and each value is a callable implementing said conversion. For instance, passing `{'decimal': decimal.Decimal}` would add `getdecimal()` on both the parser object and all section proxies. In other words, it will be possible to write both `parser_instance.getdecimal('section', 'key', fallback=0)` and `parser_instance['section'].getdecimal('key', 0)`.

  If the converter needs to access the state of the parser, it can be implemented as a method on a config parser subclass. If the name of this method starts with `get`, it will be available on all section proxies, in the dict-compatible form (see the `getdecimal()` example above).

More advanced customization may be achieved by overriding default values of these parser attributes. The defaults are defined on the classes, so they may be overridden by subclasses or by attribute assignment.

`configparser.BOOLEAN_STATES`
By default when using *`getboolean()`*, config parsers consider the following values `True`: `'1'`, `'yes'`, `'true'`, `'on'` and the following values `False`: `'0'`, `'no'`, `'false'`, `'off'`. You can override this by specifying a custom dictionary of strings and their Boolean outcomes. For example:

```
>>> custom = configparser.ConfigParser()
>>> custom['section1'] = {'funky': 'nope'}
>>> custom['section1'].getboolean('funky')
Traceback (most recent call last):
...
ValueError: Not a boolean: nope
>>> custom.BOOLEAN_STATES = {'sure': True, 'nope': False}
>>> custom['section1'].getboolean('funky')
False
```

Other typical Boolean pairs include `accept`/`reject` or `enabled`/`disabled`.

`configparser.optionxform`(*option*)
This method transforms option names on every read, get, or set operation. The default converts the name to lowercase. This also means that when a configuration file gets written, all keys will be lowercase. Override this method if that's unsuitable. For example:

```
>>> config = """
... [Section1]
... Key = Value
...
... [Section2]
```

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```
... AnotherKey = Value
... """
>>> typical = configparser.ConfigParser()
>>> typical.read_string(config)
>>> list(typical['Section1'].keys())
['key']
>>> list(typical['Section2'].keys())
['anotherkey']
>>> custom = configparser.RawConfigParser()
>>> custom.optionxform = lambda option: option
>>> custom.read_string(config)
>>> list(custom['Section1'].keys())
['Key']
>>> list(custom['Section2'].keys())
['AnotherKey']
```

`configparser.SECTCRE`
: A compiled regular expression used to parse section headers. The default matches `[section]` to the name `"section"`. Whitespace is considered part of the section name, thus `[ larch ]` will be read as a section of name `" larch "`. Override this attribute if that's unsuitable. For example:

```
>>> import re
>>> config = """
... [Section 1]
... option = value
...
... [  Section 2  ]
... another = val
... """
>>> typical = configparser.ConfigParser()
>>> typical.read_string(config)
>>> typical.sections()
['Section 1', '  Section 2  ']
>>> custom = configparser.ConfigParser()
>>> custom.SECTCRE = re.compile(r"\[ *(?P<header>[^]]+?) *\]")
>>> custom.read_string(config)
>>> custom.sections()
['Section 1', 'Section 2']
```

Note: While ConfigParser objects also use an `OPTCRE` attribute for recognizing option lines, it's not recommended to override it because that would interfere with constructor options *allow_no_value* and *delimiters*.

14.2.8 Legacy API Examples

Mainly because of backwards compatibility concerns, *configparser* provides also a legacy API with explicit `get`/`set` methods. While there are valid use cases for the methods outlined below, mapping protocol access is preferred for new projects. The legacy API is at times more advanced, low-level and downright counterintuitive.

An example of writing to a configuration file:

```
import configparser

config = configparser.RawConfigParser()

# Please note that using RawConfigParser's set functions, you can assign
# non-string values to keys internally, but will receive an error when
# attempting to write to a file or when you get it in non-raw mode. Setting
# values using the mapping protocol or ConfigParser's set() does not allow
# such assignments to take place.
config.add_section('Section1')
config.set('Section1', 'an_int', '15')
config.set('Section1', 'a_bool', 'true')
config.set('Section1', 'a_float', '3.1415')
config.set('Section1', 'baz', 'fun')
config.set('Section1', 'bar', 'Python')
config.set('Section1', 'foo', '%(bar)s is %(baz)s!')

# Writing our configuration file to 'example.cfg'
with open('example.cfg', 'w') as configfile:
    config.write(configfile)
```

An example of reading the configuration file again:

```
import configparser

config = configparser.RawConfigParser()
config.read('example.cfg')

# getfloat() raises an exception if the value is not a float
# getint() and getboolean() also do this for their respective types
a_float = config.getfloat('Section1', 'a_float')
an_int = config.getint('Section1', 'an_int')
print(a_float + an_int)

# Notice that the next output does not interpolate '%(bar)s' or '%(baz)s'.
# This is because we are using a RawConfigParser().
if config.getboolean('Section1', 'a_bool'):
    print(config.get('Section1', 'foo'))
```

To get interpolation, use *ConfigParser*:

```
import configparser

cfg = configparser.ConfigParser()
cfg.read('example.cfg')

# Set the optional *raw* argument of get() to True if you wish to disable
# interpolation in a single get operation.
print(cfg.get('Section1', 'foo', raw=False))  # -> "Python is fun!"
print(cfg.get('Section1', 'foo', raw=True))   # -> "%(bar)s is %(baz)s!"

# The optional *vars* argument is a dict with members that will take
# precedence in interpolation.
print(cfg.get('Section1', 'foo', vars={'bar': 'Documentation',
                                       'baz': 'evil'}))

# The optional *fallback* argument can be used to provide a fallback value
```

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```
print(cfg.get('Section1', 'foo'))
      # -> "Python is fun!"

print(cfg.get('Section1', 'foo', fallback='Monty is not.'))
      # -> "Python is fun!"

print(cfg.get('Section1', 'monster', fallback='No such things as monsters.'))
      # -> "No such things as monsters."

# A bare print(cfg.get('Section1', 'monster')) would raise NoOptionError
# but we can also use:

print(cfg.get('Section1', 'monster', fallback=None))
      # -> None
```

Default values are available in both types of ConfigParsers. They are used in interpolation if an option used is not defined elsewhere.

```
import configparser

# New instance with 'bar' and 'baz' defaulting to 'Life' and 'hard' each
config = configparser.ConfigParser({'bar': 'Life', 'baz': 'hard'})
config.read('example.cfg')

print(config.get('Section1', 'foo'))     # -> "Python is fun!"
config.remove_option('Section1', 'bar')
config.remove_option('Section1', 'baz')
print(config.get('Section1', 'foo'))     # -> "Life is hard!"
```

14.2.9 ConfigParser Objects

class configparser.ConfigParser(*defaults=None, dict_type=dict, allow_no_value=False, delimiters=('=', ':'), comment_prefixes=('#', ';'), inline_comment_prefixes=None, strict=True, empty_lines_in_values=True, default_section=configparser.DEFAULTSECT, interpolation=BasicInterpolation(), converters={}*)

The main configuration parser. When *defaults* is given, it is initialized into the dictionary of intrinsic defaults. When *dict_type* is given, it will be used to create the dictionary objects for the list of sections, for the options within a section, and for the default values.

When *delimiters* is given, it is used as the set of substrings that divide keys from values. When *comment_prefixes* is given, it will be used as the set of substrings that prefix comments in otherwise empty lines. Comments can be indented. When *inline_comment_prefixes* is given, it will be used as the set of substrings that prefix comments in non-empty lines.

When *strict* is `True` (the default), the parser won't allow for any section or option duplicates while reading from a single source (file, string or dictionary), raising *DuplicateSectionError* or *DuplicateOptionError*. When *empty_lines_in_values* is `False` (default: `True`), each empty line marks the end of an option. Otherwise, internal empty lines of a multiline option are kept as part of the value. When *allow_no_value* is `True` (default: `False`), options without values are accepted; the value held for these is `None` and they are serialized without the trailing delimiter.

When *default_section* is given, it specifies the name for the special section holding default values for other sections and interpolation purposes (normally named `"DEFAULT"`). This value can be retrieved and changed on runtime using the `default_section` instance attribute.

Interpolation behaviour may be customized by providing a custom handler through the *interpolation* argument. `None` can be used to turn off interpolation completely, `ExtendedInterpolation()` provides a more advanced variant inspired by `zc.buildout`. More on the subject in the *dedicated documentation section*.

All option names used in interpolation will be passed through the *optionxform()* method just like any other option name reference. For example, using the default implementation of *optionxform()* (which converts option names to lower case), the values `foo %(bar)s` and `foo %(BAR)s` are equivalent.

When *converters* is given, it should be a dictionary where each key represents the name of a type converter and each value is a callable implementing the conversion from string to the desired datatype. Every converter gets its own corresponding `get*()` method on the parser object and section proxies.

Changed in version 3.1: The default *dict_type* is *collections.OrderedDict*.

Changed in version 3.2: *allow_no_value*, *delimiters*, *comment_prefixes*, *strict*, *empty_lines_in_values*, *default_section* and *interpolation* were added.

Changed in version 3.5: The *converters* argument was added.

Changed in version 3.7: The *defaults* argument is read with *read_dict()*, providing consistent behavior across the parser: non-string keys and values are implicitly converted to strings.

Changed in version 3.7: The default *dict_type* is *dict*, since it now preserves insertion order.

defaults()
Return a dictionary containing the instance-wide defaults.

sections()
Return a list of the sections available; the *default section* is not included in the list.

add_section(*section*)
Add a section named *section* to the instance. If a section by the given name already exists, *DuplicateSectionError* is raised. If the *default section* name is passed, *ValueError* is raised. The name of the section must be a string; if not, *TypeError* is raised.

Changed in version 3.2: Non-string section names raise *TypeError*.

has_section(*section*)
Indicates whether the named *section* is present in the configuration. The *default section* is not acknowledged.

options(*section*)
Return a list of options available in the specified *section*.

has_option(*section*, *option*)
If the given *section* exists, and contains the given *option*, return *True*; otherwise return *False*. If the specified *section* is *None* or an empty string, DEFAULT is assumed.

read(*filenames*, *encoding=None*)
Attempt to read and parse a list of filenames, returning a list of filenames which were successfully parsed.

If *filenames* is a string, a *bytes* object or a *path-like object*, it is treated as a single filename. If a file named in *filenames* cannot be opened, that file will be ignored. This is designed so that you can specify a list of potential configuration file locations (for example, the current directory, the user's home directory, and some system-wide directory), and all existing configuration files in the list will be read.

If none of the named files exist, the *ConfigParser* instance will contain an empty dataset. An application which requires initial values to be loaded from a file should load the required file or files using *read_file()* before calling *read()* for any optional files:

```
import configparser, os

config = configparser.ConfigParser()
config.read_file(open('defaults.cfg'))
config.read(['site.cfg', os.path.expanduser('~/.myapp.cfg')],
            encoding='cp1250')
```

New in version 3.2: The *encoding* parameter. Previously, all files were read using the default encoding for *open()*.

New in version 3.6.1: The *filenames* parameter accepts a *path-like object*.

New in version 3.7: The *filenames* parameter accepts a *bytes* object.

read_file(*f*, *source=None*)
Read and parse configuration data from *f* which must be an iterable yielding Unicode strings (for example files opened in text mode).

Optional argument *source* specifies the name of the file being read. If not given and *f* has a `name` attribute, that is used for *source*; the default is `'<???>'`.

New in version 3.2: Replaces *readfp()*.

read_string(*string*, *source='<string>'*)
Parse configuration data from a string.

Optional argument *source* specifies a context-specific name of the string passed. If not given, `'<string>'` is used. This should commonly be a filesystem path or a URL.

New in version 3.2.

read_dict(*dictionary*, *source='<dict>'*)
Load configuration from any object that provides a dict-like `items()` method. Keys are section names, values are dictionaries with keys and values that should be present in the section. If the used dictionary type preserves order, sections and their keys will be added in order. Values are automatically converted to strings.

Optional argument *source* specifies a context-specific name of the dictionary passed. If not given, `<dict>` is used.

This method can be used to copy state between parsers.

New in version 3.2.

get(*section*, *option*, ***, *raw=False*, *vars=None*[, *fallback*])
Get an *option* value for the named *section*. If *vars* is provided, it must be a dictionary. The *option* is looked up in *vars* (if provided), *section*, and in *DEFAULTSECT* in that order. If the key is not found and *fallback* is provided, it is used as a fallback value. `None` can be provided as a *fallback* value.

All the `'%'` interpolations are expanded in the return values, unless the *raw* argument is true. Values for interpolation keys are looked up in the same manner as the option.

Changed in version 3.2: Arguments *raw*, *vars* and *fallback* are keyword only to protect users from trying to use the third argument as the *fallback* fallback (especially when using the mapping protocol).

getint(*section*, *option*, ***, *raw=False*, *vars=None*[, *fallback*])
A convenience method which coerces the *option* in the specified *section* to an integer. See *get()* for explanation of *raw*, *vars* and *fallback*.

getfloat(*section*, *option*, *, *raw=False*, *vars=None*[, *fallback*])
A convenience method which coerces the *option* in the specified *section* to a floating point number. See *get()* for explanation of *raw*, *vars* and *fallback*.

getboolean(*section*, *option*, *, *raw=False*, *vars=None*[, *fallback*])
A convenience method which coerces the *option* in the specified *section* to a Boolean value. Note that the accepted values for the option are `'1'`, `'yes'`, `'true'`, and `'on'`, which cause this method to return `True`, and `'0'`, `'no'`, `'false'`, and `'off'`, which cause it to return `False`. These string values are checked in a case-insensitive manner. Any other value will cause it to raise *ValueError*. See *get()* for explanation of *raw*, *vars* and *fallback*.

items(*raw=False*, *vars=None*)
items(*section*, *raw=False*, *vars=None*)
When *section* is not given, return a list of *section_name*, *section_proxy* pairs, including DEFAULTSECT.

Otherwise, return a list of *name*, *value* pairs for the options in the given *section*. Optional arguments have the same meaning as for the *get()* method.

set(*section*, *option*, *value*)
If the given section exists, set the given option to the specified value; otherwise raise *NoSectionError*. *option* and *value* must be strings; if not, *TypeError* is raised.

write(*fileobject*, *space_around_delimiters=True*)
Write a representation of the configuration to the specified *file object*, which must be opened in text mode (accepting strings). This representation can be parsed by a future *read()* call. If *space_around_delimiters* is true, delimiters between keys and values are surrounded by spaces.

remove_option(*section*, *option*)
Remove the specified *option* from the specified *section*. If the section does not exist, raise *NoSectionError*. If the option existed to be removed, return *True*; otherwise return *False*.

remove_section(*section*)
Remove the specified *section* from the configuration. If the section in fact existed, return `True`. Otherwise return `False`.

optionxform(*option*)
Transforms the option name *option* as found in an input file or as passed in by client code to the form that should be used in the internal structures. The default implementation returns a lower-case version of *option*; subclasses may override this or client code can set an attribute of this name on instances to affect this behavior.

You don't need to subclass the parser to use this method, you can also set it on an instance, to a function that takes a string argument and returns a string. Setting it to `str`, for example, would make option names case sensitive:

```
cfgparser = ConfigParser()
cfgparser.optionxform = str
```

Note that when reading configuration files, whitespace around the option names is stripped before *optionxform()* is called.

readfp(*fp*, *filename=None*)
Deprecated since version 3.2: Use *read_file()* instead.

Changed in version 3.2: *readfp()* now iterates on *fp* instead of calling `fp.readline()`.

For existing code calling *readfp()* with arguments which don't support iteration, the following generator may be used as a wrapper around the file-like object:

```
def readline_generator(fp):
    line = fp.readline()
    while line:
        yield line
        line = fp.readline()
```

Instead of `parser.readfp(fp)` use `parser.read_file(readline_generator(fp))`.

`configparser.MAX_INTERPOLATION_DEPTH`
The maximum depth for recursive interpolation for `get()` when the *raw* parameter is false. This is relevant only when the default *interpolation* is used.

14.2.10 RawConfigParser Objects

`class configparser.RawConfigParser`(*defaults=None, dict_type=dict, allow_no_value=False, *, delimiters=('=', ':'), comment_prefixes=('#', ';'), inline_comment_prefixes=None, strict=True, empty_lines_in_values=True, default_section=configparser.DEFAULTSECT*[, *interpolation*])

Legacy variant of the *ConfigParser*. It has interpolation disabled by default and allows for non-string section names, option names, and values via its unsafe `add_section` and `set` methods, as well as the legacy `defaults=` keyword argument handling.

Changed in version 3.7: The default *dict_type* is *dict*, since it now preserves insertion order.

Note: Consider using *ConfigParser* instead which checks types of the values to be stored internally. If you don't want interpolation, you can use `ConfigParser(interpolation=None)`.

`add_section`(*section*)
Add a section named *section* to the instance. If a section by the given name already exists, *DuplicateSectionError* is raised. If the *default section* name is passed, *ValueError* is raised.

Type of *section* is not checked which lets users create non-string named sections. This behaviour is unsupported and may cause internal errors.

`set`(*section*, *option*, *value*)
If the given section exists, set the given option to the specified value; otherwise raise *NoSectionError*. While it is possible to use *RawConfigParser* (or *ConfigParser* with *raw* parameters set to true) for *internal* storage of non-string values, full functionality (including interpolation and output to files) can only be achieved using string values.

This method lets users assign non-string values to keys internally. This behaviour is unsupported and will cause errors when attempting to write to a file or get it in non-raw mode. **Use the mapping protocol API** which does not allow such assignments to take place.

14.2.11 Exceptions

`exception configparser.Error`
Base class for all other *configparser* exceptions.

`exception configparser.NoSectionError`
Exception raised when a specified section is not found.

exception configparser.**DuplicateSectionError**
Exception raised if `add_section()` is called with the name of a section that is already present or in strict parsers when a section if found more than once in a single input file, string or dictionary.

New in version 3.2: Optional `source` and `lineno` attributes and arguments to `__init__()` were added.

exception configparser.**DuplicateOptionError**
Exception raised by strict parsers if a single option appears twice during reading from a single file, string or dictionary. This catches misspellings and case sensitivity-related errors, e.g. a dictionary may have two keys representing the same case-insensitive configuration key.

exception configparser.**NoOptionError**
Exception raised when a specified option is not found in the specified section.

exception configparser.**InterpolationError**
Base class for exceptions raised when problems occur performing string interpolation.

exception configparser.**InterpolationDepthError**
Exception raised when string interpolation cannot be completed because the number of iterations exceeds *MAX_INTERPOLATION_DEPTH*. Subclass of *InterpolationError*.

exception configparser.**InterpolationMissingOptionError**
Exception raised when an option referenced from a value does not exist. Subclass of *InterpolationError*.

exception configparser.**InterpolationSyntaxError**
Exception raised when the source text into which substitutions are made does not conform to the required syntax. Subclass of *InterpolationError*.

exception configparser.**MissingSectionHeaderError**
Exception raised when attempting to parse a file which has no section headers.

exception configparser.**ParsingError**
Exception raised when errors occur attempting to parse a file.

Changed in version 3.2: The `filename` attribute and `__init__()` argument were renamed to `source` for consistency.

14.3 netrc — netrc file processing

Source code: Lib/netrc.py

The *netrc* class parses and encapsulates the netrc file format used by the Unix **ftp** program and other FTP clients.

class netrc.**netrc**([*file*])
A *netrc* instance or subclass instance encapsulates data from a netrc file. The initialization argument, if present, specifies the file to parse. If no argument is given, the file `.netrc` in the user's home directory – as determined by *os.path.expanduser()* – will be read. Otherwise, a *FileNotFoundError* exception will be raised. Parse errors will raise *NetrcParseError* with diagnostic information including the file name, line number, and terminating token. If no argument is specified on a POSIX system, the presence of passwords in the `.netrc` file will raise a *NetrcParseError* if the file ownership or permissions are insecure (owned by a user other than the user running the process, or accessible for read or write by any other user). This implements security behavior equivalent to that of ftp and other programs that use `.netrc`.

Changed in version 3.4: Added the POSIX permission check.

Changed in version 3.7: *os.path.expanduser()* is used to find the location of the `.netrc` file when *file* is not passed as argument.

exception `netrc.NetrcParseError`
Exception raised by the *netrc* class when syntactical errors are encountered in source text. Instances of this exception provide three interesting attributes: `msg` is a textual explanation of the error, `filename` is the name of the source file, and `lineno` gives the line number on which the error was found.

14.3.1 netrc Objects

A *netrc* instance has the following methods:

`netrc.authenticators(`*host*`)`
Return a 3-tuple `(login, account, password)` of authenticators for *host*. If the netrc file did not contain an entry for the given host, return the tuple associated with the 'default' entry. If neither matching host nor default entry is available, return `None`.

`netrc.__repr__()`
Dump the class data as a string in the format of a netrc file. (This discards comments and may reorder the entries.)

Instances of *netrc* have public instance variables:

`netrc.hosts`
Dictionary mapping host names to `(login, account, password)` tuples. The 'default' entry, if any, is represented as a pseudo-host by that name.

`netrc.macros`
Dictionary mapping macro names to string lists.

Note: Passwords are limited to a subset of the ASCII character set. All ASCII punctuation is allowed in passwords, however, note that whitespace and non-printable characters are not allowed in passwords. This is a limitation of the way the .netrc file is parsed and may be removed in the future.

14.4 `xdrlib` — Encode and decode XDR data

Source code: Lib/xdrlib.py

The *xdrlib* module supports the External Data Representation Standard as described in **RFC 1014**, written by Sun Microsystems, Inc. June 1987. It supports most of the data types described in the RFC.

The *xdrlib* module defines two classes, one for packing variables into XDR representation, and another for unpacking from XDR representation. There are also two exception classes.

class `xdrlib.Packer`
Packer is the class for packing data into XDR representation. The *Packer* class is instantiated with no arguments.

class `xdrlib.Unpacker(`*data*`)`
`Unpacker` is the complementary class which unpacks XDR data values from a string buffer. The input buffer is given as *data*.

See also:

RFC 1014 - XDR: External Data Representation Standard This RFC defined the encoding of data which was XDR at the time this module was originally written. It has apparently been obsoleted by **RFC 1832**.

RFC 1832 - XDR: External Data Representation Standard Newer RFC that provides a revised definition of XDR.

14.4.1 Packer Objects

Packer instances have the following methods:

`Packer.get_buffer()`
Returns the current pack buffer as a string.

`Packer.reset()`
Resets the pack buffer to the empty string.

In general, you can pack any of the most common XDR data types by calling the appropriate `pack_type()` method. Each method takes a single argument, the value to pack. The following simple data type packing methods are supported: `pack_uint()`, `pack_int()`, `pack_enum()`, `pack_bool()`, `pack_uhyper()`, and `pack_hyper()`.

`Packer.pack_float(`*value*`)`
Packs the single-precision floating point number *value*.

`Packer.pack_double(`*value*`)`
Packs the double-precision floating point number *value*.

The following methods support packing strings, bytes, and opaque data:

`Packer.pack_fstring(`*n*, *s*`)`
Packs a fixed length string, *s*. *n* is the length of the string but it is *not* packed into the data buffer. The string is padded with null bytes if necessary to guaranteed 4 byte alignment.

`Packer.pack_fopaque(`*n*, *data*`)`
Packs a fixed length opaque data stream, similarly to *pack_fstring()*.

`Packer.pack_string(`*s*`)`
Packs a variable length string, *s*. The length of the string is first packed as an unsigned integer, then the string data is packed with *pack_fstring()*.

`Packer.pack_opaque(`*data*`)`
Packs a variable length opaque data string, similarly to *pack_string()*.

`Packer.pack_bytes(`*bytes*`)`
Packs a variable length byte stream, similarly to *pack_string()*.

The following methods support packing arrays and lists:

`Packer.pack_list(`*list*, *pack_item*`)`
Packs a *list* of homogeneous items. This method is useful for lists with an indeterminate size; i.e. the size is not available until the entire list has been walked. For each item in the list, an unsigned integer `1` is packed first, followed by the data value from the list. *pack_item* is the function that is called to pack the individual item. At the end of the list, an unsigned integer `0` is packed.

For example, to pack a list of integers, the code might appear like this:

```
import xdrlib
p = xdrlib.Packer()
p.pack_list([1, 2, 3], p.pack_int)
```

Packer.**pack_farray**(*n*, *array*, *pack_item*)
Packs a fixed length list (*array*) of homogeneous items. *n* is the length of the list; it is *not* packed into the buffer, but a *ValueError* exception is raised if `len(array)` is not equal to *n*. As above, *pack_item* is the function used to pack each element.

Packer.**pack_array**(*list*, *pack_item*)
Packs a variable length *list* of homogeneous items. First, the length of the list is packed as an unsigned integer, then each element is packed as in *pack_farray()* above.

14.4.2 Unpacker Objects

The *Unpacker* class offers the following methods:

Unpacker.**reset**(*data*)
Resets the string buffer with the given *data*.

Unpacker.**get_position**()
Returns the current unpack position in the data buffer.

Unpacker.**set_position**(*position*)
Sets the data buffer unpack position to *position*. You should be careful about using *get_position()* and *set_position()*.

Unpacker.**get_buffer**()
Returns the current unpack data buffer as a string.

Unpacker.**done**()
Indicates unpack completion. Raises an *Error* exception if all of the data has not been unpacked.

In addition, every data type that can be packed with a *Packer*, can be unpacked with an *Unpacker*. Unpacking methods are of the form `unpack_type()`, and take no arguments. They return the unpacked object.

Unpacker.**unpack_float**()
Unpacks a single-precision floating point number.

Unpacker.**unpack_double**()
Unpacks a double-precision floating point number, similarly to *unpack_float()*.

In addition, the following methods unpack strings, bytes, and opaque data:

Unpacker.**unpack_fstring**(*n*)
Unpacks and returns a fixed length string. *n* is the number of characters expected. Padding with null bytes to guaranteed 4 byte alignment is assumed.

Unpacker.**unpack_fopaque**(*n*)
Unpacks and returns a fixed length opaque data stream, similarly to *unpack_fstring()*.

Unpacker.**unpack_string**()
Unpacks and returns a variable length string. The length of the string is first unpacked as an unsigned integer, then the string data is unpacked with *unpack_fstring()*.

Unpacker.**unpack_opaque**()
Unpacks and returns a variable length opaque data string, similarly to *unpack_string()*.

Unpacker.**unpack_bytes**()
Unpacks and returns a variable length byte stream, similarly to *unpack_string()*.

The following methods support unpacking arrays and lists:

Unpacker.**unpack_list**(*unpack_item*)
Unpacks and returns a list of homogeneous items. The list is unpacked one element at a time by first unpacking an unsigned integer flag. If the flag is `1`, then the item is unpacked and appended to the

list. A flag of 0 indicates the end of the list. *unpack_item* is the function that is called to unpack the items.

Unpacker.unpack_farray(*n*, *unpack_item*)
Unpacks and returns (as a list) a fixed length array of homogeneous items. *n* is number of list elements to expect in the buffer. As above, *unpack_item* is the function used to unpack each element.

Unpacker.unpack_array(*unpack_item*)
Unpacks and returns a variable length *list* of homogeneous items. First, the length of the list is unpacked as an unsigned integer, then each element is unpacked as in *unpack_farray()* above.

14.4.3 Exceptions

Exceptions in this module are coded as class instances:

exception xdrlib.Error
The base exception class. *Error* has a single public attribute **msg** containing the description of the error.

exception xdrlib.ConversionError
Class derived from *Error*. Contains no additional instance variables.

Here is an example of how you would catch one of these exceptions:

```
import xdrlib
p = xdrlib.Packer()
try:
    p.pack_double(8.01)
except xdrlib.ConversionError as instance:
    print('packing the double failed:', instance.msg)
```

14.5 plistlib — Generate and parse Mac OS X .plist files

Source code: Lib/plistlib.py

This module provides an interface for reading and writing the "property list" files used mainly by Mac OS X and supports both binary and XML plist files.

The property list (.plist) file format is a simple serialization supporting basic object types, like dictionaries, lists, numbers and strings. Usually the top level object is a dictionary.

To write out and to parse a plist file, use the *dump()* and *load()* functions.

To work with plist data in bytes objects, use *dumps()* and *loads()*.

Values can be strings, integers, floats, booleans, tuples, lists, dictionaries (but only with string keys), *Data*, *bytes*, bytesarray or *datetime.datetime* objects.

Changed in version 3.4: New API, old API deprecated. Support for binary format plists added.

See also:

PList manual page Apple's documentation of the file format.

This module defines the following functions:

plistlib.load(*fp*, *, *fmt=None*, *use_builtin_types=True*, *dict_type=dict*)
Read a plist file. *fp* should be a readable and binary file object. Return the unpacked root object (which usually is a dictionary).

The *fmt* is the format of the file and the following values are valid:

- *None*: Autodetect the file format
- *FMT_XML*: XML file format
- *FMT_BINARY*: Binary plist format

If *use_builtin_types* is true (the default) binary data will be returned as instances of *bytes*, otherwise it is returned as instances of *Data*.

The *dict_type* is the type used for dictionaries that are read from the plist file.

XML data for the *FMT_XML* format is parsed using the Expat parser from *xml.parsers.expat* – see its documentation for possible exceptions on ill-formed XML. Unknown elements will simply be ignored by the plist parser.

The parser for the binary format raises `InvalidFileException` when the file cannot be parsed.

New in version 3.4.

plistlib.loads(*data*, *, *fmt=None*, *use_builtin_types=True*, *dict_type=dict*)
Load a plist from a bytes object. See *load()* for an explanation of the keyword arguments.

New in version 3.4.

plistlib.dump(*value*, *fp*, *, *fmt=FMT_XML*, *sort_keys=True*, *skipkeys=False*)
Write *value* to a plist file. *Fp* should be a writable, binary file object.

The *fmt* argument specifies the format of the plist file and can be one of the following values:

- *FMT_XML*: XML formatted plist file
- *FMT_BINARY*: Binary formatted plist file

When *sort_keys* is true (the default) the keys for dictionaries will be written to the plist in sorted order, otherwise they will be written in the iteration order of the dictionary.

When *skipkeys* is false (the default) the function raises *TypeError* when a key of a dictionary is not a string, otherwise such keys are skipped.

A *TypeError* will be raised if the object is of an unsupported type or a container that contains objects of unsupported types.

An *OverflowError* will be raised for integer values that cannot be represented in (binary) plist files.

New in version 3.4.

plistlib.dumps(*value*, *, *fmt=FMT_XML*, *sort_keys=True*, *skipkeys=False*)
Return *value* as a plist-formatted bytes object. See the documentation for *dump()* for an explanation of the keyword arguments of this function.

New in version 3.4.

The following functions are deprecated:

plistlib.readPlist(*pathOrFile*)
Read a plist file. *pathOrFile* may be either a file name or a (readable and binary) file object. Returns the unpacked root object (which usually is a dictionary).

This function calls *load()* to do the actual work, see the documentation of *that function* for an explanation of the keyword arguments.

Deprecated since version 3.4: Use *load()* instead.

Changed in version 3.7: Dict values in the result are now normal dicts. You no longer can use attribute access to access items of these dictionaries.

plistlib.writePlist(*rootObject*, *pathOrFile*)
Write *rootObject* to an XML plist file. *pathOrFile* may be either a file name or a (writable and binary) file object

Deprecated since version 3.4: Use *dump()* instead.

plistlib.readPlistFromBytes(*data*)
Read a plist data from a bytes object. Return the root object.

See *load()* for a description of the keyword arguments.

Deprecated since version 3.4: Use *loads()* instead.

Changed in version 3.7: Dict values in the result are now normal dicts. You no longer can use attribute access to access items of these dictionaries.

plistlib.writePlistToBytes(*rootObject*)
Return *rootObject* as an XML plist-formatted bytes object.

Deprecated since version 3.4: Use *dumps()* instead.

The following classes are available:

class plistlib.Data(*data*)
Return a "data" wrapper object around the bytes object *data*. This is used in functions converting from/to plists to represent the `<data>` type available in plists.

It has one attribute, `data`, that can be used to retrieve the Python bytes object stored in it.

Deprecated since version 3.4: Use a *bytes* object instead.

The following constants are available:

plistlib.FMT_XML
The XML format for plist files.

New in version 3.4.

plistlib.FMT_BINARY
The binary format for plist files

New in version 3.4.

14.5.1 Examples

Generating a plist:

```
pl = dict(
    aString = "Doodah",
    aList = ["A", "B", 12, 32.1, [1, 2, 3]],
    aFloat = 0.1,
    anInt = 728,
    aDict = dict(
        anotherString = "<hello & hi there!>",
        aThirdString = "M\xe4ssig, Ma\xdf",
        aTrueValue = True,
        aFalseValue = False,
    ),
    someData = b"<binary gunk>",
    someMoreData = b"<lots of binary gunk>" * 10,
    aDate = datetime.datetime.fromtimestamp(time.mktime(time.gmtime())),
```

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```
)
with open(fileName, 'wb') as fp:
    dump(pl, fp)
```

Parsing a plist:

```
with open(fileName, 'rb') as fp:
    pl = load(fp)
print(pl["aKey"])
```

CHAPTER

FIFTEEN

CRYPTOGRAPHIC SERVICES

The modules described in this chapter implement various algorithms of a cryptographic nature. They are available at the discretion of the installation. On Unix systems, the *crypt* module may also be available. Here's an overview:

15.1 hashlib — Secure hashes and message digests

Source code: Lib/hashlib.py

This module implements a common interface to many different secure hash and message digest algorithms. Included are the FIPS secure hash algorithms SHA1, SHA224, SHA256, SHA384, and SHA512 (defined in FIPS 180-2) as well as RSA's MD5 algorithm (defined in Internet **RFC 1321**). The terms "secure hash" and "message digest" are interchangeable. Older algorithms were called message digests. The modern term is secure hash.

Note: If you want the adler32 or crc32 hash functions, they are available in the *zlib* module.

Warning: Some algorithms have known hash collision weaknesses, refer to the "See also" section at the end.

15.1.1 Hash algorithms

There is one constructor method named for each type of *hash*. All return a hash object with the same simple interface. For example: use `sha256()` to create a SHA-256 hash object. You can now feed this object with *bytes-like objects* (normally *bytes*) using the `update()` method. At any point you can ask it for the *digest* of the concatenation of the data fed to it so far using the `digest()` or `hexdigest()` methods.

Note: For better multithreading performance, the Python *GIL* is released for data larger than 2047 bytes at object creation or on update.

Note: Feeding string objects into `update()` is not supported, as hashes work on bytes, not on characters.

Constructors for hash algorithms that are always present in this module are `sha1()`, `sha224()`, `sha256()`, `sha384()`, `sha512()`, *blake2b()*, and *blake2s()*. `md5()` is normally available as well, though it may be

missing if you are using a rare "FIPS compliant" build of Python. Additional algorithms may also be available depending upon the OpenSSL library that Python uses on your platform. On most platforms the `sha3_224()`, `sha3_256()`, `sha3_384()`, `sha3_512()`, `shake_128()`, `shake_256()` are also available.

New in version 3.6: SHA3 (Keccak) and SHAKE constructors `sha3_224()`, `sha3_256()`, `sha3_384()`, `sha3_512()`, `shake_128()`, `shake_256()`.

New in version 3.6: *blake2b()* and *blake2s()* were added.

For example, to obtain the digest of the byte string `b'Nobody inspects the spammish repetition'`:

```
>>> import hashlib
>>> m = hashlib.sha256()
>>> m.update(b"Nobody inspects")
>>> m.update(b" the spammish repetition")
>>> m.digest()
b'\x03\x1e\xdd}Ae\x15\x93\xc5\xfe\\\x00o\xa5u+7\xfd\xdf\xf7\xbcN\x84:\xa6\xaf\x0c\x95\x0fK\x94\x06'
>>> m.digest_size
32
>>> m.block_size
64
```

More condensed:

```
>>> hashlib.sha224(b"Nobody inspects the spammish repetition").hexdigest()
'a4337bc45a8fc544c03f52dc550cd6e1e87021bc896588bd79e901e2'
```

hashlib.new(*name*[, *data*])
: Is a generic constructor that takes the string name of the desired algorithm as its first parameter. It also exists to allow access to the above listed hashes as well as any other algorithms that your OpenSSL library may offer. The named constructors are much faster than *new()* and should be preferred.

Using *new()* with an algorithm provided by OpenSSL:

```
>>> h = hashlib.new('ripemd160')
>>> h.update(b"Nobody inspects the spammish repetition")
>>> h.hexdigest()
'cc4a5ce1b3df48aec5d22d1f16b894a0b894eccc'
```

Hashlib provides the following constant attributes:

hashlib.algorithms_guaranteed
: A set containing the names of the hash algorithms guaranteed to be supported by this module on all platforms. Note that 'md5' is in this list despite some upstream vendors offering an odd "FIPS compliant" Python build that excludes it.

  New in version 3.2.

hashlib.algorithms_available
: A set containing the names of the hash algorithms that are available in the running Python interpreter. These names will be recognized when passed to *new()*. *algorithms_guaranteed* will always be a subset. The same algorithm may appear multiple times in this set under different names (thanks to OpenSSL).

  New in version 3.2.

The following values are provided as constant attributes of the hash objects returned by the constructors:

hash.digest_size
: The size of the resulting hash in bytes.

hash.block_size
: The internal block size of the hash algorithm in bytes.

A hash object has the following attributes:

`hash.name`
: The canonical name of this hash, always lowercase and always suitable as a parameter to *new()* to create another hash of this type.

  Changed in version 3.4: The name attribute has been present in CPython since its inception, but until Python 3.4 was not formally specified, so may not exist on some platforms.

A hash object has the following methods:

`hash.update(`*arg*`)`
: Update the hash object with the object *arg*, which must be interpretable as a buffer of bytes. Repeated calls are equivalent to a single call with the concatenation of all the arguments: `m.update(a); m.update(b)` is equivalent to `m.update(a+b)`.

  Changed in version 3.1: The Python GIL is released to allow other threads to run while hash updates on data larger than 2047 bytes is taking place when using hash algorithms supplied by OpenSSL.

`hash.digest()`
: Return the digest of the data passed to the *update()* method so far. This is a bytes object of size *digest_size* which may contain bytes in the whole range from 0 to 255.

`hash.hexdigest()`
: Like *digest()* except the digest is returned as a string object of double length, containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

`hash.copy()`
: Return a copy ("clone") of the hash object. This can be used to efficiently compute the digests of data sharing a common initial substring.

15.1.2 SHAKE variable length digests

The `shake_128()` and `shake_256()` algorithms provide variable length digests with length_in_bits//2 up to 128 or 256 bits of security. As such, their digest methods require a length. Maximum length is not limited by the SHAKE algorithm.

`shake.digest(`*length*`)`
: Return the digest of the data passed to the `update()` method so far. This is a bytes object of size `length` which may contain bytes in the whole range from 0 to 255.

`shake.hexdigest(`*length*`)`
: Like *digest()* except the digest is returned as a string object of double length, containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

15.1.3 Key derivation

Key derivation and key stretching algorithms are designed for secure password hashing. Naive algorithms such as `sha1(password)` are not resistant against brute-force attacks. A good password hashing function must be tunable, slow, and include a salt.

`hashlib.pbkdf2_hmac(`*hash_name*, *password*, *salt*, *iterations*, *dklen=None*`)`
: The function provides PKCS#5 password-based key derivation function 2. It uses HMAC as pseudo-random function.

  The string *hash_name* is the desired name of the hash digest algorithm for HMAC, e.g. 'sha1' or 'sha256'. *password* and *salt* are interpreted as buffers of bytes. Applications and libraries should limit *password* to a sensible length (e.g. 1024). *salt* should be about 16 or more bytes from a proper source, e.g. *os.urandom()*.

The number of *iterations* should be chosen based on the hash algorithm and computing power. As of 2013, at least 100,000 iterations of SHA-256 are suggested.

dklen is the length of the derived key. If *dklen* is `None` then the digest size of the hash algorithm *hash_name* is used, e.g. 64 for SHA-512.

```
>>> import hashlib, binascii
>>> dk = hashlib.pbkdf2_hmac('sha256', b'password', b'salt', 100000)
>>> binascii.hexlify(dk)
b'0394a2ede332c9a13eb82e9b24631604c31df978b4e2f0fbd2c549944f9d79a5'
```

New in version 3.4.

Note: A fast implementation of *pbkdf2_hmac* is available with OpenSSL. The Python implementation uses an inline version of *hmac*. It is about three times slower and doesn't release the GIL.

`hashlib.scrypt`(*password*, ***, *salt*, *n*, *r*, *p*, *maxmem=0*, *dklen=64*)

The function provides scrypt password-based key derivation function as defined in **RFC 7914**.

password and *salt* must be bytes-like objects. Applications and libraries should limit *password* to a sensible length (e.g. 1024). *salt* should be about 16 or more bytes from a proper source, e.g. *os.urandom()*.

n is the CPU/Memory cost factor, *r* the block size, *p* parallelization factor and *maxmem* limits memory (OpenSSL 1.1.0 defaults to 32 MiB). *dklen* is the length of the derived key.

Availability: OpenSSL 1.1+

New in version 3.6.

15.1.4 BLAKE2

BLAKE2 is a cryptographic hash function defined in **RFC 7693** that comes in two flavors:

- **BLAKE2b**, optimized for 64-bit platforms and produces digests of any size between 1 and 64 bytes,
- **BLAKE2s**, optimized for 8- to 32-bit platforms and produces digests of any size between 1 and 32 bytes.

BLAKE2 supports **keyed mode** (a faster and simpler replacement for HMAC), **salted hashing**, **personalization**, and **tree hashing**.

Hash objects from this module follow the API of standard library's *hashlib* objects.

Creating hash objects

New hash objects are created by calling constructor functions:

`hashlib.blake2b`(*data=b''*, *digest_size=64*, *key=b''*, *salt=b''*, *person=b''*, *fanout=1*, *depth=1*, *leaf_size=0*, *node_offset=0*, *node_depth=0*, *inner_size=0*, *last_node=False*)

`hashlib.blake2s`(*data=b''*, *digest_size=32*, *key=b''*, *salt=b''*, *person=b''*, *fanout=1*, *depth=1*, *leaf_size=0*, *node_offset=0*, *node_depth=0*, *inner_size=0*, *last_node=False*)

These functions return the corresponding hash objects for calculating BLAKE2b or BLAKE2s. They optionally take these general parameters:

- *data*: initial chunk of data to hash, which must be interpretable as buffer of bytes.
- *digest_size*: size of output digest in bytes.
- *key*: key for keyed hashing (up to 64 bytes for BLAKE2b, up to 32 bytes for BLAKE2s).

- *salt*: salt for randomized hashing (up to 16 bytes for BLAKE2b, up to 8 bytes for BLAKE2s).
- *person*: personalization string (up to 16 bytes for BLAKE2b, up to 8 bytes for BLAKE2s).

The following table shows limits for general parameters (in bytes):

Hash	digest_size	len(key)	len(salt)	len(person)
BLAKE2b	64	64	16	16
BLAKE2s	32	32	8	8

Note: BLAKE2 specification defines constant lengths for salt and personalization parameters, however, for convenience, this implementation accepts byte strings of any size up to the specified length. If the length of the parameter is less than specified, it is padded with zeros, thus, for example, `b'salt'` and `b'salt\x00'` is the same value. (This is not the case for *key*.)

These sizes are available as module *constants* described below.

Constructor functions also accept the following tree hashing parameters:

- *fanout*: fanout (0 to 255, 0 if unlimited, 1 in sequential mode).
- *depth*: maximal depth of tree (1 to 255, 255 if unlimited, 1 in sequential mode).
- *leaf_size*: maximal byte length of leaf (0 to 2**32-1, 0 if unlimited or in sequential mode).
- *node_offset*: node offset (0 to 2**64-1 for BLAKE2b, 0 to 2**48-1 for BLAKE2s, 0 for the first, leftmost, leaf, or in sequential mode).
- *node_depth*: node depth (0 to 255, 0 for leaves, or in sequential mode).
- *inner_size*: inner digest size (0 to 64 for BLAKE2b, 0 to 32 for BLAKE2s, 0 in sequential mode).
- *last_node*: boolean indicating whether the processed node is the last one (*False* for sequential mode).

See section 2.10 in BLAKE2 specification for comprehensive review of tree hashing.

Constants

`blake2b.SALT_SIZE`

`blake2s.SALT_SIZE`

Salt length (maximum length accepted by constructors).

`blake2b.PERSON_SIZE`

`blake2s.PERSON_SIZE`

Personalization string length (maximum length accepted by constructors).

`blake2b.MAX_KEY_SIZE`

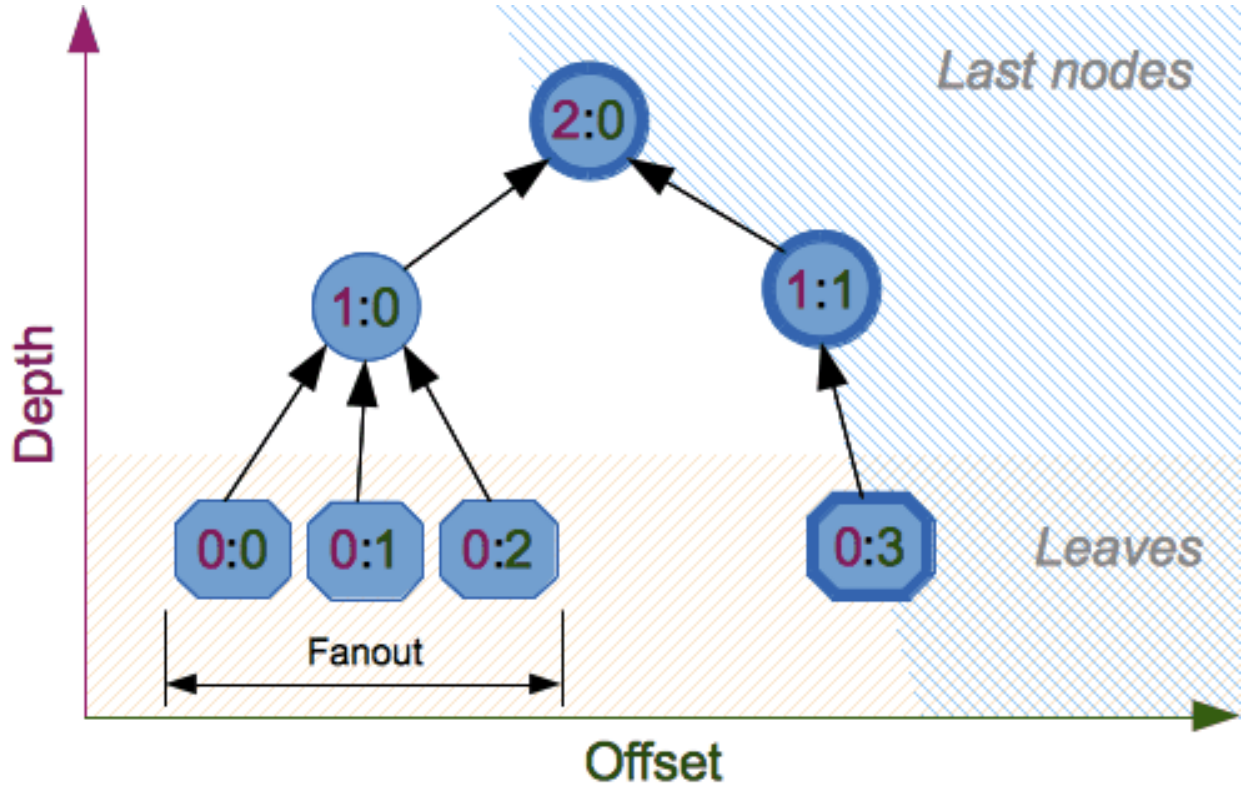
`blake2s.MAX_KEY_SIZE`

Maximum key size.

`blake2b.MAX_DIGEST_SIZE`

`blake2s.MAX_DIGEST_SIZE`

Maximum digest size that the hash function can output.



Examples

Simple hashing

To calculate hash of some data, you should first construct a hash object by calling the appropriate constructor function (*blake2b()* or *blake2s()*), then update it with the data by calling `update()` on the object, and, finally, get the digest out of the object by calling `digest()` (or `hexdigest()` for hex-encoded string).

```
>>> from hashlib import blake2b
>>> h = blake2b()
>>> h.update(b'Hello world')
>>> h.hexdigest()

↪'6ff843ba685842aa82031d3f53c48b66326df7639a63d128974c5c14f31a0f33343a8c65551134ed1ae0f2b0dd2bb495dc81039e3eeb0aa1
↪'
```

As a shortcut, you can pass the first chunk of data to update directly to the constructor as the first argument (or as *data* keyword argument):

```
>>> from hashlib import blake2b
>>> blake2b(b'Hello world').hexdigest()

↪'6ff843ba685842aa82031d3f53c48b66326df7639a63d128974c5c14f31a0f33343a8c65551134ed1ae0f2b0dd2bb495dc81039e3eeb0aa1
↪'
```

You can call *hash.update()* as many times as you need to iteratively update the hash:

```
>>> from hashlib import blake2b
>>> items = [b'Hello', b' ', b'world']
>>> h = blake2b()
>>> for item in items:
...     h.update(item)
>>> h.hexdigest()

↪'6ff843ba685842aa82031d3f53c48b66326df7639a63d128974c5c14f31a0f33343a8c65551134ed1ae0f2b0dd2bb495dc81039e3eeb0aa1
↪'
```

Using different digest sizes

BLAKE2 has configurable size of digests up to 64 bytes for BLAKE2b and up to 32 bytes for BLAKE2s. For example, to replace SHA-1 with BLAKE2b without changing the size of output, we can tell BLAKE2b to produce 20-byte digests:

```
>>> from hashlib import blake2b
>>> h = blake2b(digest_size=20)
>>> h.update(b'Replacing SHA1 with the more secure function')
>>> h.hexdigest()
'd24f26cf8de66472d58d4e1b1774b4c9158b1f4c'
>>> h.digest_size
20
>>> len(h.digest())
20
```

Hash objects with different digest sizes have completely different outputs (shorter hashes are *not* prefixes of longer hashes); BLAKE2b and BLAKE2s produce different outputs even if the output length is the same:

```
>>> from hashlib import blake2b, blake2s
>>> blake2b(digest_size=10).hexdigest()
'6fa1d8fcfd719046d762'
>>> blake2b(digest_size=11).hexdigest()
'eb6ec15daf9546254f0809'
>>> blake2s(digest_size=10).hexdigest()
'1bf21a98c78a1c376ae9'
>>> blake2s(digest_size=11).hexdigest()
'567004bf96e4a25773ebf4'
```

Keyed hashing

Keyed hashing can be used for authentication as a faster and simpler replacement for Hash-based message authentication code (HMAC). BLAKE2 can be securely used in prefix-MAC mode thanks to the indifferentiability property inherited from BLAKE.

This example shows how to get a (hex-encoded) 128-bit authentication code for message `b'message data'` with key `b'pseudorandom key'`:

```
>>> from hashlib import blake2b
>>> h = blake2b(key=b'pseudorandom key', digest_size=16)
>>> h.update(b'message data')
>>> h.hexdigest()
'3d363ff7401e02026f4a4687d4863ced'
```

As a practical example, a web application can symmetrically sign cookies sent to users and later verify them to make sure they weren't tampered with:

```
>>> from hashlib import blake2b
>>> from hmac import compare_digest
>>>
>>> SECRET_KEY = b'pseudorandomly generated server secret key'
>>> AUTH_SIZE = 16
>>>
>>> def sign(cookie):
...     h = blake2b(digest_size=AUTH_SIZE, key=SECRET_KEY)
...     h.update(cookie)
...     return h.hexdigest().encode('utf-8')
>>>
>>> def verify(cookie, sig):
...     good_sig = sign(cookie)
...     return compare_digest(good_sig, sig)
>>>
>>> cookie = b'user-alice'
>>> sig = sign(cookie)
>>> print("{0},{1}".format(cookie.decode('utf-8'), sig))
user-alice,b'43b3c982cf697e0c5ab22172d1ca7421'
>>> verify(cookie, sig)
True
>>> verify(b'user-bob', sig)
False
>>> verify(cookie, b'0102030405060708090a0b0c0d0e0f00')
False
```

Even though there's a native keyed hashing mode, BLAKE2 can, of course, be used in HMAC construction with *hmac* module:

```
>>> import hmac, hashlib
>>> m = hmac.new(b'secret key', digestmod=hashlib.blake2s)
>>> m.update(b'message')
>>> m.hexdigest()
'e3c8102868d28b5ff85fc35dda07329970d1a01e273c37481326fe0c861c8142'
```

Randomized hashing

By setting *salt* parameter users can introduce randomization to the hash function. Randomized hashing is useful for protecting against collision attacks on the hash function used in digital signatures.

> Randomized hashing is designed for situations where one party, the message preparer, generates all or part of a message to be signed by a second party, the message signer. If the message preparer is able to find cryptographic hash function collisions (i.e., two messages producing the same hash value), then they might prepare meaningful versions of the message that would produce the same hash value and digital signature, but with different results (e.g., transferring $1,000,000 to an account, rather than $10). Cryptographic hash functions have been designed with collision resistance as a major goal, but the current concentration on attacking cryptographic hash functions may result in a given cryptographic hash function providing less collision resistance than expected. Randomized hashing offers the signer additional protection by reducing the likelihood that a preparer can generate two or more messages that ultimately yield the same hash value during the digital signature generation process — even if it is practical to find collisions for the hash function. However, the use of randomized hashing may reduce the amount of security provided by a digital signature when all portions of the message are prepared by the signer.

(NIST SP-800-106 "Randomized Hashing for Digital Signatures")

In BLAKE2 the salt is processed as a one-time input to the hash function during initialization, rather than as an input to each compression function.

Warning: *Salted hashing* (or just hashing) with BLAKE2 or any other general-purpose cryptographic hash function, such as SHA-256, is not suitable for hashing passwords. See BLAKE2 FAQ for more information.

```
>>> import os
>>> from hashlib import blake2b
>>> msg = b'some message'
>>> # Calculate the first hash with a random salt.
>>> salt1 = os.urandom(blake2b.SALT_SIZE)
>>> h1 = blake2b(salt=salt1)
>>> h1.update(msg)
>>> # Calculate the second hash with a different random salt.
>>> salt2 = os.urandom(blake2b.SALT_SIZE)
>>> h2 = blake2b(salt=salt2)
>>> h2.update(msg)
>>> # The digests are different.
>>> h1.digest() != h2.digest()
True
```

Personalization

Sometimes it is useful to force hash function to produce different digests for the same input for different purposes. Quoting the authors of the Skein hash function:

> We recommend that all application designers seriously consider doing this; we have seen many protocols where a hash that is computed in one part of the protocol can be used in an entirely different part because two hash computations were done on similar or related data, and the attacker can force the application to make the hash inputs the same. Personalizing each hash function used in the protocol summarily stops this type of attack.
>
> (The Skein Hash Function Family, p. 21)

BLAKE2 can be personalized by passing bytes to the *person* argument:

```
>>> from hashlib import blake2b
>>> FILES_HASH_PERSON = b'MyApp Files Hash'
>>> BLOCK_HASH_PERSON = b'MyApp Block Hash'
>>> h = blake2b(digest_size=32, person=FILES_HASH_PERSON)
>>> h.update(b'the same content')
>>> h.hexdigest()
'20d9cd024d4fb086aae819a1432dd2466de12947831b75c5a30cf2676095d3b4'
>>> h = blake2b(digest_size=32, person=BLOCK_HASH_PERSON)
>>> h.update(b'the same content')
>>> h.hexdigest()
'cf68fb5761b9c44e7878bfb2c4c9aea52264a80b75005e65619778de59f383a3'
```

Personalization together with the keyed mode can also be used to derive different keys from a single one.

```
>>> from hashlib import blake2s
>>> from base64 import b64decode, b64encode
```

(continues on next page)

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```
>>> orig_key = b64decode(b'Rm5EPJai72qcK3RGBpW3vPNfZy5OZothY+kHY6h21KM=')
>>> enc_key = blake2s(key=orig_key, person=b'kEncrypt').digest()
>>> mac_key = blake2s(key=orig_key, person=b'kMAC').digest()
>>> print(b64encode(enc_key).decode('utf-8'))
rbPb15S/Z9t+agffno5wuhB77VbRi6F9Iv2qIxU7WHw=
>>> print(b64encode(mac_key).decode('utf-8'))
G9GtHFE1YluXY1zWPlYk1e/nWfu0WSEb0KRcjhDeP/o=
```

Tree mode

Here's an example of hashing a minimal tree with two leaf nodes:

```
  10
 /  \
00  01
```

This example uses 64-byte internal digests, and returns the 32-byte final digest:

```
>>> from hashlib import blake2b
>>>
>>> FANOUT = 2
>>> DEPTH = 2
>>> LEAF_SIZE = 4096
>>> INNER_SIZE = 64
>>>
>>> buf = bytearray(6000)
>>>
>>> # Left leaf
... h00 = blake2b(buf[0:LEAF_SIZE], fanout=FANOUT, depth=DEPTH,
...               leaf_size=LEAF_SIZE, inner_size=INNER_SIZE,
...               node_offset=0, node_depth=0, last_node=False)
>>> # Right leaf
... h01 = blake2b(buf[LEAF_SIZE:], fanout=FANOUT, depth=DEPTH,
...               leaf_size=LEAF_SIZE, inner_size=INNER_SIZE,
...               node_offset=1, node_depth=0, last_node=True)
>>> # Root node
... h10 = blake2b(digest_size=32, fanout=FANOUT, depth=DEPTH,
...               leaf_size=LEAF_SIZE, inner_size=INNER_SIZE,
...               node_offset=0, node_depth=1, last_node=True)
>>> h10.update(h00.digest())
>>> h10.update(h01.digest())
>>> h10.hexdigest()
'3ad2a9b37c6070e374c7a8c508fe20ca86b6ed54e286e93a0318e95e881db5aa'
```

Credits

BLAKE2 was designed by *Jean-Philippe Aumasson*, *Samuel Neves*, *Zooko Wilcox-O'Hearn*, and *Christian Winnerlein* based on SHA-3 finalist BLAKE created by *Jean-Philippe Aumasson*, *Luca Henzen*, *Willi Meier*, and *Raphael C.-W. Phan*.

It uses core algorithm from ChaCha cipher designed by *Daniel J. Bernstein*.

The stdlib implementation is based on pyblake2 module. It was written by *Dmitry Chestnykh* based on C implementation written by *Samuel Neves*. The documentation was copied from pyblake2 and written by *Dmitry Chestnykh*.

The C code was partly rewritten for Python by *Christian Heimes*.

The following public domain dedication applies for both C hash function implementation, extension code, and this documentation:

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The following people have helped with development or contributed their changes to the project and the public domain according to the Creative Commons Public Domain Dedication 1.0 Universal:

- *Alexandr Sokolovskiy*

See also:

Module *hmac* A module to generate message authentication codes using hashes.

Module *base64* Another way to encode binary hashes for non-binary environments.

https://blake2.net Official BLAKE2 website.

https://csrc.nist.gov/csrc/media/publications/fips/180/2/archive/2002-08-01/documents/fips180-2.pdf The FIPS 180-2 publication on Secure Hash Algorithms.

https://en.wikipedia.org/wiki/Cryptographic_hash_function#Cryptographic_hash_algorithms Wikipedia article with information on which algorithms have known issues and what that means regarding their use.

https://www.ietf.org/rfc/rfc2898.txt PKCS #5: Password-Based Cryptography Specification Version 2.0

15.2 hmac — Keyed-Hashing for Message Authentication

Source code: Lib/hmac.py

This module implements the HMAC algorithm as described by **RFC 2104**.

`hmac.new`(*key*, *msg=None*, *digestmod=None*)

Return a new hmac object. *key* is a bytes or bytearray object giving the secret key. If *msg* is present, the method call `update(msg)` is made. *digestmod* is the digest name, digest constructor or module for the HMAC object to use. It supports any name suitable to *hashlib.new()* and defaults to the `hashlib.md5` constructor.

Changed in version 3.4: Parameter *key* can be a bytes or bytearray object. Parameter *msg* can be of any type supported by *hashlib*. Parameter *digestmod* can be the name of a hash algorithm.

Deprecated since version 3.4, will be removed in version 3.8: MD5 as implicit default digest for *digestmod* is deprecated.

`hmac.digest`(*key*, *msg*, *digest*)

Return digest of *msg* for given secret *key* and *digest*. The function is equivalent to `HMAC(key, msg, digest).digest()`, but uses an optimized C or inline implementation, which is faster for messages that fit into memory. The parameters *key*, *msg*, and *digest* have the same meaning as in *new()*.

CPython implementation detail, the optimized C implementation is only used when *digest* is a string and name of a digest algorithm, which is supported by OpenSSL.

New in version 3.7.

An HMAC object has the following methods:

HMAC.update(*msg*)
Update the hmac object with *msg*. Repeated calls are equivalent to a single call with the concatenation of all the arguments: `m.update(a); m.update(b)` is equivalent to `m.update(a + b)`.

Changed in version 3.4: Parameter *msg* can be of any type supported by *hashlib*.

HMAC.digest()
Return the digest of the bytes passed to the *update()* method so far. This bytes object will be the same length as the *digest_size* of the digest given to the constructor. It may contain non-ASCII bytes, including NUL bytes.

> **Warning:** When comparing the output of *digest()* to an externally-supplied digest during a verification routine, it is recommended to use the *compare_digest()* function instead of the `==` operator to reduce the vulnerability to timing attacks.

HMAC.hexdigest()
Like *digest()* except the digest is returned as a string twice the length containing only hexadecimal digits. This may be used to exchange the value safely in email or other non-binary environments.

> **Warning:** When comparing the output of *hexdigest()* to an externally-supplied digest during a verification routine, it is recommended to use the *compare_digest()* function instead of the `==` operator to reduce the vulnerability to timing attacks.

HMAC.copy()
Return a copy ("clone") of the hmac object. This can be used to efficiently compute the digests of strings that share a common initial substring.

A hash object has the following attributes:

HMAC.digest_size
The size of the resulting HMAC digest in bytes.

HMAC.block_size
The internal block size of the hash algorithm in bytes.

New in version 3.4.

HMAC.name
The canonical name of this HMAC, always lowercase, e.g. `hmac-md5`.

New in version 3.4.

This module also provides the following helper function:

hmac.compare_digest(*a*, *b*)
Return `a == b`. This function uses an approach designed to prevent timing analysis by avoiding content-based short circuiting behaviour, making it appropriate for cryptography. *a* and *b* must both be of the same type: either *str* (ASCII only, as e.g. returned by *HMAC.hexdigest()*), or a *bytes-like object*.

> **Note:** If *a* and *b* are of different lengths, or if an error occurs, a timing attack could theoretically reveal information about the types and lengths of *a* and *b*—but not their values.

New in version 3.3.

See also:

Module *hashlib* The Python module providing secure hash functions.

15.3 secrets — Generate secure random numbers for managing secrets

New in version 3.6.

Source code: Lib/secrets.py

The *secrets* module is used for generating cryptographically strong random numbers suitable for managing data such as passwords, account authentication, security tokens, and related secrets.

In particularly, *secrets* should be used in preference to the default pseudo-random number generator in the *random* module, which is designed for modelling and simulation, not security or cryptography.

See also:

PEP 506

15.3.1 Random numbers

The *secrets* module provides access to the most secure source of randomness that your operating system provides.

class secrets.SystemRandom
A class for generating random numbers using the highest-quality sources provided by the operating system. See *random.SystemRandom* for additional details.

secrets.choice(*sequence*)
Return a randomly-chosen element from a non-empty sequence.

secrets.randbelow(*n*)
Return a random int in the range [0, *n*).

secrets.randbits(*k*)
Return an int with *k* random bits.

15.3.2 Generating tokens

The *secrets* module provides functions for generating secure tokens, suitable for applications such as password resets, hard-to-guess URLs, and similar.

secrets.token_bytes([*nbytes=None*])
Return a random byte string containing *nbytes* number of bytes. If *nbytes* is `None` or not supplied, a reasonable default is used.

```
>>> token_bytes(16)
b'\xebr\x17D*t\xae\xd4\xe3S\xb6\xe2\xebP1\x8b'
```

secrets.token_hex([*nbytes=None*])
Return a random text string, in hexadecimal. The string has *nbytes* random bytes, each byte converted to two hex digits. If *nbytes* is `None` or not supplied, a reasonable default is used.

```
>>> token_hex(16)
'f9bf78b9a18ce6d46a0cd2b0b86df9da'
```

secrets.token_urlsafe([*nbytes=None*])
Return a random URL-safe text string, containing *nbytes* random bytes. The text is Base64 encoded, so on average each byte results in approximately 1.3 characters. If *nbytes* is `None` or not supplied, a reasonable default is used.

```
>>> token_urlsafe(16)
'Drmhze6EPcv0fN_81Bj-nA'
```

How many bytes should tokens use?

To be secure against brute-force attacks, tokens need to have sufficient randomness. Unfortunately, what is considered sufficient will necessarily increase as computers get more powerful and able to make more guesses in a shorter period. As of 2015, it is believed that 32 bytes (256 bits) of randomness is sufficient for the typical use-case expected for the *secrets* module.

For those who want to manage their own token length, you can explicitly specify how much randomness is used for tokens by giving an *int* argument to the various `token_*` functions. That argument is taken as the number of bytes of randomness to use.

Otherwise, if no argument is provided, or if the argument is `None`, the `token_*` functions will use a reasonable default instead.

Note: That default is subject to change at any time, including during maintenance releases.

15.3.3 Other functions

secrets.compare_digest(*a*, *b*)
Return `True` if strings *a* and *b* are equal, otherwise `False`, in such a way as to reduce the risk of timing attacks. See *hmac.compare_digest()* for additional details.

15.3.4 Recipes and best practices

This section shows recipes and best practices for using *secrets* to manage a basic level of security.

Generate an eight-character alphanumeric password:

```
import string
alphabet = string.ascii_letters + string.digits
password = ''.join(choice(alphabet) for i in range(8))
```

Note: Applications should not store passwords in a recoverable format, whether plain text or encrypted. They should be salted and hashed using a cryptographically-strong one-way (irreversible) hash function.

Generate a ten-character alphanumeric password with at least one lowercase character, at least one uppercase character, and at least three digits:

```
import string
alphabet = string.ascii_letters + string.digits
while True:
    password = ''.join(choice(alphabet) for i in range(10))
    if (any(c.islower() for c in password)
```

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```
            and any(c.isupper() for c in password)
            and sum(c.isdigit() for c in password) >= 3):
        break
```

Generate an XKCD-style passphrase:

```
# On standard Linux systems, use a convenient dictionary file.
# Other platforms may need to provide their own word-list.
with open('/usr/share/dict/words') as f:
    words = [word.strip() for word in f]
    password = ' '.join(choice(words) for i in range(4))
```

Generate a hard-to-guess temporary URL containing a security token suitable for password recovery applications:

```
url = 'https://mydomain.com/reset=' + token_urlsafe()
```

CHAPTER

SIXTEEN

GENERIC OPERATING SYSTEM SERVICES

The modules described in this chapter provide interfaces to operating system features that are available on (almost) all operating systems, such as files and a clock. The interfaces are generally modeled after the Unix or C interfaces, but they are available on most other systems as well. Here's an overview:

16.1 os — Miscellaneous operating system interfaces

Source code: Lib/os.py

This module provides a portable way of using operating system dependent functionality. If you just want to read or write a file see *open()*, if you want to manipulate paths, see the *os.path* module, and if you want to read all the lines in all the files on the command line see the *fileinput* module. For creating temporary files and directories see the *tempfile* module, and for high-level file and directory handling see the *shutil* module.

Notes on the availability of these functions:

- The design of all built-in operating system dependent modules of Python is such that as long as the same functionality is available, it uses the same interface; for example, the function `os.stat(path)` returns stat information about *path* in the same format (which happens to have originated with the POSIX interface).
- Extensions peculiar to a particular operating system are also available through the *os* module, but using them is of course a threat to portability.
- All functions accepting path or file names accept both bytes and string objects, and result in an object of the same type, if a path or file name is returned.
- An "Availability: Unix" note means that this function is commonly found on Unix systems. It does not make any claims about its existence on a specific operating system.
- If not separately noted, all functions that claim "Availability: Unix" are supported on Mac OS X, which builds on a Unix core.

Note: All functions in this module raise *OSError* in the case of invalid or inaccessible file names and paths, or other arguments that have the correct type, but are not accepted by the operating system.

---

exception os.error
An alias for the built-in *OSError* exception.

os.name
The name of the operating system dependent module imported. The following names have currently been registered: `'posix'`, `'nt'`, `'java'`.

See also:

sys.platform has a finer granularity. *os.uname()* gives system-dependent version information.

The *platform* module provides detailed checks for the system's identity.

16.1.1 File Names, Command Line Arguments, and Environment Variables

In Python, file names, command line arguments, and environment variables are represented using the string type. On some systems, decoding these strings to and from bytes is necessary before passing them to the operating system. Python uses the file system encoding to perform this conversion (see *sys.getfilesystemencoding()*).

Changed in version 3.1: On some systems, conversion using the file system encoding may fail. In this case, Python uses the *surrogateescape encoding error handler*, which means that undecodable bytes are replaced by a Unicode character U+DCxx on decoding, and these are again translated to the original byte on encoding.

The file system encoding must guarantee to successfully decode all bytes below 128. If the file system encoding fails to provide this guarantee, API functions may raise UnicodeErrors.

16.1.2 Process Parameters

These functions and data items provide information and operate on the current process and user.

`os.ctermid()`
Return the filename corresponding to the controlling terminal of the process.

Availability: Unix.

`os.environ`
A *mapping* object representing the string environment. For example, `environ['HOME']` is the pathname of your home directory (on some platforms), and is equivalent to `getenv("HOME")` in C.

This mapping is captured the first time the *os* module is imported, typically during Python startup as part of processing `site.py`. Changes to the environment made after this time are not reflected in `os.environ`, except for changes made by modifying `os.environ` directly.

If the platform supports the *putenv()* function, this mapping may be used to modify the environment as well as query the environment. *putenv()* will be called automatically when the mapping is modified.

On Unix, keys and values use *sys.getfilesystemencoding()* and `'surrogateescape'` error handler. Use *environb* if you would like to use a different encoding.

Note: Calling *putenv()* directly does not change `os.environ`, so it's better to modify `os.environ`.

Note: On some platforms, including FreeBSD and Mac OS X, setting `environ` may cause memory leaks. Refer to the system documentation for `putenv()`.

If *putenv()* is not provided, a modified copy of this mapping may be passed to the appropriate process-creation functions to cause child processes to use a modified environment.

If the platform supports the *unsetenv()* function, you can delete items in this mapping to unset environment variables. *unsetenv()* will be called automatically when an item is deleted from `os.environ`, and when one of the `pop()` or `clear()` methods is called.

os.environb
: Bytes version of *environ*: a *mapping* object representing the environment as byte strings. *environ* and *environb* are synchronized (modify *environb* updates *environ*, and vice versa).

  environb is only available if *supports_bytes_environ* is True.

  New in version 3.2.

os.chdir(*path*)
os.fchdir(*fd*)
os.getcwd()
: These functions are described in *Files and Directories*.

os.fsencode(*filename*)
: Encode *path-like* *filename* to the filesystem encoding with 'surrogateescape' error handler, or 'strict' on Windows; return *bytes* unchanged.

  fsdecode() is the reverse function.

  New in version 3.2.

  Changed in version 3.6: Support added to accept objects implementing the *os.PathLike* interface.

os.fsdecode(*filename*)
: Decode the *path-like* *filename* from the filesystem encoding with 'surrogateescape' error handler, or 'strict' on Windows; return *str* unchanged.

  fsencode() is the reverse function.

  New in version 3.2.

  Changed in version 3.6: Support added to accept objects implementing the *os.PathLike* interface.

os.fspath(*path*)
: Return the file system representation of the path.

  If *str* or *bytes* is passed in, it is returned unchanged. Otherwise *__fspath__()* is called and its value is returned as long as it is a *str* or *bytes* object. In all other cases, *TypeError* is raised.

  New in version 3.6.

class os.PathLike
: An *abstract base class* for objects representing a file system path, e.g. *pathlib.PurePath*.

  New in version 3.6.

  abstractmethod __fspath__()
  : Return the file system path representation of the object.

    The method should only return a *str* or *bytes* object, with the preference being for *str*.

os.getenv(*key*, *default=None*)
: Return the value of the environment variable *key* if it exists, or *default* if it doesn't. *key*, *default* and the result are str.

  On Unix, keys and values are decoded with *sys.getfilesystemencoding()* and 'surrogateescape' error handler. Use *os.getenvb()* if you would like to use a different encoding.

  Availability: most flavors of Unix, Windows.

os.getenvb(*key*, *default=None*)
: Return the value of the environment variable *key* if it exists, or *default* if it doesn't. *key*, *default* and the result are bytes.

  getenvb() is only available if *supports_bytes_environ* is True.

  Availability: most flavors of Unix.

New in version 3.2.

os.get_exec_path(*env=None*)
Returns the list of directories that will be searched for a named executable, similar to a shell, when launching a process. *env*, when specified, should be an environment variable dictionary to lookup the PATH in. By default, when *env* is None, *environ* is used.

New in version 3.2.

os.getegid()
Return the effective group id of the current process. This corresponds to the "set id" bit on the file being executed in the current process.

Availability: Unix.

os.geteuid()
Return the current process's effective user id.

Availability: Unix.

os.getgid()
Return the real group id of the current process.

Availability: Unix.

os.getgrouplist(*user*, *group*)
Return list of group ids that *user* belongs to. If *group* is not in the list, it is included; typically, *group* is specified as the group ID field from the password record for *user*.

Availability: Unix.

New in version 3.3.

os.getgroups()
Return list of supplemental group ids associated with the current process.

Availability: Unix.

Note: On Mac OS X, *getgroups()* behavior differs somewhat from other Unix platforms. If the Python interpreter was built with a deployment target of 10.5 or earlier, *getgroups()* returns the list of effective group ids associated with the current user process; this list is limited to a system-defined number of entries, typically 16, and may be modified by calls to *setgroups()* if suitably privileged. If built with a deployment target greater than 10.5, *getgroups()* returns the current group access list for the user associated with the effective user id of the process; the group access list may change over the lifetime of the process, it is not affected by calls to *setgroups()*, and its length is not limited to 16. The deployment target value, MACOSX_DEPLOYMENT_TARGET, can be obtained with *sysconfig.get_config_var()*.

---

os.getlogin()
Return the name of the user logged in on the controlling terminal of the process. For most purposes, it is more useful to use *getpass.getuser()* since the latter checks the environment variables LOGNAME or USERNAME to find out who the user is, and falls back to pwd.getpwuid(os.getuid())[0] to get the login name of the current real user id.

Availability: Unix, Windows.

os.getpgid(*pid*)
Return the process group id of the process with process id *pid*. If *pid* is 0, the process group id of the current process is returned.

Availability: Unix.

os.**getpgrp**()
Return the id of the current process group.

Availability: Unix.

os.**getpid**()
Return the current process id.

os.**getppid**()
Return the parent's process id. When the parent process has exited, on Unix the id returned is the one of the init process (1), on Windows it is still the same id, which may be already reused by another process.

Availability: Unix, Windows.

Changed in version 3.2: Added support for Windows.

os.**getpriority**(*which*, *who*)
Get program scheduling priority. The value *which* is one of *PRIO_PROCESS*, *PRIO_PGRP*, or *PRIO_USER*, and *who* is interpreted relative to *which* (a process identifier for *PRIO_PROCESS*, process group identifier for *PRIO_PGRP*, and a user ID for *PRIO_USER*). A zero value for *who* denotes (respectively) the calling process, the process group of the calling process, or the real user ID of the calling process.

Availability: Unix.

New in version 3.3.

os.**PRIO_PROCESS**
os.**PRIO_PGRP**
os.**PRIO_USER**
Parameters for the *getpriority()* and *setpriority()* functions.

Availability: Unix.

New in version 3.3.

os.**getresuid**()
Return a tuple (ruid, euid, suid) denoting the current process's real, effective, and saved user ids.

Availability: Unix.

New in version 3.2.

os.**getresgid**()
Return a tuple (rgid, egid, sgid) denoting the current process's real, effective, and saved group ids.

Availability: Unix.

New in version 3.2.

os.**getuid**()
Return the current process's real user id.

Availability: Unix.

os.**initgroups**(*username*, *gid*)
Call the system initgroups() to initialize the group access list with all of the groups of which the specified username is a member, plus the specified group id.

Availability: Unix.

New in version 3.2.

os.**putenv**(*key*, *value*)
Set the environment variable named *key* to the string *value*. Such changes to the environment affect subprocesses started with *os.system()*, *popen()* or *fork()* and *execv()*.

Availability: most flavors of Unix, Windows.

Note: On some platforms, including FreeBSD and Mac OS X, setting `environ` may cause memory leaks. Refer to the system documentation for putenv.

When *putenv()* is supported, assignments to items in `os.environ` are automatically translated into corresponding calls to *putenv()*; however, calls to *putenv()* don't update `os.environ`, so it is actually preferable to assign to items of `os.environ`.

`os.setegid(`*egid*`)`
Set the current process's effective group id.

Availability: Unix.

`os.seteuid(`*euid*`)`
Set the current process's effective user id.

Availability: Unix.

`os.setgid(`*gid*`)`
Set the current process' group id.

Availability: Unix.

`os.setgroups(`*groups*`)`
Set the list of supplemental group ids associated with the current process to *groups*. *groups* must be a sequence, and each element must be an integer identifying a group. This operation is typically available only to the superuser.

Availability: Unix.

Note: On Mac OS X, the length of *groups* may not exceed the system-defined maximum number of effective group ids, typically 16. See the documentation for *getgroups()* for cases where it may not return the same group list set by calling setgroups().

`os.setpgrp()`
Call the system call `setpgrp()` or `setpgrp(0, 0)` depending on which version is implemented (if any). See the Unix manual for the semantics.

Availability: Unix.

`os.setpgid(`*pid*, *pgrp*`)`
Call the system call `setpgid()` to set the process group id of the process with id *pid* to the process group with id *pgrp*. See the Unix manual for the semantics.

Availability: Unix.

`os.setpriority(`*which*, *who*, *priority*`)`
Set program scheduling priority. The value *which* is one of *PRIO_PROCESS*, *PRIO_PGRP*, or *PRIO_USER*, and *who* is interpreted relative to *which* (a process identifier for *PRIO_PROCESS*, process group identifier for *PRIO_PGRP*, and a user ID for *PRIO_USER*). A zero value for *who* denotes (respectively) the calling process, the process group of the calling process, or the real user ID of the calling process. *priority* is a value in the range -20 to 19. The default priority is 0; lower priorities cause more favorable scheduling.

Availability: Unix

New in version 3.3.

`os.setregid(`*rgid*, *egid*`)`
Set the current process's real and effective group ids.

Availability: Unix.

os.**setresgid**(*rgid*, *egid*, *sgid*)
Set the current process's real, effective, and saved group ids.

Availability: Unix.

New in version 3.2.

os.**setresuid**(*ruid*, *euid*, *suid*)
Set the current process's real, effective, and saved user ids.

Availability: Unix.

New in version 3.2.

os.**setreuid**(*ruid*, *euid*)
Set the current process's real and effective user ids.

Availability: Unix.

os.**getsid**(*pid*)
Call the system call `getsid()`. See the Unix manual for the semantics.

Availability: Unix.

os.**setsid**()
Call the system call `setsid()`. See the Unix manual for the semantics.

Availability: Unix.

os.**setuid**(*uid*)
Set the current process's user id.

Availability: Unix.

os.**strerror**(*code*)
Return the error message corresponding to the error code in *code*. On platforms where `strerror()` returns `NULL` when given an unknown error number, *ValueError* is raised.

os.**supports_bytes_environ**
`True` if the native OS type of the environment is bytes (eg. `False` on Windows).

New in version 3.2.

os.**umask**(*mask*)
Set the current numeric umask and return the previous umask.

os.**uname**()
Returns information identifying the current operating system. The return value is an object with five attributes:

- `sysname` - operating system name
- `nodename` - name of machine on network (implementation-defined)
- `release` - operating system release
- `version` - operating system version
- `machine` - hardware identifier

For backwards compatibility, this object is also iterable, behaving like a five-tuple containing `sysname`, `nodename`, `release`, `version`, and `machine` in that order.

Some systems truncate `nodename` to 8 characters or to the leading component; a better way to get the hostname is *socket.gethostname()* or even `socket.gethostbyaddr(socket.gethostname())`.

Availability: recent flavors of Unix.

Changed in version 3.3: Return type changed from a tuple to a tuple-like object with named attributes.

os.unsetenv(*key*)
Unset (delete) the environment variable named *key*. Such changes to the environment affect subprocesses started with *os.system()*, *popen()* or *fork()* and *execv()*.

When *unsetenv()* is supported, deletion of items in os.environ is automatically translated into a corresponding call to *unsetenv()*; however, calls to *unsetenv()* don't update os.environ, so it is actually preferable to delete items of os.environ.

Availability: most flavors of Unix, Windows.

16.1.3 File Object Creation

This function creates new *file objects*. (See also *open()* for opening file descriptors.)

os.fdopen(*fd*, **args*, ***kwargs*)
Return an open file object connected to the file descriptor *fd*. This is an alias of the *open()* built-in function and accepts the same arguments. The only difference is that the first argument of *fdopen()* must always be an integer.

16.1.4 File Descriptor Operations

These functions operate on I/O streams referenced using file descriptors.

File descriptors are small integers corresponding to a file that has been opened by the current process. For example, standard input is usually file descriptor 0, standard output is 1, and standard error is 2. Further files opened by a process will then be assigned 3, 4, 5, and so forth. The name "file descriptor" is slightly deceptive; on Unix platforms, sockets and pipes are also referenced by file descriptors.

The *fileno()* method can be used to obtain the file descriptor associated with a *file object* when required. Note that using the file descriptor directly will bypass the file object methods, ignoring aspects such as internal buffering of data.

os.close(*fd*)
Close file descriptor *fd*.

Note: This function is intended for low-level I/O and must be applied to a file descriptor as returned by *os.open()* or *pipe()*. To close a "file object" returned by the built-in function *open()* or by *popen()* or *fdopen()*, use its *close()* method.

---

os.closerange(*fd_low*, *fd_high*)
Close all file descriptors from *fd_low* (inclusive) to *fd_high* (exclusive), ignoring errors. Equivalent to (but much faster than):

```
for fd in range(fd_low, fd_high):
    try:
        os.close(fd)
    except OSError:
        pass
```

os.device_encoding(*fd*)
Return a string describing the encoding of the device associated with *fd* if it is connected to a terminal; else return *None*.

os.dup(*fd*)
Return a duplicate of file descriptor *fd*. The new file descriptor is *non-inheritable*.

On Windows, when duplicating a standard stream (0: stdin, 1: stdout, 2: stderr), the new file descriptor is *inheritable*.

Changed in version 3.4: The new file descriptor is now non-inheritable.

`os.dup2`(*fd*, *fd2*, *inheritable=True*)
Duplicate file descriptor *fd* to *fd2*, closing the latter first if necessary. Return *fd2*. The new file descriptor is *inheritable* by default or non-inheritable if *inheritable* is `False`.

Changed in version 3.4: Add the optional *inheritable* parameter.

Changed in version 3.7: Return *fd2* on success. Previously, `None` was always returned.

`os.fchmod`(*fd*, *mode*)
Change the mode of the file given by *fd* to the numeric *mode*. See the docs for *chmod()* for possible values of *mode*. As of Python 3.3, this is equivalent to `os.chmod(fd, mode)`.

Availability: Unix.

`os.fchown`(*fd*, *uid*, *gid*)
Change the owner and group id of the file given by *fd* to the numeric *uid* and *gid*. To leave one of the ids unchanged, set it to -1. See *chown()*. As of Python 3.3, this is equivalent to `os.chown(fd, uid, gid)`.

Availability: Unix.

`os.fdatasync`(*fd*)
Force write of file with filedescriptor *fd* to disk. Does not force update of metadata.

Availability: Unix.

Note: This function is not available on MacOS.

`os.fpathconf`(*fd*, *name*)
Return system configuration information relevant to an open file. *name* specifies the configuration value to retrieve; it may be a string which is the name of a defined system value; these names are specified in a number of standards (POSIX.1, Unix 95, Unix 98, and others). Some platforms define additional names as well. The names known to the host operating system are given in the `pathconf_names` dictionary. For configuration variables not included in that mapping, passing an integer for *name* is also accepted.

If *name* is a string and is not known, *ValueError* is raised. If a specific value for *name* is not supported by the host system, even if it is included in `pathconf_names`, an *OSError* is raised with *errno.EINVAL* for the error number.

As of Python 3.3, this is equivalent to `os.pathconf(fd, name)`.

Availability: Unix.

`os.fstat`(*fd*)
Get the status of the file descriptor *fd*. Return a *stat_result* object.

As of Python 3.3, this is equivalent to `os.stat(fd)`.

See also:

The *stat()* function.

`os.fstatvfs`(*fd*)
Return information about the filesystem containing the file associated with file descriptor *fd*, like *statvfs()*. As of Python 3.3, this is equivalent to `os.statvfs(fd)`.

Availability: Unix.

os.fsync(*fd*)
Force write of file with filedescriptor *fd* to disk. On Unix, this calls the native `fsync()` function; on Windows, the MS `_commit()` function.

If you're starting with a buffered Python *file object* *f*, first do `f.flush()`, and then do `os.fsync(f.fileno())`, to ensure that all internal buffers associated with *f* are written to disk.

Availability: Unix, Windows.

os.ftruncate(*fd*, *length*)
Truncate the file corresponding to file descriptor *fd*, so that it is at most *length* bytes in size. As of Python 3.3, this is equivalent to `os.truncate(fd, length)`.

Availability: Unix, Windows.

Changed in version 3.5: Added support for Windows

os.get_blocking(*fd*)
Get the blocking mode of the file descriptor: `False` if the *O_NONBLOCK* flag is set, `True` if the flag is cleared.

See also *set_blocking()* and *socket.socket.setblocking()*.

Availability: Unix.

New in version 3.5.

os.isatty(*fd*)
Return `True` if the file descriptor *fd* is open and connected to a tty(-like) device, else `False`.

os.lockf(*fd*, *cmd*, *len*)
Apply, test or remove a POSIX lock on an open file descriptor. *fd* is an open file descriptor. *cmd* specifies the command to use - one of *F_LOCK*, *F_TLOCK*, *F_ULOCK* or *F_TEST*. *len* specifies the section of the file to lock.

Availability: Unix.

New in version 3.3.

os.F_LOCK
os.F_TLOCK
os.F_ULOCK
os.F_TEST
Flags that specify what action *lockf()* will take.

Availability: Unix.

New in version 3.3.

os.lseek(*fd*, *pos*, *how*)
Set the current position of file descriptor *fd* to position *pos*, modified by *how*: *SEEK_SET* or `0` to set the position relative to the beginning of the file; *SEEK_CUR* or `1` to set it relative to the current position; *SEEK_END* or `2` to set it relative to the end of the file. Return the new cursor position in bytes, starting from the beginning.

os.SEEK_SET
os.SEEK_CUR
os.SEEK_END
Parameters to the *lseek()* function. Their values are 0, 1, and 2, respectively.

New in version 3.3: Some operating systems could support additional values, like `os.SEEK_HOLE` or `os.SEEK_DATA`.

os.open(*path*, *flags*, *mode=0o777*, ***, *dir_fd=None*)
Open the file *path* and set various flags according to *flags* and possibly its mode according to *mode*.

When computing *mode*, the current umask value is first masked out. Return the file descriptor for the newly opened file. The new file descriptor is *non-inheritable*.

For a description of the flag and mode values, see the C run-time documentation; flag constants (like *O_RDONLY* and *O_WRONLY*) are defined in the *os* module. In particular, on Windows adding *O_BINARY* is needed to open files in binary mode.

This function can support *paths relative to directory descriptors* with the *dir_fd* parameter.

Changed in version 3.4: The new file descriptor is now non-inheritable.

Note: This function is intended for low-level I/O. For normal usage, use the built-in function *open()*, which returns a *file object* with `read()` and `write()` methods (and many more). To wrap a file descriptor in a file object, use *fdopen()*.

New in version 3.3: The *dir_fd* argument.

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the function now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

Changed in version 3.6: Accepts a *path-like object*.

The following constants are options for the *flags* parameter to the *open()* function. They can be combined using the bitwise OR operator `|`. Some of them are not available on all platforms. For descriptions of their availability and use, consult the *open(2)* manual page on Unix or the MSDN on Windows.

`os.O_RDONLY`
`os.O_WRONLY`
`os.O_RDWR`
`os.O_APPEND`
`os.O_CREAT`
`os.O_EXCL`
`os.O_TRUNC`
The above constants are available on Unix and Windows.

`os.O_DSYNC`
`os.O_RSYNC`
`os.O_SYNC`
`os.O_NDELAY`
`os.O_NONBLOCK`
`os.O_NOCTTY`
`os.O_CLOEXEC`
The above constants are only available on Unix.

Changed in version 3.3: Add *O_CLOEXEC* constant.

`os.O_BINARY`
`os.O_NOINHERIT`
`os.O_SHORT_LIVED`
`os.O_TEMPORARY`
`os.O_RANDOM`
`os.O_SEQUENTIAL`
`os.O_TEXT`
The above constants are only available on Windows.

`os.O_ASYNC`
`os.O_DIRECT`
`os.O_DIRECTORY`

os.O_NOFOLLOW
os.O_NOATIME
os.O_PATH
os.O_TMPFILE
os.O_SHLOCK
os.O_EXLOCK

The above constants are extensions and not present if they are not defined by the C library.

Changed in version 3.4: Add *O_PATH* on systems that support it. Add *O_TMPFILE*, only available on Linux Kernel 3.11 or newer.

os.openpty()

Open a new pseudo-terminal pair. Return a pair of file descriptors `(master, slave)` for the pty and the tty, respectively. The new file descriptors are *non-inheritable*. For a (slightly) more portable approach, use the *pty* module.

Availability: some flavors of Unix.

Changed in version 3.4: The new file descriptors are now non-inheritable.

os.pipe()

Create a pipe. Return a pair of file descriptors `(r, w)` usable for reading and writing, respectively. The new file descriptor is *non-inheritable*.

Availability: Unix, Windows.

Changed in version 3.4: The new file descriptors are now non-inheritable.

os.pipe2(*flags*)

Create a pipe with *flags* set atomically. *flags* can be constructed by ORing together one or more of these values: *O_NONBLOCK*, *O_CLOEXEC*. Return a pair of file descriptors `(r, w)` usable for reading and writing, respectively.

Availability: some flavors of Unix.

New in version 3.3.

os.posix_fallocate(*fd*, *offset*, *len*)

Ensures that enough disk space is allocated for the file specified by *fd* starting from *offset* and continuing for *len* bytes.

Availability: Unix.

New in version 3.3.

os.posix_fadvise(*fd*, *offset*, *len*, *advice*)

Announces an intention to access data in a specific pattern thus allowing the kernel to make optimizations. The advice applies to the region of the file specified by *fd* starting at *offset* and continuing for *len* bytes. *advice* is one of *POSIX_FADV_NORMAL*, *POSIX_FADV_SEQUENTIAL*, *POSIX_FADV_RANDOM*, *POSIX_FADV_NOREUSE*, *POSIX_FADV_WILLNEED* or *POSIX_FADV_DONTNEED*.

Availability: Unix.

New in version 3.3.

os.POSIX_FADV_NORMAL
os.POSIX_FADV_SEQUENTIAL
os.POSIX_FADV_RANDOM
os.POSIX_FADV_NOREUSE
os.POSIX_FADV_WILLNEED
os.POSIX_FADV_DONTNEED

Flags that can be used in *advice* in *posix_fadvise()* that specify the access pattern that is likely to be used.

Availability: Unix.

New in version 3.3.

os.pread(*fd*, *n*, *offset*)
Read at most *n* bytes from file descriptor *fd* at a position of *offset*, leaving the file offset unchanged.

Return a bytestring containing the bytes read. If the end of the file referred to by *fd* has been reached, an empty bytes object is returned.

Availability: Unix.

New in version 3.3.

os.preadv(*fd*, *buffers*, *offset*, *flags=0*)
Read from a file descriptor *fd* at a position of *offset* into mutable *bytes-like objects* *buffers*, leaving the file offset unchanged. Transfer data into each buffer until it is full and then move on to the next buffer in the sequence to hold the rest of the data.

The flags argument contains a bitwise OR of zero or more of the following flags:

- *RWF_HIPRI*
- *RWF_NOWAIT*

Return the total number of bytes actually read which can be less than the total capacity of all the objects.

The operating system may set a limit (*sysconf()* value `'SC_IOV_MAX'`) on the number of buffers that can be used.

Combine the functionality of *os.readv()* and *os.pread()*.

Availability: Linux 2.6.30 and newer, FreeBSD 6.0 and newer, OpenBSD 2.7 and newer. Using flags requires Linux 4.6 or newer.

New in version 3.7.

os.RWF_NOWAIT
Do not wait for data which is not immediately available. If this flag is specified, the system call will return instantly if it would have to read data from the backing storage or wait for a lock.

If some data was successfully read, it will return the number of bytes read. If no bytes were read, it will return `-1` and set errno to *errno.EAGAIN*.

Availability: Linux 4.14 and newer.

New in version 3.7.

os.RWF_HIPRI
High priority read/write. Allows block-based filesystems to use polling of the device, which provides lower latency, but may use additional resources.

Currently, on Linux, this feature is usable only on a file descriptor opened using the *O_DIRECT* flag.

Availability: Linux 4.6 and newer.

New in version 3.7.

os.pwrite(*fd*, *str*, *offset*)
Write the bytestring in *str* to file descriptor *fd* at position of *offset*, leaving the file offset unchanged.

Return the number of bytes actually written.

Availability: Unix.

New in version 3.3.

os.**pwritev**(*fd*, *buffers*, *offset*, *flags=0*)

Write the *buffers* contents to file descriptor *fd* at a offset *offset*, leaving the file offset unchanged. *buffers* must be a sequence of *bytes-like objects*. Buffers are processed in array order. Entire contents of the first buffer is written before proceeding to the second, and so on.

The flags argument contains a bitwise OR of zero or more of the following flags:

- *RWF_DSYNC*
- *RWF_SYNC*

Return the total number of bytes actually written.

The operating system may set a limit (*sysconf()* value `'SC_IOV_MAX'`) on the number of buffers that can be used.

Combine the functionality of *os.writev()* and *os.pwrite()*.

Availability: Linux 2.6.30 and newer, FreeBSD 6.0 and newer, OpenBSD 2.7 and newer. Using flags requires Linux 4.7 or newer.

New in version 3.7.

os.**RWF_DSYNC**

Provide a per-write equivalent of the *O_DSYNC* `open(2)` flag. This flag effect applies only to the data range written by the system call.

Availability: Linux 4.7 and newer.

New in version 3.7.

os.**RWF_SYNC**

Provide a per-write equivalent of the *O_SYNC* `open(2)` flag. This flag effect applies only to the data range written by the system call.

Availability: Linux 4.7 and newer.

New in version 3.7.

os.**read**(*fd*, *n*)

Read at most *n* bytes from file descriptor *fd*.

Return a bytestring containing the bytes read. If the end of the file referred to by *fd* has been reached, an empty bytes object is returned.

Note: This function is intended for low-level I/O and must be applied to a file descriptor as returned by *os.open()* or *pipe()*. To read a "file object" returned by the built-in function *open()* or by *popen()* or *fdopen()*, or *sys.stdin*, use its `read()` or `readline()` methods.

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the function now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

os.**sendfile**(*out*, *in*, *offset*, *count*)

os.**sendfile**(*out*, *in*, *offset*, *count*[, *headers*][, *trailers*], *flags=0*)

Copy *count* bytes from file descriptor *in* to file descriptor *out* starting at *offset*. Return the number of bytes sent. When EOF is reached return 0.

The first function notation is supported by all platforms that define *sendfile()*.

On Linux, if *offset* is given as `None`, the bytes are read from the current position of *in* and the position of *in* is updated.

The second case may be used on Mac OS X and FreeBSD where *headers* and *trailers* are arbitrary sequences of buffers that are written before and after the data from *in* is written. It returns the same as the first case.

On Mac OS X and FreeBSD, a value of 0 for *count* specifies to send until the end of *in* is reached.

All platforms support sockets as *out* file descriptor, and some platforms allow other types (e.g. regular file, pipe) as well.

Cross-platform applications should not use *headers*, *trailers* and *flags* arguments.

Availability: Unix.

Note: For a higher-level wrapper of *sendfile()*, see *socket.socket.sendfile()*.

New in version 3.3.

os.set_blocking(*fd*, *blocking*)
Set the blocking mode of the specified file descriptor. Set the *O_NONBLOCK* flag if blocking is `False`, clear the flag otherwise.

See also *get_blocking()* and *socket.socket.setblocking()*.

Availability: Unix.

New in version 3.5.

os.SF_NODISKIO
os.SF_MNOWAIT
os.SF_SYNC
Parameters to the *sendfile()* function, if the implementation supports them.

Availability: Unix.

New in version 3.3.

os.readv(*fd*, *buffers*)
Read from a file descriptor *fd* into a number of mutable *bytes-like objects* *buffers*. Transfer data into each buffer until it is full and then move on to the next buffer in the sequence to hold the rest of the data.

Return the total number of bytes actually read which can be less than the total capacity of all the objects.

The operating system may set a limit (*sysconf()* value `'SC_IOV_MAX'`) on the number of buffers that can be used.

Availability: Unix.

New in version 3.3.

os.tcgetpgrp(*fd*)
Return the process group associated with the terminal given by *fd* (an open file descriptor as returned by *os.open()*).

Availability: Unix.

os.tcsetpgrp(*fd*, *pg*)
Set the process group associated with the terminal given by *fd* (an open file descriptor as returned by *os.open()*) to *pg*.

Availability: Unix.

os.**ttyname**(*fd*)
Return a string which specifies the terminal device associated with file descriptor *fd*. If *fd* is not associated with a terminal device, an exception is raised.

Availability: Unix.

os.**write**(*fd*, *str*)
Write the bytestring in *str* to file descriptor *fd*.

Return the number of bytes actually written.

Note: This function is intended for low-level I/O and must be applied to a file descriptor as returned by *os.open()* or *pipe()*. To write a "file object" returned by the built-in function *open()* or by *popen()* or *fdopen()*, or *sys.stdout* or *sys.stderr*, use its `write()` method.

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the function now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

os.**writev**(*fd*, *buffers*)
Write the contents of *buffers* to file descriptor *fd*. *buffers* must be a sequence of *bytes-like objects*. Buffers are processed in array order. Entire contents of the first buffer is written before proceeding to the second, and so on.

Returns the total number of bytes actually written.

The operating system may set a limit (*sysconf()* value `'SC_IOV_MAX'`) on the number of buffers that can be used.

Availability: Unix.

New in version 3.3.

Querying the size of a terminal

New in version 3.3.

os.**get_terminal_size**(*fd=STDOUT_FILENO*)
Return the size of the terminal window as `(columns, lines)`, tuple of type *terminal_size*.

The optional argument `fd` (default `STDOUT_FILENO`, or standard output) specifies which file descriptor should be queried.

If the file descriptor is not connected to a terminal, an *OSError* is raised.

shutil.get_terminal_size() is the high-level function which should normally be used, `os.get_terminal_size` is the low-level implementation.

Availability: Unix, Windows.

class os.**terminal_size**
A subclass of tuple, holding `(columns, lines)` of the terminal window size.

columns
Width of the terminal window in characters.

lines
Height of the terminal window in characters.

Inheritance of File Descriptors

New in version 3.4.

A file descriptor has an "inheritable" flag which indicates if the file descriptor can be inherited by child processes. Since Python 3.4, file descriptors created by Python are non-inheritable by default.

On UNIX, non-inheritable file descriptors are closed in child processes at the execution of a new program, other file descriptors are inherited.

On Windows, non-inheritable handles and file descriptors are closed in child processes, except for standard streams (file descriptors 0, 1 and 2: stdin, stdout and stderr), which are always inherited. Using *spawn** functions, all inheritable handles and all inheritable file descriptors are inherited. Using the *subprocess* module, all file descriptors except standard streams are closed, and inheritable handles are only inherited if the *close_fds* parameter is `False`.

`os.get_inheritable(`*fd*`)`
Get the "inheritable" flag of the specified file descriptor (a boolean).

`os.set_inheritable(`*fd*, *inheritable*`)`
Set the "inheritable" flag of the specified file descriptor.

`os.get_handle_inheritable(`*handle*`)`
Get the "inheritable" flag of the specified handle (a boolean).

Availability: Windows.

`os.set_handle_inheritable(`*handle*, *inheritable*`)`
Set the "inheritable" flag of the specified handle.

Availability: Windows.

16.1.5 Files and Directories

On some Unix platforms, many of these functions support one or more of these features:

- **specifying a file descriptor:** For some functions, the *path* argument can be not only a string giving a path name, but also a file descriptor. The function will then operate on the file referred to by the descriptor. (For POSIX systems, Python will call the `f...` version of the function.)

  You can check whether or not *path* can be specified as a file descriptor on your platform using *os.supports_fd*. If it is unavailable, using it will raise a *NotImplementedError*.

  If the function also supports *dir_fd* or *follow_symlinks* arguments, it is an error to specify one of those when supplying *path* as a file descriptor.

- **paths relative to directory descriptors:** If *dir_fd* is not `None`, it should be a file descriptor referring to a directory, and the path to operate on should be relative; path will then be relative to that directory. If the path is absolute, *dir_fd* is ignored. (For POSIX systems, Python will call the `...at` or `f...at` version of the function.)

  You can check whether or not *dir_fd* is supported on your platform using *os.supports_dir_fd*. If it is unavailable, using it will raise a *NotImplementedError*.

- **not following symlinks:** If *follow_symlinks* is `False`, and the last element of the path to operate on is a symbolic link, the function will operate on the symbolic link itself instead of the file the link points to. (For POSIX systems, Python will call the `l...` version of the function.)

  You can check whether or not *follow_symlinks* is supported on your platform using *os.supports_follow_symlinks*. If it is unavailable, using it will raise a *NotImplementedError*.

os.access(*path*, *mode*, ***, *dir_fd=None*, *effective_ids=False*, *follow_symlinks=True*)

Use the real uid/gid to test for access to *path*. Note that most operations will use the effective uid/gid, therefore this routine can be used in a suid/sgid environment to test if the invoking user has the specified access to *path*. *mode* should be *F_OK* to test the existence of *path*, or it can be the inclusive OR of one or more of *R_OK*, *W_OK*, and *X_OK* to test permissions. Return *True* if access is allowed, *False* if not. See the Unix man page *access(2)* for more information.

This function can support specifying *paths relative to directory descriptors* and *not following symlinks*.

If *effective_ids* is `True`, *access()* will perform its access checks using the effective uid/gid instead of the real uid/gid. *effective_ids* may not be supported on your platform; you can check whether or not it is available using *os.supports_effective_ids*. If it is unavailable, using it will raise a *NotImplementedError*.

Note: Using *access()* to check if a user is authorized to e.g. open a file before actually doing so using *open()* creates a security hole, because the user might exploit the short time interval between checking and opening the file to manipulate it. It's preferable to use *EAFP* techniques. For example:

```
if os.access("myfile", os.R_OK):
    with open("myfile") as fp:
        return fp.read()
return "some default data"
```

is better written as:

```
try:
    fp = open("myfile")
except PermissionError:
    return "some default data"
else:
    with fp:
        return fp.read()
```

Note: I/O operations may fail even when *access()* indicates that they would succeed, particularly for operations on network filesystems which may have permissions semantics beyond the usual POSIX permission-bit model.

Changed in version 3.3: Added the *dir_fd*, *effective_ids*, and *follow_symlinks* parameters.

Changed in version 3.6: Accepts a *path-like object*.

os.F_OK
os.R_OK
os.W_OK
os.X_OK

Values to pass as the *mode* parameter of *access()* to test the existence, readability, writability and executability of *path*, respectively.

os.chdir(*path*)

Change the current working directory to *path*.

This function can support *specifying a file descriptor*. The descriptor must refer to an opened directory, not an open file.

New in version 3.3: Added support for specifying *path* as a file descriptor on some platforms.

Changed in version 3.6: Accepts a *path-like object*.

os.**chflags**(*path*, *flags*, ***, *follow_symlinks=True*)

Set the flags of *path* to the numeric *flags*. *flags* may take a combination (bitwise OR) of the following values (as defined in the *stat* module):

- *stat.UF_NODUMP*
- *stat.UF_IMMUTABLE*
- *stat.UF_APPEND*
- *stat.UF_OPAQUE*
- *stat.UF_NOUNLINK*
- *stat.UF_COMPRESSED*
- *stat.UF_HIDDEN*
- *stat.SF_ARCHIVED*
- *stat.SF_IMMUTABLE*
- *stat.SF_APPEND*
- *stat.SF_NOUNLINK*
- *stat.SF_SNAPSHOT*

This function can support *not following symlinks*.

Availability: Unix.

New in version 3.3: The *follow_symlinks* argument.

Changed in version 3.6: Accepts a *path-like object*.

os.**chmod**(*path*, *mode*, ***, *dir_fd=None*, *follow_symlinks=True*)

Change the mode of *path* to the numeric *mode*. *mode* may take one of the following values (as defined in the *stat* module) or bitwise ORed combinations of them:

- *stat.S_ISUID*
- *stat.S_ISGID*
- *stat.S_ENFMT*
- *stat.S_ISVTX*
- *stat.S_IREAD*
- *stat.S_IWRITE*
- *stat.S_IEXEC*
- *stat.S_IRWXU*
- *stat.S_IRUSR*
- *stat.S_IWUSR*
- *stat.S_IXUSR*
- *stat.S_IRWXG*
- *stat.S_IRGRP*
- *stat.S_IWGRP*
- *stat.S_IXGRP*
- *stat.S_IRWXO*
- *stat.S_IROTH*

- *stat.S_IWOTH*
- *stat.S_IXOTH*

This function can support *specifying a file descriptor*, *paths relative to directory descriptors* and *not following symlinks*.

Note: Although Windows supports *chmod()*, you can only set the file's read-only flag with it (via the `stat.S_IWRITE` and `stat.S_IREAD` constants or a corresponding integer value). All other bits are ignored.

New in version 3.3: Added support for specifying *path* as an open file descriptor, and the *dir_fd* and *follow_symlinks* arguments.

Changed in version 3.6: Accepts a *path-like object*.

`os.chown`(*path*, *uid*, *gid*, ***, *dir_fd=None*, *follow_symlinks=True*)
Change the owner and group id of *path* to the numeric *uid* and *gid*. To leave one of the ids unchanged, set it to -1.

This function can support *specifying a file descriptor*, *paths relative to directory descriptors* and *not following symlinks*.

See *shutil.chown()* for a higher-level function that accepts names in addition to numeric ids.

Availability: Unix.

New in version 3.3: Added support for specifying an open file descriptor for *path*, and the *dir_fd* and *follow_symlinks* arguments.

Changed in version 3.6: Supports a *path-like object*.

`os.chroot`(*path*)
Change the root directory of the current process to *path*.

Availability: Unix.

Changed in version 3.6: Accepts a *path-like object*.

`os.fchdir`(*fd*)
Change the current working directory to the directory represented by the file descriptor *fd*. The descriptor must refer to an opened directory, not an open file. As of Python 3.3, this is equivalent to `os.chdir(fd)`.

Availability: Unix.

`os.getcwd`()
Return a string representing the current working directory.

`os.getcwdb`()
Return a bytestring representing the current working directory.

`os.lchflags`(*path*, *flags*)
Set the flags of *path* to the numeric *flags*, like *chflags()*, but do not follow symbolic links. As of Python 3.3, this is equivalent to `os.chflags(path, flags, follow_symlinks=False)`.

Availability: Unix.

Changed in version 3.6: Accepts a *path-like object*.

`os.lchmod`(*path*, *mode*)
Change the mode of *path* to the numeric *mode*. If path is a symlink, this affects the symlink rather than the target. See the docs for *chmod()* for possible values of *mode*. As of Python 3.3, this is equivalent to `os.chmod(path, mode, follow_symlinks=False)`.

Availability: Unix.

Changed in version 3.6: Accepts a *path-like object*.

`os.lchown`(*path*, *uid*, *gid*)
Change the owner and group id of *path* to the numeric *uid* and *gid*. This function will not follow symbolic links. As of Python 3.3, this is equivalent to `os.chown(path, uid, gid, follow_symlinks=False)`.

Availability: Unix.

Changed in version 3.6: Accepts a *path-like object*.

`os.link`(*src*, *dst*, ***, *src_dir_fd=None*, *dst_dir_fd=None*, *follow_symlinks=True*)
Create a hard link pointing to *src* named *dst*.

This function can support specifying *src_dir_fd* and/or *dst_dir_fd* to supply *paths relative to directory descriptors*, and *not following symlinks*.

Availability: Unix, Windows.

Changed in version 3.2: Added Windows support.

New in version 3.3: Added the *src_dir_fd*, *dst_dir_fd*, and *follow_symlinks* arguments.

Changed in version 3.6: Accepts a *path-like object* for *src* and *dst*.

`os.listdir`(*path='.'*)
Return a list containing the names of the entries in the directory given by *path*. The list is in arbitrary order, and does not include the special entries `'.'` and `'..'` even if they are present in the directory.

path may be a *path-like object*. If *path* is of type `bytes` (directly or indirectly through the *PathLike* interface), the filenames returned will also be of type `bytes`; in all other circumstances, they will be of type `str`.

This function can also support *specifying a file descriptor*; the file descriptor must refer to a directory.

Note: To encode `str` filenames to `bytes`, use *fsencode()*.

See also:

The *scandir()* function returns directory entries along with file attribute information, giving better performance for many common use cases.

Changed in version 3.2: The *path* parameter became optional.

New in version 3.3: Added support for specifying an open file descriptor for *path*.

Changed in version 3.6: Accepts a *path-like object*.

`os.lstat`(*path*, ***, *dir_fd=None*)
Perform the equivalent of an `lstat()` system call on the given path. Similar to *stat()*, but does not follow symbolic links. Return a *stat_result* object.

On platforms that do not support symbolic links, this is an alias for *stat()*.

As of Python 3.3, this is equivalent to `os.stat(path, dir_fd=dir_fd, follow_symlinks=False)`.

This function can also support *paths relative to directory descriptors*.

See also:

The *stat()* function.

Changed in version 3.2: Added support for Windows 6.0 (Vista) symbolic links.

Changed in version 3.3: Added the *dir_fd* parameter.

Changed in version 3.6: Accepts a *path-like object* for *src* and *dst*.

os.mkdir(*path*, *mode=0o777*, ***, *dir_fd=None*)
Create a directory named *path* with numeric mode *mode*.

If the directory already exists, *FileExistsError* is raised.

On some systems, *mode* is ignored. Where it is used, the current umask value is first masked out. If bits other than the last 9 (i.e. the last 3 digits of the octal representation of the *mode*) are set, their meaning is platform-dependent. On some platforms, they are ignored and you should call *chmod()* explicitly to set them.

This function can also support *paths relative to directory descriptors*.

It is also possible to create temporary directories; see the *tempfile* module's *tempfile.mkdtemp()* function.

New in version 3.3: The *dir_fd* argument.

Changed in version 3.6: Accepts a *path-like object*.

os.makedirs(*name*, *mode=0o777*, *exist_ok=False*)
Recursive directory creation function. Like *mkdir()*, but makes all intermediate-level directories needed to contain the leaf directory.

The *mode* parameter is passed to *mkdir()* for creating the leaf directory; see *the mkdir() description* for how it is interpreted. To set the file permission bits of any newly-created parent directories you can set the umask before invoking *makedirs()*. The file permission bits of existing parent directories are not changed.

If *exist_ok* is `False` (the default), an *OSError* is raised if the target directory already exists.

Note: *makedirs()* will become confused if the path elements to create include *pardir* (eg. ".." on UNIX systems).

This function handles UNC paths correctly.

New in version 3.2: The *exist_ok* parameter.

Changed in version 3.4.1: Before Python 3.4.1, if *exist_ok* was `True` and the directory existed, *makedirs()* would still raise an error if *mode* did not match the mode of the existing directory. Since this behavior was impossible to implement safely, it was removed in Python 3.4.1. See bpo-21082.

Changed in version 3.6: Accepts a *path-like object*.

Changed in version 3.7: The *mode* argument no longer affects the file permission bits of newly-created intermediate-level directories.

os.mkfifo(*path*, *mode=0o666*, ***, *dir_fd=None*)
Create a FIFO (a named pipe) named *path* with numeric mode *mode*. The current umask value is first masked out from the mode.

This function can also support *paths relative to directory descriptors*.

FIFOs are pipes that can be accessed like regular files. FIFOs exist until they are deleted (for example with *os.unlink()*). Generally, FIFOs are used as rendezvous between "client" and "server" type processes: the server opens the FIFO for reading, and the client opens it for writing. Note that *mkfifo()* doesn't open the FIFO — it just creates the rendezvous point.

Availability: Unix.

New in version 3.3: The *dir_fd* argument.

Changed in version 3.6: Accepts a *path-like object*.

os.**mknod**(*path*, *mode=0o600*, *device=0*, ***, *dir_fd=None*)
Create a filesystem node (file, device special file or named pipe) named *path*. *mode* specifies both the permissions to use and the type of node to be created, being combined (bitwise OR) with one of `stat.S_IFREG`, `stat.S_IFCHR`, `stat.S_IFBLK`, and `stat.S_IFIFO` (those constants are available in *stat*). For `stat.S_IFCHR` and `stat.S_IFBLK`, *device* defines the newly created device special file (probably using *os.makedev()*), otherwise it is ignored.

This function can also support *paths relative to directory descriptors*.

Availability: Unix.

New in version 3.3: The *dir_fd* argument.

Changed in version 3.6: Accepts a *path-like object*.

os.**major**(*device*)
Extract the device major number from a raw device number (usually the `st_dev` or `st_rdev` field from `stat`).

os.**minor**(*device*)
Extract the device minor number from a raw device number (usually the `st_dev` or `st_rdev` field from `stat`).

os.**makedev**(*major*, *minor*)
Compose a raw device number from the major and minor device numbers.

os.**pathconf**(*path*, *name*)
Return system configuration information relevant to a named file. *name* specifies the configuration value to retrieve; it may be a string which is the name of a defined system value; these names are specified in a number of standards (POSIX.1, Unix 95, Unix 98, and others). Some platforms define additional names as well. The names known to the host operating system are given in the `pathconf_names` dictionary. For configuration variables not included in that mapping, passing an integer for *name* is also accepted.

If *name* is a string and is not known, *ValueError* is raised. If a specific value for *name* is not supported by the host system, even if it is included in `pathconf_names`, an *OSError* is raised with *errno.EINVAL* for the error number.

This function can support *specifying a file descriptor*.

Availability: Unix.

Changed in version 3.6: Accepts a *path-like object*.

os.**pathconf_names**
Dictionary mapping names accepted by *pathconf()* and *fpathconf()* to the integer values defined for those names by the host operating system. This can be used to determine the set of names known to the system.

Availability: Unix.

os.**readlink**(*path*, ***, *dir_fd=None*)
Return a string representing the path to which the symbolic link points. The result may be either an absolute or relative pathname; if it is relative, it may be converted to an absolute pathname using `os.path.join(os.path.dirname(path), result)`.

If the *path* is a string object (directly or indirectly through a *PathLike* interface), the result will also be a string object, and the call may raise a UnicodeDecodeError. If the *path* is a bytes object (direct or indirectly), the result will be a bytes object.

This function can also support *paths relative to directory descriptors*.

Availability: Unix, Windows

Changed in version 3.2: Added support for Windows 6.0 (Vista) symbolic links.

New in version 3.3: The *dir_fd* argument.

Changed in version 3.6: Accepts a *path-like object*.

os.remove(*path*, ***, *dir_fd=None*)
Remove (delete) the file *path*. If *path* is a directory, *OSError* is raised. Use *rmdir()* to remove directories.

This function can support *paths relative to directory descriptors*.

On Windows, attempting to remove a file that is in use causes an exception to be raised; on Unix, the directory entry is removed but the storage allocated to the file is not made available until the original file is no longer in use.

This function is semantically identical to *unlink()*.

New in version 3.3: The *dir_fd* argument.

Changed in version 3.6: Accepts a *path-like object*.

os.removedirs(*name*)
Remove directories recursively. Works like *rmdir()* except that, if the leaf directory is successfully removed, *removedirs()* tries to successively remove every parent directory mentioned in *path* until an error is raised (which is ignored, because it generally means that a parent directory is not empty). For example, `os.removedirs('foo/bar/baz')` will first remove the directory `'foo/bar/baz'`, and then remove `'foo/bar'` and `'foo'` if they are empty. Raises *OSError* if the leaf directory could not be successfully removed.

Changed in version 3.6: Accepts a *path-like object*.

os.rename(*src*, *dst*, ***, *src_dir_fd=None*, *dst_dir_fd=None*)
Rename the file or directory *src* to *dst*. If *dst* is a directory, *OSError* will be raised. On Unix, if *dst* exists and is a file, it will be replaced silently if the user has permission. The operation may fail on some Unix flavors if *src* and *dst* are on different filesystems. If successful, the renaming will be an atomic operation (this is a POSIX requirement). On Windows, if *dst* already exists, *OSError* will be raised even if it is a file.

This function can support specifying *src_dir_fd* and/or *dst_dir_fd* to supply *paths relative to directory descriptors*.

If you want cross-platform overwriting of the destination, use *replace()*.

New in version 3.3: The *src_dir_fd* and *dst_dir_fd* arguments.

Changed in version 3.6: Accepts a *path-like object* for *src* and *dst*.

os.renames(*old*, *new*)
Recursive directory or file renaming function. Works like *rename()*, except creation of any intermediate directories needed to make the new pathname good is attempted first. After the rename, directories corresponding to rightmost path segments of the old name will be pruned away using *removedirs()*.

Note: This function can fail with the new directory structure made if you lack permissions needed to remove the leaf directory or file.

Changed in version 3.6: Accepts a *path-like object* for *old* and *new*.

os.replace(*src*, *dst*, ***, *src_dir_fd=None*, *dst_dir_fd=None*)
Rename the file or directory *src* to *dst*. If *dst* is a directory, *OSError* will be raised. If *dst* exists and is a file, it will be replaced silently if the user has permission. The operation may fail if *src* and *dst* are on different filesystems. If successful, the renaming will be an atomic operation (this is a POSIX requirement).

This function can support specifying *src_dir_fd* and/or *dst_dir_fd* to supply *paths relative to directory descriptors*.

New in version 3.3.

Changed in version 3.6: Accepts a *path-like object* for *src* and *dst*.

os.rmdir(*path*, ***, *dir_fd=None*)

Remove (delete) the directory *path*. Only works when the directory is empty, otherwise, *OSError* is raised. In order to remove whole directory trees, *shutil.rmtree()* can be used.

This function can support *paths relative to directory descriptors*.

New in version 3.3: The *dir_fd* parameter.

Changed in version 3.6: Accepts a *path-like object*.

os.scandir(*path='.'*)

Return an iterator of *os.DirEntry* objects corresponding to the entries in the directory given by *path*. The entries are yielded in arbitrary order, and the special entries `'.'` and `'..'` are not included.

Using *scandir()* instead of *listdir()* can significantly increase the performance of code that also needs file type or file attribute information, because *os.DirEntry* objects expose this information if the operating system provides it when scanning a directory. All *os.DirEntry* methods may perform a system call, but *is_dir()* and *is_file()* usually only require a system call for symbolic links; *os.DirEntry.stat()* always requires a system call on Unix but only requires one for symbolic links on Windows.

path may be a *path-like object*. If *path* is of type `bytes` (directly or indirectly through the *PathLike* interface), the type of the *name* and *path* attributes of each *os.DirEntry* will be `bytes`; in all other circumstances, they will be of type `str`.

This function can also support *specifying a file descriptor*; the file descriptor must refer to a directory.

The *scandir()* iterator supports the *context manager* protocol and has the following method:

scandir.close()

Close the iterator and free acquired resources.

This is called automatically when the iterator is exhausted or garbage collected, or when an error happens during iterating. However it is advisable to call it explicitly or use the `with` statement.

New in version 3.6.

The following example shows a simple use of *scandir()* to display all the files (excluding directories) in the given *path* that don't start with `'.'`. The `entry.is_file()` call will generally not make an additional system call:

```
with os.scandir(path) as it:
    for entry in it:
        if not entry.name.startswith('.') and entry.is_file():
            print(entry.name)
```

Note: On Unix-based systems, *scandir()* uses the system's opendir() and readdir() functions. On Windows, it uses the Win32 FindFirstFileW and FindNextFileW functions.

New in version 3.5.

New in version 3.6: Added support for the *context manager* protocol and the *close()* method. If a *scandir()* iterator is neither exhausted nor explicitly closed a *ResourceWarning* will be emitted in its destructor.

The function accepts a *path-like object*.

Changed in version 3.7: Added support for *file descriptors* on Unix.

class os.DirEntry

Object yielded by *scandir()* to expose the file path and other file attributes of a directory entry.

scandir() will provide as much of this information as possible without making additional system calls. When a `stat()` or `lstat()` system call is made, the `os.DirEntry` object will cache the result.

`os.DirEntry` instances are not intended to be stored in long-lived data structures; if you know the file metadata has changed or if a long time has elapsed since calling *scandir()*, call `os.stat(entry.path)` to fetch up-to-date information.

Because the `os.DirEntry` methods can make operating system calls, they may also raise *OSError*. If you need very fine-grained control over errors, you can catch *OSError* when calling one of the `os.DirEntry` methods and handle as appropriate.

To be directly usable as a *path-like object*, `os.DirEntry` implements the *PathLike* interface.

Attributes and methods on a `os.DirEntry` instance are as follows:

name

The entry's base filename, relative to the *scandir()* *path* argument.

The *name* attribute will be `bytes` if the *scandir()* *path* argument is of type `bytes` and `str` otherwise. Use *fsdecode()* to decode byte filenames.

path

The entry's full path name: equivalent to `os.path.join(scandir_path, entry.name)` where *scandir_path* is the *scandir()* *path* argument. The path is only absolute if the *scandir()* *path* argument was absolute. If the *scandir()* *path* argument was a *file descriptor*, the *path* attribute is the same as the *name* attribute.

The *path* attribute will be `bytes` if the *scandir()* *path* argument is of type `bytes` and `str` otherwise. Use *fsdecode()* to decode byte filenames.

inode()

Return the inode number of the entry.

The result is cached on the `os.DirEntry` object. Use `os.stat(entry.path, follow_symlinks=False).st_ino` to fetch up-to-date information.

On the first, uncached call, a system call is required on Windows but not on Unix.

is_dir(**, follow_symlinks=True*)

Return `True` if this entry is a directory or a symbolic link pointing to a directory; return `False` if the entry is or points to any other kind of file, or if it doesn't exist anymore.

If *follow_symlinks* is `False`, return `True` only if this entry is a directory (without following symlinks); return `False` if the entry is any other kind of file or if it doesn't exist anymore.

The result is cached on the `os.DirEntry` object, with a separate cache for *follow_symlinks* `True` and `False`. Call *os.stat()* along with *stat.S_ISDIR()* to fetch up-to-date information.

On the first, uncached call, no system call is required in most cases. Specifically, for non-symlinks, neither Windows or Unix require a system call, except on certain Unix file systems, such as network file systems, that return `dirent.d_type == DT_UNKNOWN`. If the entry is a symlink, a system call will be required to follow the symlink unless *follow_symlinks* is `False`.

This method can raise *OSError*, such as *PermissionError*, but *FileNotFoundError* is caught and not raised.

is_file(**, follow_symlinks=True*)

Return `True` if this entry is a file or a symbolic link pointing to a file; return `False` if the entry is or points to a directory or other non-file entry, or if it doesn't exist anymore.

If *follow_symlinks* is `False`, return `True` only if this entry is a file (without following symlinks); return `False` if the entry is a directory or other non-file entry, or if it doesn't exist anymore.

The result is cached on the `os.DirEntry` object. Caching, system calls made, and exceptions raised are as per *is_dir()*.

`is_symlink()`
Return `True` if this entry is a symbolic link (even if broken); return `False` if the entry points to a directory or any kind of file, or if it doesn't exist anymore.

The result is cached on the `os.DirEntry` object. Call *os.path.islink()* to fetch up-to-date information.

On the first, uncached call, no system call is required in most cases. Specifically, neither Windows or Unix require a system call, except on certain Unix file systems, such as network file systems, that return `dirent.d_type == DT_UNKNOWN`.

This method can raise *OSError*, such as *PermissionError*, but *FileNotFoundError* is caught and not raised.

`stat`(**, follow_symlinks=True*)
Return a *stat_result* object for this entry. This method follows symbolic links by default; to stat a symbolic link add the `follow_symlinks=False` argument.

On Unix, this method always requires a system call. On Windows, it only requires a system call if *follow_symlinks* is `True` and the entry is a symbolic link.

On Windows, the `st_ino`, `st_dev` and `st_nlink` attributes of the *stat_result* are always set to zero. Call *os.stat()* to get these attributes.

The result is cached on the `os.DirEntry` object, with a separate cache for *follow_symlinks* `True` and `False`. Call *os.stat()* to fetch up-to-date information.

Note that there is a nice correspondence between several attributes and methods of `os.DirEntry` and of *pathlib.Path*. In particular, the `name` attribute has the same meaning, as do the `is_dir()`, `is_file()`, `is_symlink()` and `stat()` methods.

New in version 3.5.

Changed in version 3.6: Added support for the *PathLike* interface. Added support for *bytes* paths on Windows.

`os.stat`(*path*, ***, *dir_fd=None*, *follow_symlinks=True*)
Get the status of a file or a file descriptor. Perform the equivalent of a `stat()` system call on the given path. *path* may be specified as either a string or bytes – directly or indirectly through the *PathLike* interface – or as an open file descriptor. Return a *stat_result* object.

This function normally follows symlinks; to stat a symlink add the argument `follow_symlinks=False`, or use *lstat()*.

This function can support *specifying a file descriptor* and *not following symlinks*.

Example:

```
>>> import os
>>> statinfo = os.stat('somefile.txt')
>>> statinfo
os.stat_result(st_mode=33188, st_ino=7876932, st_dev=234881026,
st_nlink=1, st_uid=501, st_gid=501, st_size=264, st_atime=1297230295,
st_mtime=1297230027, st_ctime=1297230027)
>>> statinfo.st_size
264
```

See also:

fstat() and *lstat()* functions.

New in version 3.3: Added the *dir_fd* and *follow_symlinks* arguments, specifying a file descriptor instead of a path.

Changed in version 3.6: Accepts a *path-like object*.

class os.stat_result

Object whose attributes correspond roughly to the members of the `stat` structure. It is used for the result of *os.stat()*, *os.fstat()* and *os.lstat()*.

Attributes:

st_mode
File mode: file type and file mode bits (permissions).

st_ino
Platform dependent, but if non-zero, uniquely identifies the file for a given value of `st_dev`. Typically:

- the inode number on Unix,
- the file index on Windows

st_dev
Identifier of the device on which this file resides.

st_nlink
Number of hard links.

st_uid
User identifier of the file owner.

st_gid
Group identifier of the file owner.

st_size
Size of the file in bytes, if it is a regular file or a symbolic link. The size of a symbolic link is the length of the pathname it contains, without a terminating null byte.

Timestamps:

st_atime
Time of most recent access expressed in seconds.

st_mtime
Time of most recent content modification expressed in seconds.

st_ctime
Platform dependent:

- the time of most recent metadata change on Unix,
- the time of creation on Windows, expressed in seconds.

st_atime_ns
Time of most recent access expressed in nanoseconds as an integer.

st_mtime_ns
Time of most recent content modification expressed in nanoseconds as an integer.

st_ctime_ns
Platform dependent:

- the time of most recent metadata change on Unix,

- the time of creation on Windows, expressed in nanoseconds as an integer.

Note: The exact meaning and resolution of the *st_atime*, *st_mtime*, and *st_ctime* attributes depend on the operating system and the file system. For example, on Windows systems using the FAT or FAT32 file systems, *st_mtime* has 2-second resolution, and *st_atime* has only 1-day resolution. See your operating system documentation for details.

Similarly, although *st_atime_ns*, *st_mtime_ns*, and *st_ctime_ns* are always expressed in nanoseconds, many systems do not provide nanosecond precision. On systems that do provide nanosecond precision, the floating-point object used to store *st_atime*, *st_mtime*, and *st_ctime* cannot preserve all of it, and as such will be slightly inexact. If you need the exact timestamps you should always use *st_atime_ns*, *st_mtime_ns*, and *st_ctime_ns*.

On some Unix systems (such as Linux), the following attributes may also be available:

st_blocks
Number of 512-byte blocks allocated for file. This may be smaller than *st_size*/512 when the file has holes.

st_blksize
"Preferred" blocksize for efficient file system I/O. Writing to a file in smaller chunks may cause an inefficient read-modify-rewrite.

st_rdev
Type of device if an inode device.

st_flags
User defined flags for file.

On other Unix systems (such as FreeBSD), the following attributes may be available (but may be only filled out if root tries to use them):

st_gen
File generation number.

st_birthtime
Time of file creation.

On Solaris and derivatives, the following attributes may also be available:

st_fstype
String that uniquely identifies the type of the filesystem that contains the file.

On Mac OS systems, the following attributes may also be available:

st_rsize
Real size of the file.

st_creator
Creator of the file.

st_type
File type.

On Windows systems, the following attribute is also available:

st_file_attributes
Windows file attributes: `dwFileAttributes` member of the `BY_HANDLE_FILE_INFORMATION` structure returned by `GetFileInformationByHandle()`. See the `FILE_ATTRIBUTE_*` constants in the *stat* module.

The standard module *stat* defines functions and constants that are useful for extracting information from a `stat` structure. (On Windows, some items are filled with dummy values.)

For backward compatibility, a *stat_result* instance is also accessible as a tuple of at least 10 integers giving the most important (and portable) members of the `stat` structure, in the order *st_mode*, *st_ino*, *st_dev*, *st_nlink*, *st_uid*, *st_gid*, *st_size*, *st_atime*, *st_mtime*, *st_ctime*. More items may be added at the end by some implementations. For compatibility with older Python versions, accessing *stat_result* as a tuple always returns integers.

New in version 3.3: Added the *st_atime_ns*, *st_mtime_ns*, and *st_ctime_ns* members.

New in version 3.5: Added the *st_file_attributes* member on Windows.

Changed in version 3.5: Windows now returns the file index as *st_ino* when available.

New in version 3.7: Added the *st_fstype* member to Solaris/derivatives.

os.statvfs(*path*)

Perform a `statvfs()` system call on the given path. The return value is an object whose attributes describe the filesystem on the given path, and correspond to the members of the `statvfs` structure, namely: `f_bsize`, `f_frsize`, `f_blocks`, `f_bfree`, `f_bavail`, `f_files`, `f_ffree`, `f_favail`, `f_flag`, `f_namemax`, `f_fsid`.

Two module-level constants are defined for the `f_flag` attribute's bit-flags: if `ST_RDONLY` is set, the filesystem is mounted read-only, and if `ST_NOSUID` is set, the semantics of setuid/setgid bits are disabled or not supported.

Additional module-level constants are defined for GNU/glibc based systems. These are `ST_NODEV` (disallow access to device special files), `ST_NOEXEC` (disallow program execution), `ST_SYNCHRONOUS` (writes are synced at once), `ST_MANDLOCK` (allow mandatory locks on an FS), `ST_WRITE` (write on file/directory/symlink), `ST_APPEND` (append-only file), `ST_IMMUTABLE` (immutable file), `ST_NOATIME` (do not update access times), `ST_NODIRATIME` (do not update directory access times), `ST_RELATIME` (update atime relative to mtime/ctime).

This function can support *specifying a file descriptor*.

Availability: Unix.

Changed in version 3.2: The `ST_RDONLY` and `ST_NOSUID` constants were added.

New in version 3.3: Added support for specifying an open file descriptor for *path*.

Changed in version 3.4: The `ST_NODEV`, `ST_NOEXEC`, `ST_SYNCHRONOUS`, `ST_MANDLOCK`, `ST_WRITE`, `ST_APPEND`, `ST_IMMUTABLE`, `ST_NOATIME`, `ST_NODIRATIME`, and `ST_RELATIME` constants were added.

Changed in version 3.6: Accepts a *path-like object*.

New in version 3.7: Added `f_fsid`.

os.supports_dir_fd

A *Set* object indicating which functions in the *os* module permit use of their *dir_fd* parameter. Different platforms provide different functionality, and an option that might work on one might be unsupported on another. For consistency's sakes, functions that support *dir_fd* always allow specifying the parameter, but will raise an exception if the functionality is not actually available.

To check whether a particular function permits use of its *dir_fd* parameter, use the `in` operator on `supports_dir_fd`. As an example, this expression determines whether the *dir_fd* parameter of *os.stat()* is locally available:

```
os.stat in os.supports_dir_fd
```

Currently *dir_fd* parameters only work on Unix platforms; none of them work on Windows.

New in version 3.3.

os.supports_effective_ids

A *Set* object indicating which functions in the *os* module permit use of the *effective_ids* parameter

for *os.access()*. If the local platform supports it, the collection will contain *os.access()*, otherwise it will be empty.

To check whether you can use the *effective_ids* parameter for *os.access()*, use the `in` operator on `supports_effective_ids`, like so:

```
os.access in os.supports_effective_ids
```

Currently *effective_ids* only works on Unix platforms; it does not work on Windows.

New in version 3.3.

os.supports_fd

A *Set* object indicating which functions in the *os* module permit specifying their *path* parameter as an open file descriptor. Different platforms provide different functionality, and an option that might work on one might be unsupported on another. For consistency's sakes, functions that support *fd* always allow specifying the parameter, but will raise an exception if the functionality is not actually available.

To check whether a particular function permits specifying an open file descriptor for its *path* parameter, use the `in` operator on `supports_fd`. As an example, this expression determines whether *os.chdir()* accepts open file descriptors when called on your local platform:

```
os.chdir in os.supports_fd
```

New in version 3.3.

os.supports_follow_symlinks

A *Set* object indicating which functions in the *os* module permit use of their *follow_symlinks* parameter. Different platforms provide different functionality, and an option that might work on one might be unsupported on another. For consistency's sakes, functions that support *follow_symlinks* always allow specifying the parameter, but will raise an exception if the functionality is not actually available.

To check whether a particular function permits use of its *follow_symlinks* parameter, use the `in` operator on `supports_follow_symlinks`. As an example, this expression determines whether the *follow_symlinks* parameter of *os.stat()* is locally available:

```
os.stat in os.supports_follow_symlinks
```

New in version 3.3.

os.symlink(*src*, *dst*, *target_is_directory=False*, ***, *dir_fd=None*)

Create a symbolic link pointing to *src* named *dst*.

On Windows, a symlink represents either a file or a directory, and does not morph to the target dynamically. If the target is present, the type of the symlink will be created to match. Otherwise, the symlink will be created as a directory if *target_is_directory* is `True` or a file symlink (the default) otherwise. On non-Window platforms, *target_is_directory* is ignored.

Symbolic link support was introduced in Windows 6.0 (Vista). *symlink()* will raise a *NotImplementedError* on Windows versions earlier than 6.0.

This function can support *paths relative to directory descriptors*.

Note: On Windows, the *SeCreateSymbolicLinkPrivilege* is required in order to successfully create symlinks. This privilege is not typically granted to regular users but is available to accounts which can escalate privileges to the administrator level. Either obtaining the privilege or running your application as an administrator are ways to successfully create symlinks.

OSError is raised when the function is called by an unprivileged user.

Availability: Unix, Windows.

Changed in version 3.2: Added support for Windows 6.0 (Vista) symbolic links.

New in version 3.3: Added the *dir_fd* argument, and now allow *target_is_directory* on non-Windows platforms.

Changed in version 3.6: Accepts a *path-like object* for *src* and *dst*.

os.sync()
Force write of everything to disk.

Availability: Unix.

New in version 3.3.

os.truncate(*path*, *length*)
Truncate the file corresponding to *path*, so that it is at most *length* bytes in size.

This function can support *specifying a file descriptor*.

Availability: Unix, Windows.

New in version 3.3.

Changed in version 3.5: Added support for Windows

Changed in version 3.6: Accepts a *path-like object*.

os.unlink(*path*, ***, *dir_fd=None*)
Remove (delete) the file *path*. This function is semantically identical to *remove()*; the `unlink` name is its traditional Unix name. Please see the documentation for *remove()* for further information.

New in version 3.3: The *dir_fd* parameter.

Changed in version 3.6: Accepts a *path-like object*.

os.utime(*path*, *times=None*, ***[, *ns*], *dir_fd=None*, *follow_symlinks=True*)
Set the access and modified times of the file specified by *path*.

utime() takes two optional parameters, *times* and *ns*. These specify the times set on *path* and are used as follows:

- If *ns* is specified, it must be a 2-tuple of the form `(atime_ns, mtime_ns)` where each member is an int expressing nanoseconds.
- If *times* is not `None`, it must be a 2-tuple of the form `(atime, mtime)` where each member is an int or float expressing seconds.
- If *times* is `None` and *ns* is unspecified, this is equivalent to specifying `ns=(atime_ns, mtime_ns)` where both times are the current time.

It is an error to specify tuples for both *times* and *ns*.

Whether a directory can be given for *path* depends on whether the operating system implements directories as files (for example, Windows does not). Note that the exact times you set here may not be returned by a subsequent *stat()* call, depending on the resolution with which your operating system records access and modification times; see *stat()*. The best way to preserve exact times is to use the *st_atime_ns* and *st_mtime_ns* fields from the *os.stat()* result object with the *ns* parameter to *utime*.

This function can support *specifying a file descriptor*, *paths relative to directory descriptors* and *not following symlinks*.

New in version 3.3: Added support for specifying an open file descriptor for *path*, and the *dir_fd*, *follow_symlinks*, and *ns* parameters.

Changed in version 3.6: Accepts a *path-like object*.

os.walk(*top*, *topdown=True*, *onerror=None*, *followlinks=False*)

Generate the file names in a directory tree by walking the tree either top-down or bottom-up. For each directory in the tree rooted at directory *top* (including *top* itself), it yields a 3-tuple `(dirpath, dirnames, filenames)`.

dirpath is a string, the path to the directory. *dirnames* is a list of the names of the subdirectories in *dirpath* (excluding `'.'` and `'..'`). *filenames* is a list of the names of the non-directory files in *dirpath*. Note that the names in the lists contain no path components. To get a full path (which begins with *top*) to a file or directory in *dirpath*, do `os.path.join(dirpath, name)`.

If optional argument *topdown* is `True` or not specified, the triple for a directory is generated before the triples for any of its subdirectories (directories are generated top-down). If *topdown* is `False`, the triple for a directory is generated after the triples for all of its subdirectories (directories are generated bottom-up). No matter the value of *topdown*, the list of subdirectories is retrieved before the tuples for the directory and its subdirectories are generated.

When *topdown* is `True`, the caller can modify the *dirnames* list in-place (perhaps using `del` or slice assignment), and *walk()* will only recurse into the subdirectories whose names remain in *dirnames*; this can be used to prune the search, impose a specific order of visiting, or even to inform *walk()* about directories the caller creates or renames before it resumes *walk()* again. Modifying *dirnames* when *topdown* is `False` has no effect on the behavior of the walk, because in bottom-up mode the directories in *dirnames* are generated before *dirpath* itself is generated.

By default, errors from the *scandir()* call are ignored. If optional argument *onerror* is specified, it should be a function; it will be called with one argument, an *OSError* instance. It can report the error to continue with the walk, or raise the exception to abort the walk. Note that the filename is available as the `filename` attribute of the exception object.

By default, *walk()* will not walk down into symbolic links that resolve to directories. Set *followlinks* to `True` to visit directories pointed to by symlinks, on systems that support them.

Note: Be aware that setting *followlinks* to `True` can lead to infinite recursion if a link points to a parent directory of itself. *walk()* does not keep track of the directories it visited already.

Note: If you pass a relative pathname, don't change the current working directory between resumptions of *walk()*. *walk()* never changes the current directory, and assumes that its caller doesn't either.

This example displays the number of bytes taken by non-directory files in each directory under the starting directory, except that it doesn't look under any CVS subdirectory:

```
import os
from os.path import join, getsize
for root, dirs, files in os.walk('python/Lib/email'):
    print(root, "consumes", end=" ")
    print(sum(getsize(join(root, name)) for name in files), end=" ")
    print("bytes in", len(files), "non-directory files")
    if 'CVS' in dirs:
        dirs.remove('CVS')  # don't visit CVS directories
```

In the next example (simple implementation of *shutil.rmtree()*), walking the tree bottom-up is essential, *rmdir()* doesn't allow deleting a directory before the directory is empty:

```
# Delete everything reachable from the directory named in "top",
# assuming there are no symbolic links.
```

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```
# CAUTION:  This is dangerous!  For example, if top == '/', it
# could delete all your disk files.
import os
for root, dirs, files in os.walk(top, topdown=False):
    for name in files:
        os.remove(os.path.join(root, name))
    for name in dirs:
        os.rmdir(os.path.join(root, name))
```

Changed in version 3.5: This function now calls *os.scandir()* instead of *os.listdir()*, making it faster by reducing the number of calls to *os.stat()*.

Changed in version 3.6: Accepts a *path-like object*.

os.fwalk(*top='.'*, *topdown=True*, *onerror=None*, ***, *follow_symlinks=False*, *dir_fd=None*)

This behaves exactly like *walk()*, except that it yields a 4-tuple `(dirpath, dirnames, filenames, dirfd)`, and it supports `dir_fd`.

dirpath, *dirnames* and *filenames* are identical to *walk()* output, and *dirfd* is a file descriptor referring to the directory *dirpath*.

This function always supports *paths relative to directory descriptors* and *not following symlinks*. Note however that, unlike other functions, the *fwalk()* default value for *follow_symlinks* is `False`.

Note: Since *fwalk()* yields file descriptors, those are only valid until the next iteration step, so you should duplicate them (e.g. with *dup()*) if you want to keep them longer.

This example displays the number of bytes taken by non-directory files in each directory under the starting directory, except that it doesn't look under any CVS subdirectory:

```
import os
for root, dirs, files, rootfd in os.fwalk('python/Lib/email'):
    print(root, "consumes", end="")
    print(sum([os.stat(name, dir_fd=rootfd).st_size for name in files]),
          end="")
    print("bytes in", len(files), "non-directory files")
    if 'CVS' in dirs:
        dirs.remove('CVS')  # don't visit CVS directories
```

In the next example, walking the tree bottom-up is essential: *rmdir()* doesn't allow deleting a directory before the directory is empty:

```
# Delete everything reachable from the directory named in "top",
# assuming there are no symbolic links.
# CAUTION:  This is dangerous!  For example, if top == '/', it
# could delete all your disk files.
import os
for root, dirs, files, rootfd in os.fwalk(top, topdown=False):
    for name in files:
        os.unlink(name, dir_fd=rootfd)
    for name in dirs:
        os.rmdir(name, dir_fd=rootfd)
```

Availability: Unix.

New in version 3.3.

Changed in version 3.6: Accepts a *path-like object*.

Changed in version 3.7: Added support for *bytes* paths.

Linux extended attributes

New in version 3.3.

These functions are all available on Linux only.

os.getxattr(*path*, *attribute*, ***, *follow_symlinks=True*)
Return the value of the extended filesystem attribute *attribute* for *path*. *attribute* can be bytes or str (directly or indirectly through the *PathLike* interface). If it is str, it is encoded with the filesystem encoding.

This function can support *specifying a file descriptor* and *not following symlinks*.

Changed in version 3.6: Accepts a *path-like object* for *path* and *attribute*.

os.listxattr(*path=None*, ***, *follow_symlinks=True*)
Return a list of the extended filesystem attributes on *path*. The attributes in the list are represented as strings decoded with the filesystem encoding. If *path* is `None`, *listxattr()* will examine the current directory.

This function can support *specifying a file descriptor* and *not following symlinks*.

Changed in version 3.6: Accepts a *path-like object*.

os.removexattr(*path*, *attribute*, ***, *follow_symlinks=True*)
Removes the extended filesystem attribute *attribute* from *path*. *attribute* should be bytes or str (directly or indirectly through the *PathLike* interface). If it is a string, it is encoded with the filesystem encoding.

This function can support *specifying a file descriptor* and *not following symlinks*.

Changed in version 3.6: Accepts a *path-like object* for *path* and *attribute*.

os.setxattr(*path*, *attribute*, *value*, *flags=0*, ***, *follow_symlinks=True*)
Set the extended filesystem attribute *attribute* on *path* to *value*. *attribute* must be a bytes or str with no embedded NULs (directly or indirectly through the *PathLike* interface). If it is a str, it is encoded with the filesystem encoding. *flags* may be *XATTR_REPLACE* or *XATTR_CREATE*. If *XATTR_REPLACE* is given and the attribute does not exist, `EEXISTS` will be raised. If *XATTR_CREATE* is given and the attribute already exists, the attribute will not be created and `ENODATA` will be raised.

This function can support *specifying a file descriptor* and *not following symlinks*.

Note: A bug in Linux kernel versions less than 2.6.39 caused the flags argument to be ignored on some filesystems.

Changed in version 3.6: Accepts a *path-like object* for *path* and *attribute*.

os.XATTR_SIZE_MAX
The maximum size the value of an extended attribute can be. Currently, this is 64 KiB on Linux.

os.XATTR_CREATE
This is a possible value for the flags argument in *setxattr()*. It indicates the operation must create an attribute.

os.XATTR_REPLACE
This is a possible value for the flags argument in *setxattr()*. It indicates the operation must replace an existing attribute.

16.1.6 Process Management

These functions may be used to create and manage processes.

The various *exec** functions take a list of arguments for the new program loaded into the process. In each case, the first of these arguments is passed to the new program as its own name rather than as an argument a user may have typed on a command line. For the C programmer, this is the `argv[0]` passed to a program's `main()`. For example, `os.execv('/bin/echo', ['foo', 'bar'])` will only print `bar` on standard output; `foo` will seem to be ignored.

`os.abort()`
Generate a `SIGABRT` signal to the current process. On Unix, the default behavior is to produce a core dump; on Windows, the process immediately returns an exit code of `3`. Be aware that calling this function will not call the Python signal handler registered for `SIGABRT` with *signal.signal()*.

`os.execl`(*path*, *arg0*, *arg1*, *...*)
`os.execle`(*path*, *arg0*, *arg1*, *...*, *env*)
`os.execlp`(*file*, *arg0*, *arg1*, *...*)
`os.execlpe`(*file*, *arg0*, *arg1*, *...*, *env*)
`os.execv`(*path*, *args*)
`os.execve`(*path*, *args*, *env*)
`os.execvp`(*file*, *args*)
`os.execvpe`(*file*, *args*, *env*)
These functions all execute a new program, replacing the current process; they do not return. On Unix, the new executable is loaded into the current process, and will have the same process id as the caller. Errors will be reported as *OSError* exceptions.

The current process is replaced immediately. Open file objects and descriptors are not flushed, so if there may be data buffered on these open files, you should flush them using `sys.stdout.flush()` or *os.fsync()* before calling an *exec** function.

The "l" and "v" variants of the *exec** functions differ in how command-line arguments are passed. The "l" variants are perhaps the easiest to work with if the number of parameters is fixed when the code is written; the individual parameters simply become additional parameters to the `execl*()` functions. The "v" variants are good when the number of parameters is variable, with the arguments being passed in a list or tuple as the *args* parameter. In either case, the arguments to the child process should start with the name of the command being run, but this is not enforced.

The variants which include a "p" near the end (*execlp()*, *execlpe()*, *execvp()*, and *execvpe()*) will use the `PATH` environment variable to locate the program *file*. When the environment is being replaced (using one of the *exec*e* variants, discussed in the next paragraph), the new environment is used as the source of the `PATH` variable. The other variants, *execl()*, *execle()*, *execv()*, and *execve()*, will not use the `PATH` variable to locate the executable; *path* must contain an appropriate absolute or relative path.

For *execle()*, *execlpe()*, *execve()*, and *execvpe()* (note that these all end in "e"), the *env* parameter must be a mapping which is used to define the environment variables for the new process (these are used instead of the current process' environment); the functions *execl()*, *execlp()*, *execv()*, and *execvp()* all cause the new process to inherit the environment of the current process.

For *execve()* on some platforms, *path* may also be specified as an open file descriptor. This functionality may not be supported on your platform; you can check whether or not it is available using *os.supports_fd*. If it is unavailable, using it will raise a *NotImplementedError*.

Availability: Unix, Windows.

New in version 3.3: Added support for specifying an open file descriptor for *path* for *execve()*.

Changed in version 3.6: Accepts a *path-like object*.

os._exit(*n*)
Exit the process with status *n*, without calling cleanup handlers, flushing stdio buffers, etc.

Note: The standard way to exit is `sys.exit(n)`. *_exit()* should normally only be used in the child process after a *fork()*.

The following exit codes are defined and can be used with *_exit()*, although they are not required. These are typically used for system programs written in Python, such as a mail server's external command delivery program.

Note: Some of these may not be available on all Unix platforms, since there is some variation. These constants are defined where they are defined by the underlying platform.

os.EX_OK
Exit code that means no error occurred.

Availability: Unix.

os.EX_USAGE
Exit code that means the command was used incorrectly, such as when the wrong number of arguments are given.

Availability: Unix.

os.EX_DATAERR
Exit code that means the input data was incorrect.

Availability: Unix.

os.EX_NOINPUT
Exit code that means an input file did not exist or was not readable.

Availability: Unix.

os.EX_NOUSER
Exit code that means a specified user did not exist.

Availability: Unix.

os.EX_NOHOST
Exit code that means a specified host did not exist.

Availability: Unix.

os.EX_UNAVAILABLE
Exit code that means that a required service is unavailable.

Availability: Unix.

os.EX_SOFTWARE
Exit code that means an internal software error was detected.

Availability: Unix.

os.EX_OSERR
Exit code that means an operating system error was detected, such as the inability to fork or create a pipe.

Availability: Unix.

os.EX_OSFILE
Exit code that means some system file did not exist, could not be opened, or had some other kind of error.

Availability: Unix.

os.EX_CANTCREAT
: Exit code that means a user specified output file could not be created.

  Availability: Unix.

os.EX_IOERR
: Exit code that means that an error occurred while doing I/O on some file.

  Availability: Unix.

os.EX_TEMPFAIL
: Exit code that means a temporary failure occurred. This indicates something that may not really be an error, such as a network connection that couldn't be made during a retryable operation.

  Availability: Unix.

os.EX_PROTOCOL
: Exit code that means that a protocol exchange was illegal, invalid, or not understood.

  Availability: Unix.

os.EX_NOPERM
: Exit code that means that there were insufficient permissions to perform the operation (but not intended for file system problems).

  Availability: Unix.

os.EX_CONFIG
: Exit code that means that some kind of configuration error occurred.

  Availability: Unix.

os.EX_NOTFOUND
: Exit code that means something like "an entry was not found".

  Availability: Unix.

os.fork()
: Fork a child process. Return `0` in the child and the child's process id in the parent. If an error occurs *OSError* is raised.

  Note that some platforms including FreeBSD <= 6.3 and Cygwin have known issues when using fork() from a thread.

  > **Warning:** See *ssl* for applications that use the SSL module with fork().

  Availability: Unix.

os.forkpty()
: Fork a child process, using a new pseudo-terminal as the child's controlling terminal. Return a pair of `(pid, fd)`, where *pid* is `0` in the child, the new child's process id in the parent, and *fd* is the file descriptor of the master end of the pseudo-terminal. For a more portable approach, use the *pty* module. If an error occurs *OSError* is raised.

  Availability: some flavors of Unix.

os.kill(*pid*, *sig*)
: Send signal *sig* to the process *pid*. Constants for the specific signals available on the host platform are defined in the *signal* module.

Windows: The *signal.CTRL_C_EVENT* and *signal.CTRL_BREAK_EVENT* signals are special signals which can only be sent to console processes which share a common console window, e.g., some subprocesses. Any other value for *sig* will cause the process to be unconditionally killed by the TerminateProcess API, and the exit code will be set to *sig*. The Windows version of *kill()* additionally takes process handles to be killed.

See also *signal.pthread_kill()*.

New in version 3.2: Windows support.

`os.killpg`(*pgid*, *sig*)
Send the signal *sig* to the process group *pgid*.

Availability: Unix.

`os.nice`(*increment*)
Add *increment* to the process's "niceness". Return the new niceness.

Availability: Unix.

`os.plock`(*op*)
Lock program segments into memory. The value of *op* (defined in `<sys/lock.h>`) determines which segments are locked.

Availability: Unix.

`os.popen`(*cmd*, *mode='r'*, *buffering=-1*)
Open a pipe to or from command *cmd*. The return value is an open file object connected to the pipe, which can be read or written depending on whether *mode* is `'r'` (default) or `'w'`. The *buffering* argument has the same meaning as the corresponding argument to the built-in *open()* function. The returned file object reads or writes text strings rather than bytes.

The `close` method returns *None* if the subprocess exited successfully, or the subprocess's return code if there was an error. On POSIX systems, if the return code is positive it represents the return value of the process left-shifted by one byte. If the return code is negative, the process was terminated by the signal given by the negated value of the return code. (For example, the return value might be `-signal.SIGKILL` if the subprocess was killed.) On Windows systems, the return value contains the signed integer return code from the child process.

This is implemented using *subprocess.Popen*; see that class's documentation for more powerful ways to manage and communicate with subprocesses.

`os.register_at_fork`(***, *before=None*, *after_in_parent=None*, *after_in_child=None*)
Register callables to be executed when a new child process is forked using *os.fork()* or similar process cloning APIs. The parameters are optional and keyword-only. Each specifies a different call point.

- *before* is a function called before forking a child process.
- *after_in_parent* is a function called from the parent process after forking a child process.
- *after_in_child* is a function called from the child process.

These calls are only made if control is expected to return to the Python interpreter. A typical *subprocess* launch will not trigger them as the child is not going to re-enter the interpreter.

Functions registered for execution before forking are called in reverse registration order. Functions registered for execution after forking (either in the parent or in the child) are called in registration order.

Note that `fork()` calls made by third-party C code may not call those functions, unless it explicitly calls `PyOS_BeforeFork()`, `PyOS_AfterFork_Parent()` and `PyOS_AfterFork_Child()`.

There is no way to unregister a function.

Availability: Unix.

New in version 3.7.

os.**spawnl**(*mode*, *path*, *...*)
os.**spawnle**(*mode*, *path*, *...*, *env*)
os.**spawnlp**(*mode*, *file*, *...*)
os.**spawnlpe**(*mode*, *file*, *...*, *env*)
os.**spawnv**(*mode*, *path*, *args*)
os.**spawnve**(*mode*, *path*, *args*, *env*)
os.**spawnvp**(*mode*, *file*, *args*)
os.**spawnvpe**(*mode*, *file*, *args*, *env*)

Execute the program *path* in a new process.

(Note that the *subprocess* module provides more powerful facilities for spawning new processes and retrieving their results; using that module is preferable to using these functions. Check especially the *Replacing Older Functions with the subprocess Module* section.)

If *mode* is *P_NOWAIT*, this function returns the process id of the new process; if *mode* is *P_WAIT*, returns the process's exit code if it exits normally, or `-signal`, where *signal* is the signal that killed the process. On Windows, the process id will actually be the process handle, so can be used with the *waitpid()* function.

The "l" and "v" variants of the *spawn** functions differ in how command-line arguments are passed. The "l" variants are perhaps the easiest to work with if the number of parameters is fixed when the code is written; the individual parameters simply become additional parameters to the `spawnl*()` functions. The "v" variants are good when the number of parameters is variable, with the arguments being passed in a list or tuple as the *args* parameter. In either case, the arguments to the child process must start with the name of the command being run.

The variants which include a second "p" near the end (*spawnlp()*, *spawnlpe()*, *spawnvp()*, and *spawnvpe()*) will use the `PATH` environment variable to locate the program *file*. When the environment is being replaced (using one of the *spawn*e* variants, discussed in the next paragraph), the new environment is used as the source of the `PATH` variable. The other variants, *spawnl()*, *spawnle()*, *spawnv()*, and *spawnve()*, will not use the `PATH` variable to locate the executable; *path* must contain an appropriate absolute or relative path.

For *spawnle()*, *spawnlpe()*, *spawnve()*, and *spawnvpe()* (note that these all end in "e"), the *env* parameter must be a mapping which is used to define the environment variables for the new process (they are used instead of the current process' environment); the functions *spawnl()*, *spawnlp()*, *spawnv()*, and *spawnvp()* all cause the new process to inherit the environment of the current process. Note that keys and values in the *env* dictionary must be strings; invalid keys or values will cause the function to fail, with a return value of `127`.

As an example, the following calls to *spawnlp()* and *spawnvpe()* are equivalent:

```
import os
os.spawnlp(os.P_WAIT, 'cp', 'cp', 'index.html', '/dev/null')

L = ['cp', 'index.html', '/dev/null']
os.spawnvpe(os.P_WAIT, 'cp', L, os.environ)
```

Availability: Unix, Windows. *spawnlp()*, *spawnlpe()*, *spawnvp()* and *spawnvpe()* are not available on Windows. *spawnle()* and *spawnve()* are not thread-safe on Windows; we advise you to use the *subprocess* module instead.

Changed in version 3.6: Accepts a *path-like object*.

os.**P_NOWAIT**
os.**P_NOWAITO**

Possible values for the *mode* parameter to the *spawn** family of functions. If either of these values is

given, the spawn*() functions will return as soon as the new process has been created, with the process id as the return value.

Availability: Unix, Windows.

os.P_WAIT
Possible value for the *mode* parameter to the *spawn** family of functions. If this is given as *mode*, the spawn*() functions will not return until the new process has run to completion and will return the exit code of the process the run is successful, or -signal if a signal kills the process.

Availability: Unix, Windows.

os.P_DETACH
os.P_OVERLAY
Possible values for the *mode* parameter to the *spawn** family of functions. These are less portable than those listed above. *P_DETACH* is similar to *P_NOWAIT*, but the new process is detached from the console of the calling process. If *P_OVERLAY* is used, the current process will be replaced; the *spawn** function will not return.

Availability: Windows.

os.startfile(*path*[, *operation*])
Start a file with its associated application.

When *operation* is not specified or 'open', this acts like double-clicking the file in Windows Explorer, or giving the file name as an argument to the start command from the interactive command shell: the file is opened with whatever application (if any) its extension is associated.

When another *operation* is given, it must be a "command verb" that specifies what should be done with the file. Common verbs documented by Microsoft are 'print' and 'edit' (to be used on files) as well as 'explore' and 'find' (to be used on directories).

startfile() returns as soon as the associated application is launched. There is no option to wait for the application to close, and no way to retrieve the application's exit status. The *path* parameter is relative to the current directory. If you want to use an absolute path, make sure the first character is not a slash ('/'); the underlying Win32 ShellExecute() function doesn't work if it is. Use the *os.path.normpath()* function to ensure that the path is properly encoded for Win32.

To reduce interpreter startup overhead, the Win32 ShellExecute() function is not resolved until this function is first called. If the function cannot be resolved, *NotImplementedError* will be raised.

Availability: Windows.

os.system(*command*)
Execute the command (a string) in a subshell. This is implemented by calling the Standard C function system(), and has the same limitations. Changes to *sys.stdin*, etc. are not reflected in the environment of the executed command. If *command* generates any output, it will be sent to the interpreter standard output stream.

On Unix, the return value is the exit status of the process encoded in the format specified for *wait()*. Note that POSIX does not specify the meaning of the return value of the C system() function, so the return value of the Python function is system-dependent.

On Windows, the return value is that returned by the system shell after running *command*. The shell is given by the Windows environment variable COMSPEC: it is usually cmd.exe, which returns the exit status of the command run; on systems using a non-native shell, consult your shell documentation.

The *subprocess* module provides more powerful facilities for spawning new processes and retrieving their results; using that module is preferable to using this function. See the *Replacing Older Functions with the subprocess Module* section in the *subprocess* documentation for some helpful recipes.

Availability: Unix, Windows.

os.times()
Returns the current global process times. The return value is an object with five attributes:

- user - user time
- system - system time
- children_user - user time of all child processes
- children_system - system time of all child processes
- elapsed - elapsed real time since a fixed point in the past

For backwards compatibility, this object also behaves like a five-tuple containing user, system, children_user, children_system, and elapsed in that order.

See the Unix manual page *times(2)* or the corresponding Windows Platform API documentation. On Windows, only user and system are known; the other attributes are zero.

Availability: Unix, Windows.

Changed in version 3.3: Return type changed from a tuple to a tuple-like object with named attributes.

os.wait()
Wait for completion of a child process, and return a tuple containing its pid and exit status indication: a 16-bit number, whose low byte is the signal number that killed the process, and whose high byte is the exit status (if the signal number is zero); the high bit of the low byte is set if a core file was produced.

Availability: Unix.

os.waitid(*idtype*, *id*, *options*)
Wait for the completion of one or more child processes. *idtype* can be *P_PID*, *P_PGID* or *P_ALL*. *id* specifies the pid to wait on. *options* is constructed from the ORing of one or more of *WEXITED*, *WSTOPPED* or *WCONTINUED* and additionally may be ORed with *WNOHANG* or *WNOWAIT*. The return value is an object representing the data contained in the siginfo_t structure, namely: si_pid, si_uid, si_signo, si_status, si_code or None if *WNOHANG* is specified and there are no children in a waitable state.

Availability: Unix.

New in version 3.3.

os.P_PID
os.P_PGID
os.P_ALL
These are the possible values for *idtype* in *waitid()*. They affect how *id* is interpreted.

Availability: Unix.

New in version 3.3.

os.WEXITED
os.WSTOPPED
os.WNOWAIT
Flags that can be used in *options* in *waitid()* that specify what child signal to wait for.

Availability: Unix.

New in version 3.3.

os.CLD_EXITED
os.CLD_DUMPED
os.CLD_TRAPPED

os.CLD_CONTINUED
These are the possible values for si_code in the result returned by *waitid()*.

Availability: Unix.

New in version 3.3.

os.waitpid(*pid*, *options*)
The details of this function differ on Unix and Windows.

On Unix: Wait for completion of a child process given by process id *pid*, and return a tuple containing its process id and exit status indication (encoded as for *wait()*). The semantics of the call are affected by the value of the integer *options*, which should be 0 for normal operation.

If *pid* is greater than 0, *waitpid()* requests status information for that specific process. If *pid* is 0, the request is for the status of any child in the process group of the current process. If *pid* is -1, the request pertains to any child of the current process. If *pid* is less than -1, status is requested for any process in the process group -pid (the absolute value of *pid*).

An *OSError* is raised with the value of errno when the syscall returns -1.

On Windows: Wait for completion of a process given by process handle *pid*, and return a tuple containing *pid*, and its exit status shifted left by 8 bits (shifting makes cross-platform use of the function easier). A *pid* less than or equal to 0 has no special meaning on Windows, and raises an exception. The value of integer *options* has no effect. *pid* can refer to any process whose id is known, not necessarily a child process. The *spawn** functions called with *P_NOWAIT* return suitable process handles.

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the function now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

os.wait3(*options*)
Similar to *waitpid()*, except no process id argument is given and a 3-element tuple containing the child's process id, exit status indication, and resource usage information is returned. Refer to *resource.getrusage()* for details on resource usage information. The option argument is the same as that provided to *waitpid()* and *wait4()*.

Availability: Unix.

os.wait4(*pid*, *options*)
Similar to *waitpid()*, except a 3-element tuple, containing the child's process id, exit status indication, and resource usage information is returned. Refer to *resource.getrusage()* for details on resource usage information. The arguments to *wait4()* are the same as those provided to *waitpid()*.

Availability: Unix.

os.WNOHANG
The option for *waitpid()* to return immediately if no child process status is available immediately. The function returns (0, 0) in this case.

Availability: Unix.

os.WCONTINUED
This option causes child processes to be reported if they have been continued from a job control stop since their status was last reported.

Availability: some Unix systems.

os.WUNTRACED
This option causes child processes to be reported if they have been stopped but their current state has not been reported since they were stopped.

Availability: Unix.

The following functions take a process status code as returned by *system()*, *wait()*, or *waitpid()* as a parameter. They may be used to determine the disposition of a process.

`os.WCOREDUMP`(*status*)
Return `True` if a core dump was generated for the process, otherwise return `False`.

Availability: Unix.

`os.WIFCONTINUED`(*status*)
Return `True` if the process has been continued from a job control stop, otherwise return `False`.

Availability: Unix.

`os.WIFSTOPPED`(*status*)
Return `True` if the process has been stopped, otherwise return `False`.

Availability: Unix.

`os.WIFSIGNALED`(*status*)
Return `True` if the process exited due to a signal, otherwise return `False`.

Availability: Unix.

`os.WIFEXITED`(*status*)
Return `True` if the process exited using the *exit(2)* system call, otherwise return `False`.

Availability: Unix.

`os.WEXITSTATUS`(*status*)
If `WIFEXITED(status)` is true, return the integer parameter to the *exit(2)* system call. Otherwise, the return value is meaningless.

Availability: Unix.

`os.WSTOPSIG`(*status*)
Return the signal which caused the process to stop.

Availability: Unix.

`os.WTERMSIG`(*status*)
Return the signal which caused the process to exit.

Availability: Unix.

16.1.7 Interface to the scheduler

These functions control how a process is allocated CPU time by the operating system. They are only available on some Unix platforms. For more detailed information, consult your Unix manpages.

New in version 3.3.

The following scheduling policies are exposed if they are supported by the operating system.

`os.SCHED_OTHER`
The default scheduling policy.

`os.SCHED_BATCH`
Scheduling policy for CPU-intensive processes that tries to preserve interactivity on the rest of the computer.

`os.SCHED_IDLE`
Scheduling policy for extremely low priority background tasks.

`os.SCHED_SPORADIC`
Scheduling policy for sporadic server programs.

os.**SCHED_FIFO**
A First In First Out scheduling policy.

os.**SCHED_RR**
A round-robin scheduling policy.

os.**SCHED_RESET_ON_FORK**
This flag can be OR'ed with any other scheduling policy. When a process with this flag set forks, its child's scheduling policy and priority are reset to the default.

class os.**sched_param**(*sched_priority*)
This class represents tunable scheduling parameters used in *sched_setparam()*, *sched_setscheduler()*, and *sched_getparam()*. It is immutable.

At the moment, there is only one possible parameter:

sched_priority
The scheduling priority for a scheduling policy.

os.**sched_get_priority_min**(*policy*)
Get the minimum priority value for *policy*. *policy* is one of the scheduling policy constants above.

os.**sched_get_priority_max**(*policy*)
Get the maximum priority value for *policy*. *policy* is one of the scheduling policy constants above.

os.**sched_setscheduler**(*pid*, *policy*, *param*)
Set the scheduling policy for the process with PID *pid*. A *pid* of 0 means the calling process. *policy* is one of the scheduling policy constants above. *param* is a *sched_param* instance.

os.**sched_getscheduler**(*pid*)
Return the scheduling policy for the process with PID *pid*. A *pid* of 0 means the calling process. The result is one of the scheduling policy constants above.

os.**sched_setparam**(*pid*, *param*)
Set a scheduling parameters for the process with PID *pid*. A *pid* of 0 means the calling process. *param* is a *sched_param* instance.

os.**sched_getparam**(*pid*)
Return the scheduling parameters as a *sched_param* instance for the process with PID *pid*. A *pid* of 0 means the calling process.

os.**sched_rr_get_interval**(*pid*)
Return the round-robin quantum in seconds for the process with PID *pid*. A *pid* of 0 means the calling process.

os.**sched_yield**()
Voluntarily relinquish the CPU.

os.**sched_setaffinity**(*pid*, *mask*)
Restrict the process with PID *pid* (or the current process if zero) to a set of CPUs. *mask* is an iterable of integers representing the set of CPUs to which the process should be restricted.

os.**sched_getaffinity**(*pid*)
Return the set of CPUs the process with PID *pid* (or the current process if zero) is restricted to.

16.1.8 Miscellaneous System Information

os.**confstr**(*name*)
Return string-valued system configuration values. *name* specifies the configuration value to retrieve; it may be a string which is the name of a defined system value; these names are specified in a number of standards (POSIX, Unix 95, Unix 98, and others). Some platforms define additional names as well.

The names known to the host operating system are given as the keys of the `confstr_names` dictionary. For configuration variables not included in that mapping, passing an integer for *name* is also accepted.

If the configuration value specified by *name* isn't defined, `None` is returned.

If *name* is a string and is not known, *ValueError* is raised. If a specific value for *name* is not supported by the host system, even if it is included in `confstr_names`, an *OSError* is raised with *errno.EINVAL* for the error number.

Availability: Unix.

`os.confstr_names`
Dictionary mapping names accepted by *confstr()* to the integer values defined for those names by the host operating system. This can be used to determine the set of names known to the system.

Availability: Unix.

`os.cpu_count()`
Return the number of CPUs in the system. Returns `None` if undetermined.

This number is not equivalent to the number of CPUs the current process can use. The number of usable CPUs can be obtained with `len(os.sched_getaffinity(0))`

New in version 3.4.

`os.getloadavg()`
Return the number of processes in the system run queue averaged over the last 1, 5, and 15 minutes or raises *OSError* if the load average was unobtainable.

Availability: Unix.

`os.sysconf(`*name*`)`
Return integer-valued system configuration values. If the configuration value specified by *name* isn't defined, `-1` is returned. The comments regarding the *name* parameter for *confstr()* apply here as well; the dictionary that provides information on the known names is given by `sysconf_names`.

Availability: Unix.

`os.sysconf_names`
Dictionary mapping names accepted by *sysconf()* to the integer values defined for those names by the host operating system. This can be used to determine the set of names known to the system.

Availability: Unix.

The following data values are used to support path manipulation operations. These are defined for all platforms.

Higher-level operations on pathnames are defined in the *os.path* module.

`os.curdir`
The constant string used by the operating system to refer to the current directory. This is `'.'` for Windows and POSIX. Also available via *os.path*.

`os.pardir`
The constant string used by the operating system to refer to the parent directory. This is `'..'` for Windows and POSIX. Also available via *os.path*.

`os.sep`
The character used by the operating system to separate pathname components. This is `'/'` for POSIX and `'\\'` for Windows. Note that knowing this is not sufficient to be able to parse or concatenate pathnames — use *os.path.split()* and *os.path.join()* — but it is occasionally useful. Also available via *os.path*.

`os.altsep`
An alternative character used by the operating system to separate pathname components, or `None` if

only one separator character exists. This is set to `'/'` on Windows systems where `sep` is a backslash. Also available via *os.path*.

os.extsep
The character which separates the base filename from the extension; for example, the `'.'` in `os.py`. Also available via *os.path*.

os.pathsep
The character conventionally used by the operating system to separate search path components (as in `PATH`), such as `':'` for POSIX or `';'` for Windows. Also available via *os.path*.

os.defpath
The default search path used by *exec*p** and *spawn*p** if the environment doesn't have a `'PATH'` key. Also available via *os.path*.

os.linesep
The string used to separate (or, rather, terminate) lines on the current platform. This may be a single character, such as `'\n'` for POSIX, or multiple characters, for example, `'\r\n'` for Windows. Do not use *os.linesep* as a line terminator when writing files opened in text mode (the default); use a single `'\n'` instead, on all platforms.

os.devnull
The file path of the null device. For example: `'/dev/null'` for POSIX, `'nul'` for Windows. Also available via *os.path*.

os.RTLD_LAZY
os.RTLD_NOW
os.RTLD_GLOBAL
os.RTLD_LOCAL
os.RTLD_NODELETE
os.RTLD_NOLOAD
os.RTLD_DEEPBIND
Flags for use with the *setdlopenflags()* and *getdlopenflags()* functions. See the Unix manual page *dlopen(3)* for what the different flags mean.

New in version 3.3.

16.1.9 Random numbers

os.getrandom(*size*, *flags=0*)
Get up to *size* random bytes. The function can return less bytes than requested.

These bytes can be used to seed user-space random number generators or for cryptographic purposes.

`getrandom()` relies on entropy gathered from device drivers and other sources of environmental noise. Unnecessarily reading large quantities of data will have a negative impact on other users of the `/dev/random` and `/dev/urandom` devices.

The flags argument is a bit mask that can contain zero or more of the following values ORed together: *os.GRND_RANDOM* and *GRND_NONBLOCK*.

See also the Linux getrandom() manual page.

Availability: Linux 3.17 and newer.

New in version 3.6.

os.urandom(*size*)
Return a string of *size* random bytes suitable for cryptographic use.

This function returns random bytes from an OS-specific randomness source. The returned data should be unpredictable enough for cryptographic applications, though its exact quality depends on the OS implementation.

On Linux, if the `getrandom()` syscall is available, it is used in blocking mode: block until the system urandom entropy pool is initialized (128 bits of entropy are collected by the kernel). See the **PEP 524** for the rationale. On Linux, the *getrandom()* function can be used to get random bytes in non-blocking mode (using the *GRND_NONBLOCK* flag) or to poll until the system urandom entropy pool is initialized.

On a Unix-like system, random bytes are read from the `/dev/urandom` device. If the `/dev/urandom` device is not available or not readable, the *NotImplementedError* exception is raised.

On Windows, it will use `CryptGenRandom()`.

See also:

The *secrets* module provides higher level functions. For an easy-to-use interface to the random number generator provided by your platform, please see *random.SystemRandom*.

Changed in version 3.6.0: On Linux, `getrandom()` is now used in blocking mode to increase the security.

Changed in version 3.5.2: On Linux, if the `getrandom()` syscall blocks (the urandom entropy pool is not initialized yet), fall back on reading `/dev/urandom`.

Changed in version 3.5: On Linux 3.17 and newer, the `getrandom()` syscall is now used when available. On OpenBSD 5.6 and newer, the C `getentropy()` function is now used. These functions avoid the usage of an internal file descriptor.

`os.GRND_NONBLOCK`
By default, when reading from `/dev/random`, *getrandom()* blocks if no random bytes are available, and when reading from `/dev/urandom`, it blocks if the entropy pool has not yet been initialized.

If the *GRND_NONBLOCK* flag is set, then *getrandom()* does not block in these cases, but instead immediately raises *BlockingIOError*.

New in version 3.6.

`os.GRND_RANDOM`
If this bit is set, then random bytes are drawn from the `/dev/random` pool instead of the `/dev/urandom` pool.

New in version 3.6.

16.2 `io` — Core tools for working with streams

Source code: Lib/io.py

16.2.1 Overview

The *io* module provides Python's main facilities for dealing with various types of I/O. There are three main types of I/O: *text I/O*, *binary I/O* and *raw I/O*. These are generic categories, and various backing stores can be used for each of them. A concrete object belonging to any of these categories is called a *file object*. Other common terms are *stream* and *file-like object*.

Independently of its category, each concrete stream object will also have various capabilities: it can be read-only, write-only, or read-write. It can also allow arbitrary random access (seeking forwards or backwards to any location), or only sequential access (for example in the case of a socket or pipe).

All streams are careful about the type of data you give to them. For example giving a *str* object to the `write()` method of a binary stream will raise a `TypeError`. So will giving a *bytes* object to the `write()` method of a text stream.

Changed in version 3.3: Operations that used to raise *IOError* now raise *OSError*, since *IOError* is now an alias of *OSError*.

Text I/O

Text I/O expects and produces *str* objects. This means that whenever the backing store is natively made of bytes (such as in the case of a file), encoding and decoding of data is made transparently as well as optional translation of platform-specific newline characters.

The easiest way to create a text stream is with *open()*, optionally specifying an encoding:

```
f = open("myfile.txt", "r", encoding="utf-8")
```

In-memory text streams are also available as *StringIO* objects:

```
f = io.StringIO("some initial text data")
```

The text stream API is described in detail in the documentation of *TextIOBase*.

Binary I/O

Binary I/O (also called *buffered I/O*) expects *bytes-like objects* and produces *bytes* objects. No encoding, decoding, or newline translation is performed. This category of streams can be used for all kinds of non-text data, and also when manual control over the handling of text data is desired.

The easiest way to create a binary stream is with *open()* with `'b'` in the mode string:

```
f = open("myfile.jpg", "rb")
```

In-memory binary streams are also available as *BytesIO* objects:

```
f = io.BytesIO(b"some initial binary data: \x00\x01")
```

The binary stream API is described in detail in the docs of *BufferedIOBase*.

Other library modules may provide additional ways to create text or binary streams. See *socket.socket.makefile()* for example.

Raw I/O

Raw I/O (also called *unbuffered I/O*) is generally used as a low-level building-block for binary and text streams; it is rarely useful to directly manipulate a raw stream from user code. Nevertheless, you can create a raw stream by opening a file in binary mode with buffering disabled:

```
f = open("myfile.jpg", "rb", buffering=0)
```

The raw stream API is described in detail in the docs of *RawIOBase*.

16.2.2 High-level Module Interface

`io.DEFAULT_BUFFER_SIZE`
An int containing the default buffer size used by the module's buffered I/O classes. *open()* uses the file's blksize (as obtained by *os.stat()*) if possible.

`io.open`(*file*, *mode='r'*, *buffering=-1*, *encoding=None*, *errors=None*, *newline=None*, *closefd=True*, *opener=None*)
This is an alias for the builtin *open()* function.

`exception io.BlockingIOError`
This is a compatibility alias for the builtin *BlockingIOError* exception.

`exception io.UnsupportedOperation`
An exception inheriting *OSError* and *ValueError* that is raised when an unsupported operation is called on a stream.

In-memory streams

It is also possible to use a *str* or *bytes-like object* as a file for both reading and writing. For strings *StringIO* can be used like a file opened in text mode. *BytesIO* can be used like a file opened in binary mode. Both provide full read-write capabilities with random access.

See also:

sys contains the standard IO streams: *sys.stdin*, *sys.stdout*, and *sys.stderr*.

16.2.3 Class hierarchy

The implementation of I/O streams is organized as a hierarchy of classes. First *abstract base classes* (ABCs), which are used to specify the various categories of streams, then concrete classes providing the standard stream implementations.

Note: The abstract base classes also provide default implementations of some methods in order to help implementation of concrete stream classes. For example, *BufferedIOBase* provides unoptimized implementations of `readinto()` and *readline()*.

At the top of the I/O hierarchy is the abstract base class *IOBase*. It defines the basic interface to a stream. Note, however, that there is no separation between reading and writing to streams; implementations are allowed to raise *UnsupportedOperation* if they do not support a given operation.

The *RawIOBase* ABC extends *IOBase*. It deals with the reading and writing of bytes to a stream. *FileIO* subclasses *RawIOBase* to provide an interface to files in the machine's file system.

The *BufferedIOBase* ABC deals with buffering on a raw byte stream (*RawIOBase*). Its subclasses, *BufferedWriter*, *BufferedReader*, and *BufferedRWPair* buffer streams that are readable, writable, and both readable and writable. *BufferedRandom* provides a buffered interface to random access streams. Another *BufferedIOBase* subclass, *BytesIO*, is a stream of in-memory bytes.

The *TextIOBase* ABC, another subclass of *IOBase*, deals with streams whose bytes represent text, and handles encoding and decoding to and from strings. *TextIOWrapper*, which extends it, is a buffered text interface to a buffered raw stream (*BufferedIOBase*). Finally, *StringIO* is an in-memory stream for text.

Argument names are not part of the specification, and only the arguments of *open()* are intended to be used as keyword arguments.

The following table summarizes the ABCs provided by the *io* module:

ABC	Inherits	Stub Methods	Mixin Methods and Properties
IOBase		`fileno`, `seek`, and `truncate`	`close`, `closed`, `__enter__`, `__exit__`, `flush`, `isatty`, `__iter__`, `__next__`, `readable`, `readline`, `readlines`, `seekable`, `tell`, `writable`, and `writelines`
RawIOBase	*IOBase*	`readinto` and `write`	Inherited *IOBase* methods, `read`, and `readall`
BufferedIOBase	*IOBase*	`detach`, `read`, `read1`, and `write`	Inherited *IOBase* methods, `readinto`, and `readinto1`
TextIOBase	*IOBase*	`detach`, `read`, `readline`, and `write`	Inherited *IOBase* methods, `encoding`, `errors`, and `newlines`

I/O Base Classes

class io.IOBase

The abstract base class for all I/O classes, acting on streams of bytes. There is no public constructor.

This class provides empty abstract implementations for many methods that derived classes can override selectively; the default implementations represent a file that cannot be read, written or seeked.

Even though *IOBase* does not declare `read()`, `readinto()`, or `write()` because their signatures will vary, implementations and clients should consider those methods part of the interface. Also, implementations may raise a *ValueError* (or *UnsupportedOperation*) when operations they do not support are called.

The basic type used for binary data read from or written to a file is *bytes*. Other *bytes-like objects* are accepted as method arguments too. In some cases, such as *readinto()*, a writable object such as *bytearray* is required. Text I/O classes work with *str* data.

Note that calling any method (even inquiries) on a closed stream is undefined. Implementations may raise *ValueError* in this case.

IOBase (and its subclasses) supports the iterator protocol, meaning that an *IOBase* object can be iterated over yielding the lines in a stream. Lines are defined slightly differently depending on whether the stream is a binary stream (yielding bytes), or a text stream (yielding character strings). See *readline()* below.

IOBase is also a context manager and therefore supports the `with` statement. In this example, *file* is closed after the `with` statement's suite is finished—even if an exception occurs:

```
with open('spam.txt', 'w') as file:
    file.write('Spam and eggs!')
```

IOBase provides these data attributes and methods:

close()

Flush and close this stream. This method has no effect if the file is already closed. Once the file is closed, any operation on the file (e.g. reading or writing) will raise a *ValueError*.

As a convenience, it is allowed to call this method more than once; only the first call, however, will have an effect.

closed

`True` if the stream is closed.

fileno()
Return the underlying file descriptor (an integer) of the stream if it exists. An *OSError* is raised if the IO object does not use a file descriptor.

flush()
Flush the write buffers of the stream if applicable. This does nothing for read-only and non-blocking streams.

isatty()
Return `True` if the stream is interactive (i.e., connected to a terminal/tty device).

readable()
Return `True` if the stream can be read from. If `False`, `read()` will raise *OSError*.

readline(*size=-1*)
Read and return one line from the stream. If *size* is specified, at most *size* bytes will be read.

The line terminator is always `b'\n'` for binary files; for text files, the *newline* argument to *open()* can be used to select the line terminator(s) recognized.

readlines(*hint=-1*)
Read and return a list of lines from the stream. *hint* can be specified to control the number of lines read: no more lines will be read if the total size (in bytes/characters) of all lines so far exceeds *hint*.

Note that it's already possible to iterate on file objects using `for line in file: ...` without calling `file.readlines()`.

seek(*offset*[, *whence*])
Change the stream position to the given byte *offset*. *offset* is interpreted relative to the position indicated by *whence*. The default value for *whence* is `SEEK_SET`. Values for *whence* are:

- `SEEK_SET` or `0` – start of the stream (the default); *offset* should be zero or positive
- `SEEK_CUR` or `1` – current stream position; *offset* may be negative
- `SEEK_END` or `2` – end of the stream; *offset* is usually negative

Return the new absolute position.

New in version 3.1: The `SEEK_*` constants.

New in version 3.3: Some operating systems could support additional values, like `os.SEEK_HOLE` or `os.SEEK_DATA`. The valid values for a file could depend on it being open in text or binary mode.

seekable()
Return `True` if the stream supports random access. If `False`, *seek()*, *tell()* and *truncate()* will raise *OSError*.

tell()
Return the current stream position.

truncate(*size=None*)
Resize the stream to the given *size* in bytes (or the current position if *size* is not specified). The current stream position isn't changed. This resizing can extend or reduce the current file size. In case of extension, the contents of the new file area depend on the platform (on most systems, additional bytes are zero-filled). The new file size is returned.

Changed in version 3.5: Windows will now zero-fill files when extending.

writable()
Return `True` if the stream supports writing. If `False`, `write()` and *truncate()* will raise *OSError*.

writelines(*lines*)
Write a list of lines to the stream. Line separators are not added, so it is usual for each of the lines provided to have a line separator at the end.

__del__()
Prepare for object destruction. *IOBase* provides a default implementation of this method that calls the instance's *close()* method.

class io.RawIOBase
Base class for raw binary I/O. It inherits *IOBase*. There is no public constructor.

Raw binary I/O typically provides low-level access to an underlying OS device or API, and does not try to encapsulate it in high-level primitives (this is left to Buffered I/O and Text I/O, described later in this page).

In addition to the attributes and methods from *IOBase*, *RawIOBase* provides the following methods:

read(*size=-1*)
Read up to *size* bytes from the object and return them. As a convenience, if *size* is unspecified or -1, all bytes until EOF are returned. Otherwise, only one system call is ever made. Fewer than *size* bytes may be returned if the operating system call returns fewer than *size* bytes.

If 0 bytes are returned, and *size* was not 0, this indicates end of file. If the object is in non-blocking mode and no bytes are available, `None` is returned.

The default implementation defers to *readall()* and *readinto()*.

readall()
Read and return all the bytes from the stream until EOF, using multiple calls to the stream if necessary.

readinto(*b*)
Read bytes into a pre-allocated, writable *bytes-like object* *b*, and return the number of bytes read. If the object is in non-blocking mode and no bytes are available, `None` is returned.

write(*b*)
Write the given *bytes-like object*, *b*, to the underlying raw stream, and return the number of bytes written. This can be less than the length of *b* in bytes, depending on specifics of the underlying raw stream, and especially if it is in non-blocking mode. `None` is returned if the raw stream is set not to block and no single byte could be readily written to it. The caller may release or mutate *b* after this method returns, so the implementation should only access *b* during the method call.

class io.BufferedIOBase
Base class for binary streams that support some kind of buffering. It inherits *IOBase*. There is no public constructor.

The main difference with *RawIOBase* is that methods *read()*, *readinto()* and *write()* will try (respectively) to read as much input as requested or to consume all given output, at the expense of making perhaps more than one system call.

In addition, those methods can raise *BlockingIOError* if the underlying raw stream is in non-blocking mode and cannot take or give enough data; unlike their *RawIOBase* counterparts, they will never return `None`.

Besides, the *read()* method does not have a default implementation that defers to *readinto()*.

A typical *BufferedIOBase* implementation should not inherit from a *RawIOBase* implementation, but wrap one, like *BufferedWriter* and *BufferedReader* do.

BufferedIOBase provides or overrides these methods and attribute in addition to those from *IOBase*:

raw
The underlying raw stream (a *RawIOBase* instance) that *BufferedIOBase* deals with. This is not part of the *BufferedIOBase* API and may not exist on some implementations.

detach()
Separate the underlying raw stream from the buffer and return it.

After the raw stream has been detached, the buffer is in an unusable state.

Some buffers, like *BytesIO*, do not have the concept of a single raw stream to return from this method. They raise *UnsupportedOperation*.

New in version 3.1.

read(*size=-1*)
Read and return up to *size* bytes. If the argument is omitted, `None`, or negative, data is read and returned until EOF is reached. An empty *bytes* object is returned if the stream is already at EOF.

If the argument is positive, and the underlying raw stream is not interactive, multiple raw reads may be issued to satisfy the byte count (unless EOF is reached first). But for interactive raw streams, at most one raw read will be issued, and a short result does not imply that EOF is imminent.

A *BlockingIOError* is raised if the underlying raw stream is in non blocking-mode, and has no data available at the moment.

read1([*size*])
Read and return up to *size* bytes, with at most one call to the underlying raw stream's *read()* (or *readinto()*) method. This can be useful if you are implementing your own buffering on top of a *BufferedIOBase* object.

If *size* is `-1` (the default), an arbitrary number of bytes are returned (more than zero unless EOF is reached).

readinto(*b*)
Read bytes into a pre-allocated, writable *bytes-like object* *b* and return the number of bytes read.

Like *read()*, multiple reads may be issued to the underlying raw stream, unless the latter is interactive.

A *BlockingIOError* is raised if the underlying raw stream is in non blocking-mode, and has no data available at the moment.

readinto1(*b*)
Read bytes into a pre-allocated, writable *bytes-like object* *b*, using at most one call to the underlying raw stream's *read()* (or *readinto()*) method. Return the number of bytes read.

A *BlockingIOError* is raised if the underlying raw stream is in non blocking-mode, and has no data available at the moment.

New in version 3.5.

write(*b*)
Write the given *bytes-like object*, *b*, and return the number of bytes written (always equal to the length of *b* in bytes, since if the write fails an *OSError* will be raised). Depending on the actual implementation, these bytes may be readily written to the underlying stream, or held in a buffer for performance and latency reasons.

When in non-blocking mode, a *BlockingIOError* is raised if the data needed to be written to the raw stream but it couldn't accept all the data without blocking.

The caller may release or mutate *b* after this method returns, so the implementation should only access *b* during the method call.

Raw File I/O

class io.FileIO(*name*, *mode='r'*, *closefd=True*, *opener=None*)

FileIO represents an OS-level file containing bytes data. It implements the *RawIOBase* interface (and therefore the *IOBase* interface, too).

The *name* can be one of two things:

- a character string or *bytes* object representing the path to the file which will be opened. In this case closefd must be `True` (the default) otherwise an error will be raised.
- an integer representing the number of an existing OS-level file descriptor to which the resulting *FileIO* object will give access. When the FileIO object is closed this fd will be closed as well, unless *closefd* is set to `False`.

The *mode* can be `'r'`, `'w'`, `'x'` or `'a'` for reading (default), writing, exclusive creation or appending. The file will be created if it doesn't exist when opened for writing or appending; it will be truncated when opened for writing. *FileExistsError* will be raised if it already exists when opened for creating. Opening a file for creating implies writing, so this mode behaves in a similar way to `'w'`. Add a `'+'` to the mode to allow simultaneous reading and writing.

The `read()` (when called with a positive argument), `readinto()` and `write()` methods on this class will only make one system call.

A custom opener can be used by passing a callable as *opener*. The underlying file descriptor for the file object is then obtained by calling *opener* with (*name*, *flags*). *opener* must return an open file descriptor (passing *os.open* as *opener* results in functionality similar to passing `None`).

The newly created file is *non-inheritable*.

See the *open()* built-in function for examples on using the *opener* parameter.

Changed in version 3.3: The *opener* parameter was added. The `'x'` mode was added.

Changed in version 3.4: The file is now non-inheritable.

In addition to the attributes and methods from *IOBase* and *RawIOBase*, *FileIO* provides the following data attributes:

mode
The mode as given in the constructor.

name
The file name. This is the file descriptor of the file when no name is given in the constructor.

Buffered Streams

Buffered I/O streams provide a higher-level interface to an I/O device than raw I/O does.

class io.BytesIO(*[initial_bytes]*)

A stream implementation using an in-memory bytes buffer. It inherits *BufferedIOBase*. The buffer is discarded when the *close()* method is called.

The optional argument *initial_bytes* is a *bytes-like object* that contains initial data.

BytesIO provides or overrides these methods in addition to those from *BufferedIOBase* and *IOBase*:

getbuffer()
Return a readable and writable view over the contents of the buffer without copying them. Also, mutating the view will transparently update the contents of the buffer:

```
>>> b = io.BytesIO(b"abcdef")
>>> view = b.getbuffer()
>>> view[2:4] = b"56"
>>> b.getvalue()
b'ab56ef'
```

Note: As long as the view exists, the *BytesIO* object cannot be resized or closed.

New in version 3.2.

getvalue()
Return *bytes* containing the entire contents of the buffer.

read1([*size*])
In *BytesIO*, this is the same as *read()*.

Changed in version 3.7: The *size* argument is now optional.

readinto1(*b*)
In *BytesIO*, this is the same as *readinto()*.

New in version 3.5.

class io.BufferedReader(*raw*, *buffer_size=DEFAULT_BUFFER_SIZE*)
A buffer providing higher-level access to a readable, sequential *RawIOBase* object. It inherits *BufferedIOBase*. When reading data from this object, a larger amount of data may be requested from the underlying raw stream, and kept in an internal buffer. The buffered data can then be returned directly on subsequent reads.

The constructor creates a *BufferedReader* for the given readable *raw* stream and *buffer_size*. If *buffer_size* is omitted, *DEFAULT_BUFFER_SIZE* is used.

BufferedReader provides or overrides these methods in addition to those from *BufferedIOBase* and *IOBase*:

peek([*size*])
Return bytes from the stream without advancing the position. At most one single read on the raw stream is done to satisfy the call. The number of bytes returned may be less or more than requested.

read([*size*])
Read and return *size* bytes, or if *size* is not given or negative, until EOF or if the read call would block in non-blocking mode.

read1([*size*])
Read and return up to *size* bytes with only one call on the raw stream. If at least one byte is buffered, only buffered bytes are returned. Otherwise, one raw stream read call is made.

Changed in version 3.7: The *size* argument is now optional.

class io.BufferedWriter(*raw*, *buffer_size=DEFAULT_BUFFER_SIZE*)
A buffer providing higher-level access to a writeable, sequential *RawIOBase* object. It inherits *BufferedIOBase*. When writing to this object, data is normally placed into an internal buffer. The buffer will be written out to the underlying *RawIOBase* object under various conditions, including:

- when the buffer gets too small for all pending data;
- when *flush()* is called;
- when a **seek()** is requested (for *BufferedRandom* objects);
- when the *BufferedWriter* object is closed or destroyed.

The constructor creates a *BufferedWriter* for the given writeable *raw* stream. If the *buffer_size* is not given, it defaults to *DEFAULT_BUFFER_SIZE*.

BufferedWriter provides or overrides these methods in addition to those from *BufferedIOBase* and *IOBase*:

flush()
Force bytes held in the buffer into the raw stream. A *BlockingIOError* should be raised if the raw stream blocks.

write(*b***)**
Write the *bytes-like object*, *b*, and return the number of bytes written. When in non-blocking mode, a *BlockingIOError* is raised if the buffer needs to be written out but the raw stream blocks.

class io.BufferedRandom(*raw*, *buffer_size=DEFAULT_BUFFER_SIZE***)**
A buffered interface to random access streams. It inherits *BufferedReader* and *BufferedWriter*, and further supports **seek()** and **tell()** functionality.

The constructor creates a reader and writer for a seekable raw stream, given in the first argument. If the *buffer_size* is omitted it defaults to *DEFAULT_BUFFER_SIZE*.

BufferedRandom is capable of anything *BufferedReader* or *BufferedWriter* can do.

class io.BufferedRWPair(*reader*, *writer*, *buffer_size=DEFAULT_BUFFER_SIZE***)**
A buffered I/O object combining two unidirectional *RawIOBase* objects – one readable, the other writeable – into a single bidirectional endpoint. It inherits *BufferedIOBase*.

reader and *writer* are *RawIOBase* objects that are readable and writeable respectively. If the *buffer_size* is omitted it defaults to *DEFAULT_BUFFER_SIZE*.

BufferedRWPair implements all of *BufferedIOBase*'s methods except for *detach()*, which raises *UnsupportedOperation*.

> **Warning:** *BufferedRWPair* does not attempt to synchronize accesses to its underlying raw streams. You should not pass it the same object as reader and writer; use *BufferedRandom* instead.

Text I/O

class io.TextIOBase
Base class for text streams. This class provides a character and line based interface to stream I/O. There is no **readinto()** method because Python's character strings are immutable. It inherits *IOBase*. There is no public constructor.

TextIOBase provides or overrides these data attributes and methods in addition to those from *IOBase*:

encoding
The name of the encoding used to decode the stream's bytes into strings, and to encode strings into bytes.

errors
The error setting of the decoder or encoder.

newlines
A string, a tuple of strings, or **None**, indicating the newlines translated so far. Depending on the implementation and the initial constructor flags, this may not be available.

buffer
The underlying binary buffer (a *BufferedIOBase* instance) that *TextIOBase* deals with. This is not part of the *TextIOBase* API and may not exist in some implementations.

detach()
Separate the underlying binary buffer from the *TextIOBase* and return it.

After the underlying buffer has been detached, the *TextIOBase* is in an unusable state.

Some *TextIOBase* implementations, like *StringIO*, may not have the concept of an underlying buffer and calling this method will raise *UnsupportedOperation*.

New in version 3.1.

read(*size*)
Read and return at most *size* characters from the stream as a single *str*. If *size* is negative or `None`, reads until EOF.

readline(*size=-1*)
Read until newline or EOF and return a single `str`. If the stream is already at EOF, an empty string is returned.

If *size* is specified, at most *size* characters will be read.

seek(*offset*[, *whence*])
Change the stream position to the given *offset*. Behaviour depends on the *whence* parameter. The default value for *whence* is `SEEK_SET`.

- `SEEK_SET` or `0`: seek from the start of the stream (the default); *offset* must either be a number returned by *TextIOBase.tell()*, or zero. Any other *offset* value produces undefined behaviour.
- `SEEK_CUR` or `1`: "seek" to the current position; *offset* must be zero, which is a no-operation (all other values are unsupported).
- `SEEK_END` or `2`: seek to the end of the stream; *offset* must be zero (all other values are unsupported).

Return the new absolute position as an opaque number.

New in version 3.1: The `SEEK_*` constants.

tell()
Return the current stream position as an opaque number. The number does not usually represent a number of bytes in the underlying binary storage.

write(*s*)
Write the string *s* to the stream and return the number of characters written.

class io.TextIOWrapper(*buffer*, *encoding=None*, *errors=None*, *newline=None*, *line_buffering=False*, *write_through=False*)
A buffered text stream over a *BufferedIOBase* binary stream. It inherits *TextIOBase*.

encoding gives the name of the encoding that the stream will be decoded or encoded with. It defaults to *locale.getpreferredencoding(False)*.

errors is an optional string that specifies how encoding and decoding errors are to be handled. Pass `'strict'` to raise a *ValueError* exception if there is an encoding error (the default of `None` has the same effect), or pass `'ignore'` to ignore errors. (Note that ignoring encoding errors can lead to data loss.) `'replace'` causes a replacement marker (such as `'?'`) to be inserted where there is malformed data. `'backslashreplace'` causes malformed data to be replaced by a backslashed escape sequence. When writing, `'xmlcharrefreplace'` (replace with the appropriate XML character reference) or `'namereplace'` (replace with `\N{...}` escape sequences) can be used. Any other error handling name that has been registered with *codecs.register_error()* is also valid.

newline controls how line endings are handled. It can be `None`, `''`, `'\n'`, `'\r'`, and `'\r\n'`. It works as follows:

- When reading input from the stream, if *newline* is `None`, *universal newlines* mode is enabled. Lines in the input can end in `'\n'`, `'\r'`, or `'\r\n'`, and these are translated into `'\n'` before being returned to the caller. If it is `''`, universal newlines mode is enabled, but line endings are returned to the caller untranslated. If it has any of the other legal values, input lines are only terminated by the given string, and the line ending is returned to the caller untranslated.
- When writing output to the stream, if *newline* is `None`, any `'\n'` characters written are translated to the system default line separator, *os.linesep*. If *newline* is `''` or `'\n'`, no translation takes place. If *newline* is any of the other legal values, any `'\n'` characters written are translated to the given string.

If *line_buffering* is `True`, `flush()` is implied when a call to write contains a newline character or a carriage return.

If *write_through* is `True`, calls to `write()` are guaranteed not to be buffered: any data written on the *TextIOWrapper* object is immediately handled to its underlying binary *buffer*.

Changed in version 3.3: The *write_through* argument has been added.

Changed in version 3.3: The default *encoding* is now `locale.getpreferredencoding(False)` instead of `locale.getpreferredencoding()`. Don't change temporary the locale encoding using *locale.setlocale()*, use the current locale encoding instead of the user preferred encoding.

TextIOWrapper provides these members in addition to those of *TextIOBase* and its parents:

line_buffering
Whether line buffering is enabled.

write_through
Whether writes are passed immediately to the underlying binary buffer.

New in version 3.7.

reconfigure(**[, encoding][, errors][, newline][, line_buffering][, write_through]*)
Reconfigure this text stream using new settings for *encoding*, *errors*, *newline*, *line_buffering* and *write_through*.

Parameters not specified keep current settings, except `errors='strict'` is used when *encoding* is specified but *errors* is not specified.

It is not possible to change the encoding or newline if some data has already been read from the stream. On the other hand, changing encoding after write is possible.

This method does an implicit stream flush before setting the new parameters.

New in version 3.7.

class io.StringIO(*initial_value=''*, *newline='\n'*)
An in-memory stream for text I/O. The text buffer is discarded when the *close()* method is called.

The initial value of the buffer can be set by providing *initial_value*. If newline translation is enabled, newlines will be encoded as if by *write()*. The stream is positioned at the start of the buffer.

The *newline* argument works like that of *TextIOWrapper*. The default is to consider only `\n` characters as ends of lines and to do no newline translation. If *newline* is set to `None`, newlines are written as `\n` on all platforms, but universal newline decoding is still performed when reading.

StringIO provides this method in addition to those from *TextIOBase* and its parents:

getvalue()
Return a `str` containing the entire contents of the buffer. Newlines are decoded as if by *read()*, although the stream position is not changed.

Example usage:

```
import io

output = io.StringIO()
output.write('First line.\n')
print('Second line.', file=output)

# Retrieve file contents -- this will be
# 'First line.\nSecond line.\n'
contents = output.getvalue()

# Close object and discard memory buffer --
# .getvalue() will now raise an exception.
output.close()
```

class io.**IncrementalNewlineDecoder**

A helper codec that decodes newlines for *universal newlines* mode. It inherits *codecs.IncrementalDecoder*.

16.2.4 Performance

This section discusses the performance of the provided concrete I/O implementations.

Binary I/O

By reading and writing only large chunks of data even when the user asks for a single byte, buffered I/O hides any inefficiency in calling and executing the operating system's unbuffered I/O routines. The gain depends on the OS and the kind of I/O which is performed. For example, on some modern OSes such as Linux, unbuffered disk I/O can be as fast as buffered I/O. The bottom line, however, is that buffered I/O offers predictable performance regardless of the platform and the backing device. Therefore, it is almost always preferable to use buffered I/O rather than unbuffered I/O for binary data.

Text I/O

Text I/O over a binary storage (such as a file) is significantly slower than binary I/O over the same storage, because it requires conversions between unicode and binary data using a character codec. This can become noticeable handling huge amounts of text data like large log files. Also, `TextIOWrapper.tell()` and `TextIOWrapper.seek()` are both quite slow due to the reconstruction algorithm used.

StringIO, however, is a native in-memory unicode container and will exhibit similar speed to *BytesIO*.

Multi-threading

FileIO objects are thread-safe to the extent that the operating system calls (such as `read(2)` under Unix) they wrap are thread-safe too.

Binary buffered objects (instances of *BufferedReader*, *BufferedWriter*, *BufferedRandom* and *BufferedRWPair*) protect their internal structures using a lock; it is therefore safe to call them from multiple threads at once.

TextIOWrapper objects are not thread-safe.

Reentrancy

Binary buffered objects (instances of *BufferedReader*, *BufferedWriter*, *BufferedRandom* and *BufferedRWPair*) are not reentrant. While reentrant calls will not happen in normal situations, they can arise from doing I/O in a *signal* handler. If a thread tries to re-enter a buffered object which it is already accessing, a *RuntimeError* is raised. Note this doesn't prohibit a different thread from entering the buffered object.

The above implicitly extends to text files, since the *open()* function will wrap a buffered object inside a *TextIOWrapper*. This includes standard streams and therefore affects the built-in function *print()* as well.

16.3 `time` — Time access and conversions

This module provides various time-related functions. For related functionality, see also the *datetime* and *calendar* modules.

Although this module is always available, not all functions are available on all platforms. Most of the functions defined in this module call platform C library functions with the same name. It may sometimes be helpful to consult the platform documentation, because the semantics of these functions varies among platforms.

An explanation of some terminology and conventions is in order.

- The *epoch* is the point where the time starts, and is platform dependent. For Unix, the epoch is January 1, 1970, 00:00:00 (UTC). To find out what the epoch is on a given platform, look at `time.gmtime(0)`.
- The term *seconds since the epoch* refers to the total number of elapsed seconds since the epoch, typically excluding leap seconds. Leap seconds are excluded from this total on all POSIX-compliant platforms.
- The functions in this module may not handle dates and times before the epoch or far in the future. The cut-off point in the future is determined by the C library; for 32-bit systems, it is typically in 2038.
- **Year 2000 (Y2K) issues**: Python depends on the platform's C library, which generally doesn't have year 2000 issues, since all dates and times are represented internally as seconds since the epoch. Function *strptime()* can parse 2-digit years when given `%y` format code. When 2-digit years are parsed, they are converted according to the POSIX and ISO C standards: values 69–99 are mapped to 1969–1999, and values 0–68 are mapped to 2000–2068.
- UTC is Coordinated Universal Time (formerly known as Greenwich Mean Time, or GMT). The acronym UTC is not a mistake but a compromise between English and French.
- DST is Daylight Saving Time, an adjustment of the timezone by (usually) one hour during part of the year. DST rules are magic (determined by local law) and can change from year to year. The C library has a table containing the local rules (often it is read from a system file for flexibility) and is the only source of True Wisdom in this respect.
- The precision of the various real-time functions may be less than suggested by the units in which their value or argument is expressed. E.g. on most Unix systems, the clock "ticks" only 50 or 100 times a second.
- On the other hand, the precision of *time()* and *sleep()* is better than their Unix equivalents: times are expressed as floating point numbers, *time()* returns the most accurate time available (using Unix `gettimeofday()` where available), and *sleep()* will accept a time with a nonzero fraction (Unix `select()` is used to implement this, where available).
- The time value as returned by *gmtime()*, *localtime()*, and *strptime()*, and accepted by *asctime()*, *mktime()* and *strftime()*, is a sequence of 9 integers. The return values of *gmtime()*, *localtime()*, and *strptime()* also offer attribute names for individual fields.

See *struct_time* for a description of these objects.

Changed in version 3.3: The *struct_time* type was extended to provide the `tm_gmtoff` and `tm_zone` attributes when platform supports corresponding `struct tm` members.

Changed in version 3.6: The *struct_time* attributes `tm_gmtoff` and `tm_zone` are now available on all platforms.

- Use the following functions to convert between time representations:

From	To	Use
seconds since the epoch	*struct_time* in UTC	*gmtime()*
seconds since the epoch	*struct_time* in local time	*localtime()*
struct_time in UTC	seconds since the epoch	*calendar.timegm()*
struct_time in local time	seconds since the epoch	*mktime()*

16.3.1 Functions

`time.asctime([t])`
Convert a tuple or *struct_time* representing a time as returned by *gmtime()* or *localtime()* to a string of the following form: `'Sun Jun 20 23:21:05 1993'`. If *t* is not provided, the current time as returned by *localtime()* is used. Locale information is not used by *asctime()*.

Note: Unlike the C function of the same name, *asctime()* does not add a trailing newline.

`time.clock()`
On Unix, return the current processor time as a floating point number expressed in seconds. The precision, and in fact the very definition of the meaning of "processor time", depends on that of the C function of the same name.

On Windows, this function returns wall-clock seconds elapsed since the first call to this function, as a floating point number, based on the Win32 function `QueryPerformanceCounter()`. The resolution is typically better than one microsecond.

Deprecated since version 3.3: The behaviour of this function depends on the platform: use *perf_counter()* or *process_time()* instead, depending on your requirements, to have a well defined behaviour.

`time.pthread_getcpuclockid(`*thread_id*`)`
Return the *clk_id* of the thread-specific CPU-time clock for the specified *thread_id*.

Use *threading.get_ident()* or the *ident* attribute of *threading.Thread* objects to get a suitable value for *thread_id*.

Warning: Passing an invalid or expired *thread_id* may result in undefined behavior, such as segmentation fault.

Availability: Unix (see the man page for *pthread_getcpuclockid(3)* for further information)

New in version 3.7.

`time.clock_getres(`*clk_id*`)`
Return the resolution (precision) of the specified clock *clk_id*. Refer to *Clock ID Constants* for a list of accepted values for *clk_id*.

Availability: Unix.

New in version 3.3.

time.clock_gettime(*clk_id*) → float
Return the time of the specified clock *clk_id*. Refer to *Clock ID Constants* for a list of accepted values for *clk_id*.

Availability: Unix.

New in version 3.3.

time.clock_gettime_ns(*clk_id*) → int
Similar to *clock_gettime()* but return time as nanoseconds.

Availability: Unix.

New in version 3.7.

time.clock_settime(*clk_id*, *time: float*)
Set the time of the specified clock *clk_id*. Currently, *CLOCK_REALTIME* is the only accepted value for *clk_id*.

Availability: Unix.

New in version 3.3.

time.clock_settime_ns(*clk_id*, *time: int*)
Similar to *clock_settime()* but set time with nanoseconds.

Availability: Unix.

New in version 3.7.

time.ctime([*secs*])
Convert a time expressed in seconds since the epoch to a string representing local time. If *secs* is not provided or *None*, the current time as returned by *time()* is used. `ctime(secs)` is equivalent to `asctime(localtime(secs))`. Locale information is not used by *ctime()*.

time.get_clock_info(*name*)
Get information on the specified clock as a namespace object. Supported clock names and the corresponding functions to read their value are:

- `'clock'`: *time.clock()*
- `'monotonic'`: *time.monotonic()*
- `'perf_counter'`: *time.perf_counter()*
- `'process_time'`: *time.process_time()*
- `'thread_time'`: *time.thread_time()*
- `'time'`: *time.time()*

The result has the following attributes:

- *adjustable*: `True` if the clock can be changed automatically (e.g. by a NTP daemon) or manually by the system administrator, `False` otherwise
- *implementation*: The name of the underlying C function used to get the clock value. Refer to *Clock ID Constants* for possible values.
- *monotonic*: `True` if the clock cannot go backward, `False` otherwise
- *resolution*: The resolution of the clock in seconds (*float*)

New in version 3.3.

time.gmtime([*secs*])
Convert a time expressed in seconds since the epoch to a *struct_time* in UTC in which the dst flag is always zero. If *secs* is not provided or *None*, the current time as returned by *time()* is used. Fractions of

a second are ignored. See above for a description of the *struct_time* object. See *calendar.timegm()* for the inverse of this function.

time.localtime([*secs*])
Like *gmtime()* but converts to local time. If *secs* is not provided or *None*, the current time as returned by *time()* is used. The dst flag is set to `1` when DST applies to the given time.

time.mktime(*t*)
This is the inverse function of *localtime()*. Its argument is the *struct_time* or full 9-tuple (since the dst flag is needed; use `-1` as the dst flag if it is unknown) which expresses the time in *local* time, not UTC. It returns a floating point number, for compatibility with *time()*. If the input value cannot be represented as a valid time, either *OverflowError* or *ValueError* will be raised (which depends on whether the invalid value is caught by Python or the underlying C libraries). The earliest date for which it can generate a time is platform-dependent.

time.monotonic() → float
Return the value (in fractional seconds) of a monotonic clock, i.e. a clock that cannot go backwards. The clock is not affected by system clock updates. The reference point of the returned value is undefined, so that only the difference between the results of consecutive calls is valid.

On Windows versions older than Vista, *monotonic()* detects `GetTickCount()` integer overflow (32 bits, roll-over after 49.7 days). It increases an internal epoch (reference time) by 2^{32} each time that an overflow is detected. The epoch is stored in the process-local state and so the value of *monotonic()* may be different in two Python processes running for more than 49 days. On more recent versions of Windows and on other operating systems, *monotonic()* is system-wide.

New in version 3.3.

Changed in version 3.5: The function is now always available.

time.monotonic_ns() → int
Similar to *monotonic()*, but return time as nanoseconds.

New in version 3.7.

time.perf_counter() → float
Return the value (in fractional seconds) of a performance counter, i.e. a clock with the highest available resolution to measure a short duration. It does include time elapsed during sleep and is system-wide. The reference point of the returned value is undefined, so that only the difference between the results of consecutive calls is valid.

New in version 3.3.

time.perf_counter_ns() → int
Similar to *perf_counter()*, but return time as nanoseconds.

New in version 3.7.

time.process_time() → float
Return the value (in fractional seconds) of the sum of the system and user CPU time of the current process. It does not include time elapsed during sleep. It is process-wide by definition. The reference point of the returned value is undefined, so that only the difference between the results of consecutive calls is valid.

New in version 3.3.

time.process_time_ns() → int
Similar to *process_time()* but return time as nanoseconds.

New in version 3.7.

time.sleep(*secs*)
Suspend execution of the calling thread for the given number of seconds. The argument may be a floating point number to indicate a more precise sleep time. The actual suspension time may be less

than that requested because any caught signal will terminate the *sleep()* following execution of that signal's catching routine. Also, the suspension time may be longer than requested by an arbitrary amount because of the scheduling of other activity in the system.

Changed in version 3.5: The function now sleeps at least *secs* even if the sleep is interrupted by a signal, except if the signal handler raises an exception (see **PEP 475** for the rationale).

`time.strftime`(*format*[, *t*])

Convert a tuple or *struct_time* representing a time as returned by *gmtime()* or *localtime()* to a string as specified by the *format* argument. If *t* is not provided, the current time as returned by *localtime()* is used. *format* must be a string. *ValueError* is raised if any field in *t* is outside of the allowed range.

0 is a legal argument for any position in the time tuple; if it is normally illegal the value is forced to a correct one.

The following directives can be embedded in the *format* string. They are shown without the optional field width and precision specification, and are replaced by the indicated characters in the *strftime()* result:

Directive	Meaning	Notes
%a	Locale's abbreviated weekday name.	
%A	Locale's full weekday name.	
%b	Locale's abbreviated month name.	
%B	Locale's full month name.	
%c	Locale's appropriate date and time representation.	
%d	Day of the month as a decimal number [01,31].	
%H	Hour (24-hour clock) as a decimal number [00,23].	
%I	Hour (12-hour clock) as a decimal number [01,12].	
%j	Day of the year as a decimal number [001,366].	
%m	Month as a decimal number [01,12].	
%M	Minute as a decimal number [00,59].	
%p	Locale's equivalent of either AM or PM.	(1)
%S	Second as a decimal number [00,61].	(2)
%U	Week number of the year (Sunday as the first day of the week) as a decimal number [00,53]. All days in a new year preceding the first Sunday are considered to be in week 0.	(3)
%w	Weekday as a decimal number [0(Sunday),6].	
%W	Week number of the year (Monday as the first day of the week) as a decimal number [00,53]. All days in a new year preceding the first Monday are considered to be in week 0.	(3)
%x	Locale's appropriate date representation.	
%X	Locale's appropriate time representation.	
%y	Year without century as a decimal number [00,99].	
%Y	Year with century as a decimal number.	
%z	Time zone offset indicating a positive or negative time difference from UTC/GMT of the form +HHMM or -HHMM, where H represents decimal hour digits and M represents decimal minute digits [-23:59, +23:59].	
%Z	Time zone name (no characters if no time zone exists).	
%%	A literal '%' character.	

Notes:

1. When used with the *strptime()* function, the %p directive only affects the output hour field if the %I directive is used to parse the hour.
2. The range really is 0 to 61; value 60 is valid in timestamps representing leap seconds and value 61 is supported for historical reasons.
3. When used with the *strptime()* function, %U and %W are only used in calculations when the day of the week and the year are specified.

Here is an example, a format for dates compatible with that specified in the **RFC 2822** Internet email standard.[1]

```
>>> from time import gmtime, strftime
>>> strftime("%a, %d %b %Y %H:%M:%S +0000", gmtime())
'Thu, 28 Jun 2001 14:17:15 +0000'
```

Additional directives may be supported on certain platforms, but only the ones listed here have a meaning standardized by ANSI C. To see the full set of format codes supported on your platform, consult the *strftime(3)* documentation.

On some platforms, an optional field width and precision specification can immediately follow the initial '%' of a directive in the following order; this is also not portable. The field width is normally 2 except for %j where it is 3.

time.strptime(*string*[, *format*])

Parse a string representing a time according to a format. The return value is a *struct_time* as returned by *gmtime()* or *localtime()*.

The *format* parameter uses the same directives as those used by *strftime()*; it defaults to "%a %b %d %H:%M:%S %Y" which matches the formatting returned by *ctime()*. If *string* cannot be parsed according to *format*, or if it has excess data after parsing, *ValueError* is raised. The default values used to fill in any missing data when more accurate values cannot be inferred are (1900, 1, 1, 0, 0, 0, 0, 1, -1). Both *string* and *format* must be strings.

For example:

```
>>> import time
>>> time.strptime("30 Nov 00", "%d %b %y")
time.struct_time(tm_year=2000, tm_mon=11, tm_mday=30, tm_hour=0, tm_min=0,
                 tm_sec=0, tm_wday=3, tm_yday=335, tm_isdst=-1)
```

Support for the %Z directive is based on the values contained in tzname and whether daylight is true. Because of this, it is platform-specific except for recognizing UTC and GMT which are always known (and are considered to be non-daylight savings timezones).

Only the directives specified in the documentation are supported. Because strftime() is implemented per platform it can sometimes offer more directives than those listed. But strptime() is independent of any platform and thus does not necessarily support all directives available that are not documented as supported.

class time.struct_time

The type of the time value sequence returned by *gmtime()*, *localtime()*, and *strptime()*. It is an object with a *named tuple* interface: values can be accessed by index and by attribute name. The following values are present:

[1] The use of %Z is now deprecated, but the %z escape that expands to the preferred hour/minute offset is not supported by all ANSI C libraries. Also, a strict reading of the original 1982 **RFC 822** standard calls for a two-digit year (%y rather than %Y), but practice moved to 4-digit years long before the year 2000. After that, **RFC 822** became obsolete and the 4-digit year has been first recommended by **RFC 1123** and then mandated by **RFC 2822**.

Index	Attribute	Values
0	`tm_year`	(for example, 1993)
1	`tm_mon`	range [1, 12]
2	`tm_mday`	range [1, 31]
3	`tm_hour`	range [0, 23]
4	`tm_min`	range [0, 59]
5	`tm_sec`	range [0, 61]; see **(2)** in *strftime()* description
6	`tm_wday`	range [0, 6], Monday is 0
7	`tm_yday`	range [1, 366]
8	`tm_isdst`	0, 1 or -1; see below
N/A	`tm_zone`	abbreviation of timezone name
N/A	`tm_gmtoff`	offset east of UTC in seconds

Note that unlike the C structure, the month value is a range of [1, 12], not [0, 11].

In calls to *mktime()*, `tm_isdst` may be set to 1 when daylight savings time is in effect, and 0 when it is not. A value of -1 indicates that this is not known, and will usually result in the correct state being filled in.

When a tuple with an incorrect length is passed to a function expecting a *struct_time*, or having elements of the wrong type, a *TypeError* is raised.

time.time() → float
Return the time in seconds since the *epoch* as a floating point number. The specific date of the epoch and the handling of leap seconds is platform dependent. On Windows and most Unix systems, the epoch is January 1, 1970, 00:00:00 (UTC) and leap seconds are not counted towards the time in seconds since the epoch. This is commonly referred to as Unix time. To find out what the epoch is on a given platform, look at `gmtime(0)`.

Note that even though the time is always returned as a floating point number, not all systems provide time with a better precision than 1 second. While this function normally returns non-decreasing values, it can return a lower value than a previous call if the system clock has been set back between the two calls.

The number returned by *time()* may be converted into a more common time format (i.e. year, month, day, hour, etc…) in UTC by passing it to *gmtime()* function or in local time by passing it to the *localtime()* function. In both cases a *struct_time* object is returned, from which the components of the calendar date may be accessed as attributes.

time.thread_time() → float
Return the value (in fractional seconds) of the sum of the system and user CPU time of the current thread. It does not include time elapsed during sleep. It is thread-specific by definition. The reference point of the returned value is undefined, so that only the difference between the results of consecutive calls in the same thread is valid.

Availability: Windows, Linux, Unix systems supporting `CLOCK_THREAD_CPUTIME_ID`.

New in version 3.7.

time.thread_time_ns() → int
Similar to *thread_time()* but return time as nanoseconds.

New in version 3.7.

time.time_ns() → int
Similar to *time()* but returns time as an integer number of nanoseconds since the *epoch*.

New in version 3.7.

`time.tzset()`

Reset the time conversion rules used by the library routines. The environment variable `TZ` specifies how this is done. It will also set the variables `tzname` (from the `TZ` environment variable), `timezone` (non-DST seconds West of UTC), `altzone` (DST seconds west of UTC) and `daylight` (to 0 if this timezone does not have any daylight saving time rules, or to nonzero if there is a time, past, present or future when daylight saving time applies).

Availability: Unix.

Note: Although in many cases, changing the `TZ` environment variable may affect the output of functions like *`localtime()`* without calling *`tzset()`*, this behavior should not be relied on.

The `TZ` environment variable should contain no whitespace.

The standard format of the `TZ` environment variable is (whitespace added for clarity):

```
std offset [dst [offset [,start[/time], end[/time]]]]
```

Where the components are:

`std and dst` Three or more alphanumerics giving the timezone abbreviations. These will be propagated into time.tzname

`offset` The offset has the form: ± `hh[:mm[:ss]]`. This indicates the value added the local time to arrive at UTC. If preceded by a '-', the timezone is east of the Prime Meridian; otherwise, it is west. If no offset follows dst, summer time is assumed to be one hour ahead of standard time.

`start[/time], end[/time]` Indicates when to change to and back from DST. The format of the start and end dates are one of the following:

`Jn` The Julian day *n* (1 <= *n* <= 365). Leap days are not counted, so in all years February 28 is day 59 and March 1 is day 60.

`n` The zero-based Julian day (0 <= *n* <= 365). Leap days are counted, and it is possible to refer to February 29.

`Mm.n.d` The *d*'th day (0 <= *d* <= 6) of week *n* of month *m* of the year (1 <= *n* <= 5, 1 <= *m* <= 12, where week 5 means "the last *d* day in month *m*" which may occur in either the fourth or the fifth week). Week 1 is the first week in which the *d*'th day occurs. Day zero is a Sunday.

`time` has the same format as `offset` except that no leading sign ('-' or '+') is allowed. The default, if time is not given, is 02:00:00.

```
>>> os.environ['TZ'] = 'EST+05EDT,M4.1.0,M10.5.0'
>>> time.tzset()
>>> time.strftime('%X %x %Z')
'02:07:36 05/08/03 EDT'
>>> os.environ['TZ'] = 'AEST-10AEDT-11,M10.5.0,M3.5.0'
>>> time.tzset()
>>> time.strftime('%X %x %Z')
'16:08:12 05/08/03 AEST'
```

On many Unix systems (including *BSD, Linux, Solaris, and Darwin), it is more convenient to use the system's zoneinfo (*`tzfile(5)`*) database to specify the timezone rules. To do this, set the `TZ` environment variable to the path of the required timezone datafile, relative to the root of the systems 'zoneinfo' timezone database, usually located at `/usr/share/zoneinfo`. For example, `'US/Eastern'`, `'Australia/Melbourne'`, `'Egypt'` or `'Europe/Amsterdam'`.

```
>>> os.environ['TZ'] = 'US/Eastern'
>>> time.tzset()
>>> time.tzname
('EST', 'EDT')
>>> os.environ['TZ'] = 'Egypt'
>>> time.tzset()
>>> time.tzname
('EET', 'EEST')
```

16.3.2 Clock ID Constants

These constants are used as parameters for *clock_getres()* and *clock_gettime()*.

time.CLOCK_BOOTTIME
Identical to *CLOCK_MONOTONIC*, except it also includes any time that the system is suspended.

This allows applications to get a suspend-aware monotonic clock without having to deal with the complications of *CLOCK_REALTIME*, which may have discontinuities if the time is changed using `settimeofday()` or similar.

Availability: Linux 2.6.39 or later.

New in version 3.7.

time.CLOCK_HIGHRES
The Solaris OS has a `CLOCK_HIGHRES` timer that attempts to use an optimal hardware source, and may give close to nanosecond resolution. `CLOCK_HIGHRES` is the nonadjustable, high-resolution clock.

Availability: Solaris.

New in version 3.3.

time.CLOCK_MONOTONIC
Clock that cannot be set and represents monotonic time since some unspecified starting point.

Availability: Unix.

New in version 3.3.

time.CLOCK_MONOTONIC_RAW
Similar to *CLOCK_MONOTONIC*, but provides access to a raw hardware-based time that is not subject to NTP adjustments.

Availability: Linux 2.6.28 or later.

New in version 3.3.

time.CLOCK_PROCESS_CPUTIME_ID
High-resolution per-process timer from the CPU.

Availability: Unix.

New in version 3.3.

time.CLOCK_PROF
High-resolution per-process timer from the CPU.

Availability: FreeBSD, NetBSD 7 or later, OpenBSD.

New in version 3.7.

time.CLOCK_THREAD_CPUTIME_ID
Thread-specific CPU-time clock.

Availability: Unix.

New in version 3.3.

`time.CLOCK_UPTIME`
Time whose absolute value is the time the system has been running and not suspended, providing accurate uptime measurement, both absolute and interval.

Availability: FreeBSD, OpenBSD 5.5 or later.

New in version 3.7.

The following constant is the only parameter that can be sent to *clock_settime()*.

`time.CLOCK_REALTIME`
System-wide real-time clock. Setting this clock requires appropriate privileges.

Availability: Unix.

New in version 3.3.

16.3.3 Timezone Constants

`time.altzone`
The offset of the local DST timezone, in seconds west of UTC, if one is defined. This is negative if the local DST timezone is east of UTC (as in Western Europe, including the UK). Only use this if `daylight` is nonzero. See note below.

`time.daylight`
Nonzero if a DST timezone is defined. See note below.

`time.timezone`
The offset of the local (non-DST) timezone, in seconds west of UTC (negative in most of Western Europe, positive in the US, zero in the UK). See note below.

`time.tzname`
A tuple of two strings: the first is the name of the local non-DST timezone, the second is the name of the local DST timezone. If no DST timezone is defined, the second string should not be used. See note below.

Note: For the above Timezone constants (*altzone*, *daylight*, *timezone*, and *tzname*), the value is determined by the timezone rules in effect at module load time or the last time *tzset()* is called and may be incorrect for times in the past. It is recommended to use the `tm_gmtoff` and `tm_zone` results from *localtime()* to obtain timezone information.

See also:

Module *datetime* More object-oriented interface to dates and times.

Module *locale* Internationalization services. The locale setting affects the interpretation of many format specifiers in *strftime()* and *strptime()*.

Module *calendar* General calendar-related functions. *timegm()* is the inverse of *gmtime()* from this module.

16.4 `argparse` — Parser for command-line options, arguments and sub-commands

New in version 3.2.

Source code: Lib/argparse.py

Tutorial

This page contains the API reference information. For a more gentle introduction to Python command-line parsing, have a look at the argparse tutorial.

The *argparse* module makes it easy to write user-friendly command-line interfaces. The program defines what arguments it requires, and *argparse* will figure out how to parse those out of *sys.argv*. The *argparse* module also automatically generates help and usage messages and issues errors when users give the program invalid arguments.

16.4.1 Example

The following code is a Python program that takes a list of integers and produces either the sum or the max:

```
import argparse

parser = argparse.ArgumentParser(description='Process some integers.')
parser.add_argument('integers', metavar='N', type=int, nargs='+',
                    help='an integer for the accumulator')
parser.add_argument('--sum', dest='accumulate', action='store_const',
                    const=sum, default=max,
                    help='sum the integers (default: find the max)')

args = parser.parse_args()
print(args.accumulate(args.integers))
```

Assuming the Python code above is saved into a file called `prog.py`, it can be run at the command line and provides useful help messages:

```
$ python prog.py -h
usage: prog.py [-h] [--sum] N [N ...]

Process some integers.

positional arguments:
 N           an integer for the accumulator

optional arguments:
 -h, --help  show this help message and exit
 --sum       sum the integers (default: find the max)
```

When run with the appropriate arguments, it prints either the sum or the max of the command-line integers:

```
$ python prog.py 1 2 3 4
4

$ python prog.py 1 2 3 4 --sum
10
```

If invalid arguments are passed in, it will issue an error:

```
$ python prog.py a b c
usage: prog.py [-h] [--sum] N [N ...]
prog.py: error: argument N: invalid int value: 'a'
```

The following sections walk you through this example.

Creating a parser

The first step in using the *argparse* is creating an *ArgumentParser* object:

```
>>> parser = argparse.ArgumentParser(description='Process some integers.')
```

The *ArgumentParser* object will hold all the information necessary to parse the command line into Python data types.

Adding arguments

Filling an *ArgumentParser* with information about program arguments is done by making calls to the *add_argument()* method. Generally, these calls tell the *ArgumentParser* how to take the strings on the command line and turn them into objects. This information is stored and used when *parse_args()* is called. For example:

```
>>> parser.add_argument('integers', metavar='N', type=int, nargs='+',
...                     help='an integer for the accumulator')
>>> parser.add_argument('--sum', dest='accumulate', action='store_const',
...                     const=sum, default=max,
...                     help='sum the integers (default: find the max)')
```

Later, calling *parse_args()* will return an object with two attributes, `integers` and `accumulate`. The `integers` attribute will be a list of one or more ints, and the `accumulate` attribute will be either the *sum()* function, if `--sum` was specified at the command line, or the *max()* function if it was not.

Parsing arguments

ArgumentParser parses arguments through the *parse_args()* method. This will inspect the command line, convert each argument to the appropriate type and then invoke the appropriate action. In most cases, this means a simple *Namespace* object will be built up from attributes parsed out of the command line:

```
>>> parser.parse_args(['--sum', '7', '-1', '42'])
Namespace(accumulate=<built-in function sum>, integers=[7, -1, 42])
```

In a script, *parse_args()* will typically be called with no arguments, and the *ArgumentParser* will automatically determine the command-line arguments from *sys.argv*.

16.4.2 ArgumentParser objects

class argparse.ArgumentParser(*prog=None*, *usage=None*, *description=None*, *epilog=None*, *parents=[]*, *formatter_class=argparse.HelpFormatter*, *prefix_chars='-'*, *fromfile_prefix_chars=None*, *argument_default=None*, *conflict_handler='error'*, *add_help=True*, *allow_abbrev=True*)

Create a new *ArgumentParser* object. All parameters should be passed as keyword arguments. Each parameter has its own more detailed description below, but in short they are:

- *prog* - The name of the program (default: `sys.argv[0]`)
- *usage* - The string describing the program usage (default: generated from arguments added to parser)

- *description* - Text to display before the argument help (default: none)
- *epilog* - Text to display after the argument help (default: none)
- *parents* - A list of *ArgumentParser* objects whose arguments should also be included
- *formatter_class* - A class for customizing the help output
- *prefix_chars* - The set of characters that prefix optional arguments (default: '-')
- *fromfile_prefix_chars* - The set of characters that prefix files from which additional arguments should be read (default: `None`)
- *argument_default* - The global default value for arguments (default: `None`)
- *conflict_handler* - The strategy for resolving conflicting optionals (usually unnecessary)
- *add_help* - Add a `-h/--help` option to the parser (default: `True`)
- *allow_abbrev* - Allows long options to be abbreviated if the abbreviation is unambiguous. (default: `True`)

Changed in version 3.5: *allow_abbrev* parameter was added.

The following sections describe how each of these are used.

prog

By default, *ArgumentParser* objects use `sys.argv[0]` to determine how to display the name of the program in help messages. This default is almost always desirable because it will make the help messages match how the program was invoked on the command line. For example, consider a file named `myprogram.py` with the following code:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument('--foo', help='foo help')
args = parser.parse_args()
```

The help for this program will display `myprogram.py` as the program name (regardless of where the program was invoked from):

```
$ python myprogram.py --help
usage: myprogram.py [-h] [--foo FOO]

optional arguments:
 -h, --help  show this help message and exit
 --foo FOO   foo help
$ cd ..
$ python subdir/myprogram.py --help
usage: myprogram.py [-h] [--foo FOO]

optional arguments:
 -h, --help  show this help message and exit
 --foo FOO   foo help
```

To change this default behavior, another value can be supplied using the `prog=` argument to *ArgumentParser*:

```
>>> parser = argparse.ArgumentParser(prog='myprogram')
>>> parser.print_help()
usage: myprogram [-h]
```

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```
optional arguments:
 -h, --help  show this help message and exit
```

Note that the program name, whether determined from `sys.argv[0]` or from the `prog=` argument, is available to help messages using the `%(prog)s` format specifier.

```
>>> parser = argparse.ArgumentParser(prog='myprogram')
>>> parser.add_argument('--foo', help='foo of the %(prog)s program')
>>> parser.print_help()
usage: myprogram [-h] [--foo FOO]

optional arguments:
 -h, --help  show this help message and exit
 --foo FOO   foo of the myprogram program
```

usage

By default, *ArgumentParser* calculates the usage message from the arguments it contains:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo', nargs='?', help='foo help')
>>> parser.add_argument('bar', nargs='+', help='bar help')
>>> parser.print_help()
usage: PROG [-h] [--foo [FOO]] bar [bar ...]

positional arguments:
 bar          bar help

optional arguments:
 -h, --help   show this help message and exit
 --foo [FOO]  foo help
```

The default message can be overridden with the `usage=` keyword argument:

```
>>> parser = argparse.ArgumentParser(prog='PROG', usage='%(prog)s [options]')
>>> parser.add_argument('--foo', nargs='?', help='foo help')
>>> parser.add_argument('bar', nargs='+', help='bar help')
>>> parser.print_help()
usage: PROG [options]

positional arguments:
 bar          bar help

optional arguments:
 -h, --help   show this help message and exit
 --foo [FOO]  foo help
```

The `%(prog)s` format specifier is available to fill in the program name in your usage messages.

description

Most calls to the *ArgumentParser* constructor will use the `description=` keyword argument. This argument gives a brief description of what the program does and how it works. In help messages, the description is displayed between the command-line usage string and the help messages for the various arguments:

```
>>> parser = argparse.ArgumentParser(description='A foo that bars')
>>> parser.print_help()
usage: argparse.py [-h]

A foo that bars

optional arguments:
 -h, --help  show this help message and exit
```

By default, the description will be line-wrapped so that it fits within the given space. To change this behavior, see the *formatter_class* argument.

epilog

Some programs like to display additional description of the program after the description of the arguments. Such text can be specified using the `epilog=` argument to *ArgumentParser*:

```
>>> parser = argparse.ArgumentParser(
...     description='A foo that bars',
...     epilog="And that's how you'd foo a bar")
>>> parser.print_help()
usage: argparse.py [-h]

A foo that bars

optional arguments:
 -h, --help  show this help message and exit

And that's how you'd foo a bar
```

As with the *description* argument, the `epilog=` text is by default line-wrapped, but this behavior can be adjusted with the *formatter_class* argument to *ArgumentParser*.

parents

Sometimes, several parsers share a common set of arguments. Rather than repeating the definitions of these arguments, a single parser with all the shared arguments and passed to `parents=` argument to *ArgumentParser* can be used. The `parents=` argument takes a list of *ArgumentParser* objects, collects all the positional and optional actions from them, and adds these actions to the *ArgumentParser* object being constructed:

```
>>> parent_parser = argparse.ArgumentParser(add_help=False)
>>> parent_parser.add_argument('--parent', type=int)

>>> foo_parser = argparse.ArgumentParser(parents=[parent_parser])
>>> foo_parser.add_argument('foo')
>>> foo_parser.parse_args(['--parent', '2', 'XXX'])
Namespace(foo='XXX', parent=2)

>>> bar_parser = argparse.ArgumentParser(parents=[parent_parser])
>>> bar_parser.add_argument('--bar')
>>> bar_parser.parse_args(['--bar', 'YYY'])
Namespace(bar='YYY', parent=None)
```

Note that most parent parsers will specify `add_help=False`. Otherwise, the *ArgumentParser* will see two `-h/--help` options (one in the parent and one in the child) and raise an error.

Note: You must fully initialize the parsers before passing them via `parents=`. If you change the parent parsers after the child parser, those changes will not be reflected in the child.

formatter_class

ArgumentParser objects allow the help formatting to be customized by specifying an alternate formatting class. Currently, there are four such classes:

class argparse.RawDescriptionHelpFormatter
class argparse.RawTextHelpFormatter
class argparse.ArgumentDefaultsHelpFormatter
class argparse.MetavarTypeHelpFormatter

RawDescriptionHelpFormatter and *RawTextHelpFormatter* give more control over how textual descriptions are displayed. By default, *ArgumentParser* objects line-wrap the *description* and *epilog* texts in command-line help messages:

```
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     description='''this description
...         was indented weird
...             but that is okay''',
...     epilog='''
...             likewise for this epilog whose whitespace will
...         be cleaned up and whose words will be wrapped
...         across a couple lines''')
>>> parser.print_help()
usage: PROG [-h]

this description was indented weird but that is okay

optional arguments:
 -h, --help  show this help message and exit

likewise for this epilog whose whitespace will be cleaned up and whose words
will be wrapped across a couple lines
```

Passing *RawDescriptionHelpFormatter* as `formatter_class=` indicates that *description* and *epilog* are already correctly formatted and should not be line-wrapped:

```
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     formatter_class=argparse.RawDescriptionHelpFormatter,
...     description=textwrap.dedent('''\
...         Please do not mess up this text!
...         --------------------------------
...             I have indented it
...             exactly the way
...             I want it
...         '''))
>>> parser.print_help()
usage: PROG [-h]

Please do not mess up this text!
--------------------------------
```

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```
   I have indented it
   exactly the way
   I want it

optional arguments:
 -h, --help  show this help message and exit
```

RawTextHelpFormatter maintains whitespace for all sorts of help text, including argument descriptions. However, multiple new lines are replaced with one. If you wish to preserve multiple blank lines, add spaces between the newlines.

ArgumentDefaultsHelpFormatter automatically adds information about default values to each of the argument help messages:

```
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     formatter_class=argparse.ArgumentDefaultsHelpFormatter)
>>> parser.add_argument('--foo', type=int, default=42, help='FOO!')
>>> parser.add_argument('bar', nargs='*', default=[1, 2, 3], help='BAR!')
>>> parser.print_help()
usage: PROG [-h] [--foo FOO] [bar [bar ...]]

positional arguments:
 bar         BAR! (default: [1, 2, 3])

optional arguments:
 -h, --help  show this help message and exit
 --foo FOO   FOO! (default: 42)
```

MetavarTypeHelpFormatter uses the name of the *type* argument for each argument as the display name for its values (rather than using the *dest* as the regular formatter does):

```
>>> parser = argparse.ArgumentParser(
...     prog='PROG',
...     formatter_class=argparse.MetavarTypeHelpFormatter)
>>> parser.add_argument('--foo', type=int)
>>> parser.add_argument('bar', type=float)
>>> parser.print_help()
usage: PROG [-h] [--foo int] float

positional arguments:
  float

optional arguments:
  -h, --help  show this help message and exit
  --foo int
```

prefix_chars

Most command-line options will use `-` as the prefix, e.g. `-f/--foo`. Parsers that need to support different or additional prefix characters, e.g. for options like `+f` or `/foo`, may specify them using the `prefix_chars=` argument to the ArgumentParser constructor:

```
>>> parser = argparse.ArgumentParser(prog='PROG', prefix_chars='-+')
>>> parser.add_argument('+f')
```

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```
>>> parser.add_argument('++bar')
>>> parser.parse_args('+f X ++bar Y'.split())
Namespace(bar='Y', f='X')
```

The `prefix_chars=` argument defaults to `'-'`. Supplying a set of characters that does not include `-` will cause `-f/--foo` options to be disallowed.

fromfile_prefix_chars

Sometimes, for example when dealing with a particularly long argument lists, it may make sense to keep the list of arguments in a file rather than typing it out at the command line. If the `fromfile_prefix_chars=` argument is given to the *ArgumentParser* constructor, then arguments that start with any of the specified characters will be treated as files, and will be replaced by the arguments they contain. For example:

```
>>> with open('args.txt', 'w') as fp:
...     fp.write('-f\nbar')
>>> parser = argparse.ArgumentParser(fromfile_prefix_chars='@')
>>> parser.add_argument('-f')
>>> parser.parse_args(['-f', 'foo', '@args.txt'])
Namespace(f='bar')
```

Arguments read from a file must by default be one per line (but see also *convert_arg_line_to_args()*) and are treated as if they were in the same place as the original file referencing argument on the command line. So in the example above, the expression `['-f', 'foo', '@args.txt']` is considered equivalent to the expression `['-f', 'foo', '-f', 'bar']`.

The `fromfile_prefix_chars=` argument defaults to `None`, meaning that arguments will never be treated as file references.

argument_default

Generally, argument defaults are specified either by passing a default to *add_argument()* or by calling the *set_defaults()* methods with a specific set of name-value pairs. Sometimes however, it may be useful to specify a single parser-wide default for arguments. This can be accomplished by passing the `argument_default=` keyword argument to *ArgumentParser*. For example, to globally suppress attribute creation on *parse_args()* calls, we supply `argument_default=SUPPRESS`:

```
>>> parser = argparse.ArgumentParser(argument_default=argparse.SUPPRESS)
>>> parser.add_argument('--foo')
>>> parser.add_argument('bar', nargs='?')
>>> parser.parse_args(['--foo', '1', 'BAR'])
Namespace(bar='BAR', foo='1')
>>> parser.parse_args([])
Namespace()
```

allow_abbrev

Normally, when you pass an argument list to the *parse_args()* method of an *ArgumentParser*, it *recognizes abbreviations* of long options.

This feature can be disabled by setting `allow_abbrev` to `False`:

```
>>> parser = argparse.ArgumentParser(prog='PROG', allow_abbrev=False)
>>> parser.add_argument('--foobar', action='store_true')
>>> parser.add_argument('--foonley', action='store_false')
>>> parser.parse_args(['--foon'])
usage: PROG [-h] [--foobar] [--foonley]
PROG: error: unrecognized arguments: --foon
```

New in version 3.5.

conflict_handler

ArgumentParser objects do not allow two actions with the same option string. By default, *ArgumentParser* objects raise an exception if an attempt is made to create an argument with an option string that is already in use:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-f', '--foo', help='old foo help')
>>> parser.add_argument('--foo', help='new foo help')
Traceback (most recent call last):
 ..
ArgumentError: argument --foo: conflicting option string(s): --foo
```

Sometimes (e.g. when using *parents*) it may be useful to simply override any older arguments with the same option string. To get this behavior, the value `'resolve'` can be supplied to the `conflict_handler=` argument of *ArgumentParser*:

```
>>> parser = argparse.ArgumentParser(prog='PROG', conflict_handler='resolve')
>>> parser.add_argument('-f', '--foo', help='old foo help')
>>> parser.add_argument('--foo', help='new foo help')
>>> parser.print_help()
usage: PROG [-h] [-f FOO] [--foo FOO]

optional arguments:
 -h, --help  show this help message and exit
 -f FOO      old foo help
 --foo FOO   new foo help
```

Note that *ArgumentParser* objects only remove an action if all of its option strings are overridden. So, in the example above, the old `-f/--foo` action is retained as the `-f` action, because only the `--foo` option string was overridden.

add_help

By default, ArgumentParser objects add an option which simply displays the parser's help message. For example, consider a file named `myprogram.py` containing the following code:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument('--foo', help='foo help')
args = parser.parse_args()
```

If `-h` or `--help` is supplied at the command line, the ArgumentParser help will be printed:

```
$ python myprogram.py --help
usage: myprogram.py [-h] [--foo FOO]
```

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```
optional arguments:
 -h, --help  show this help message and exit
 --foo FOO   foo help
```

Occasionally, it may be useful to disable the addition of this help option. This can be achieved by passing `False` as the `add_help=` argument to *ArgumentParser*:

```
>>> parser = argparse.ArgumentParser(prog='PROG', add_help=False)
>>> parser.add_argument('--foo', help='foo help')
>>> parser.print_help()
usage: PROG [--foo FOO]

optional arguments:
 --foo FOO  foo help
```

The help option is typically `-h/--help`. The exception to this is if the `prefix_chars=` is specified and does not include `-`, in which case `-h` and `--help` are not valid options. In this case, the first character in `prefix_chars` is used to prefix the help options:

```
>>> parser = argparse.ArgumentParser(prog='PROG', prefix_chars='+/')
>>> parser.print_help()
usage: PROG [+h]

optional arguments:
  +h, ++help  show this help message and exit
```

16.4.3 The add_argument() method

`ArgumentParser.add_argument`(*name or flags...*[, *action*][, *nargs*][, *const*][, *default*][, *type*][, *choices*][, *required*][, *help*][, *metavar*][, *dest*])

Define how a single command-line argument should be parsed. Each parameter has its own more detailed description below, but in short they are:

- *name or flags* - Either a name or a list of option strings, e.g. `foo` or `-f, --foo`.
- *action* - The basic type of action to be taken when this argument is encountered at the command line.
- *nargs* - The number of command-line arguments that should be consumed.
- *const* - A constant value required by some *action* and *nargs* selections.
- *default* - The value produced if the argument is absent from the command line.
- *type* - The type to which the command-line argument should be converted.
- *choices* - A container of the allowable values for the argument.
- *required* - Whether or not the command-line option may be omitted (optionals only).
- *help* - A brief description of what the argument does.
- *metavar* - A name for the argument in usage messages.
- *dest* - The name of the attribute to be added to the object returned by *parse_args()*.

The following sections describe how each of these are used.

name or flags

The *add_argument()* method must know whether an optional argument, like `-f` or `--foo`, or a positional argument, like a list of filenames, is expected. The first arguments passed to *add_argument()* must therefore be either a series of flags, or a simple argument name. For example, an optional argument could be created like:

```
>>> parser.add_argument('-f', '--foo')
```

while a positional argument could be created like:

```
>>> parser.add_argument('bar')
```

When *parse_args()* is called, optional arguments will be identified by the `-` prefix, and the remaining arguments will be assumed to be positional:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-f', '--foo')
>>> parser.add_argument('bar')
>>> parser.parse_args(['BAR'])
Namespace(bar='BAR', foo=None)
>>> parser.parse_args(['BAR', '--foo', 'FOO'])
Namespace(bar='BAR', foo='FOO')
>>> parser.parse_args(['--foo', 'FOO'])
usage: PROG [-h] [-f FOO] bar
PROG: error: the following arguments are required: bar
```

action

ArgumentParser objects associate command-line arguments with actions. These actions can do just about anything with the command-line arguments associated with them, though most actions simply add an attribute to the object returned by *parse_args()*. The `action` keyword argument specifies how the command-line arguments should be handled. The supplied actions are:

- `'store'` - This just stores the argument's value. This is the default action. For example:

  ```
  >>> parser = argparse.ArgumentParser()
  >>> parser.add_argument('--foo')
  >>> parser.parse_args('--foo 1'.split())
  Namespace(foo='1')
  ```

- `'store_const'` - This stores the value specified by the *const* keyword argument. The `'store_const'` action is most commonly used with optional arguments that specify some sort of flag. For example:

  ```
  >>> parser = argparse.ArgumentParser()
  >>> parser.add_argument('--foo', action='store_const', const=42)
  >>> parser.parse_args(['--foo'])
  Namespace(foo=42)
  ```

- `'store_true'` and `'store_false'` - These are special cases of `'store_const'` used for storing the values `True` and `False` respectively. In addition, they create default values of `False` and `True` respectively. For example:

  ```
  >>> parser = argparse.ArgumentParser()
  >>> parser.add_argument('--foo', action='store_true')
  >>> parser.add_argument('--bar', action='store_false')
  ```

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```
>>> parser.add_argument('--baz', action='store_false')
>>> parser.parse_args('--foo --bar'.split())
Namespace(foo=True, bar=False, baz=True)
```

- `'append'` - This stores a list, and appends each argument value to the list. This is useful to allow an option to be specified multiple times. Example usage:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action='append')
>>> parser.parse_args('--foo 1 --foo 2'.split())
Namespace(foo=['1', '2'])
```

- `'append_const'` - This stores a list, and appends the value specified by the *const* keyword argument to the list. (Note that the *const* keyword argument defaults to `None`.) The `'append_const'` action is typically useful when multiple arguments need to store constants to the same list. For example:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--str', dest='types', action='append_const', const=str)
>>> parser.add_argument('--int', dest='types', action='append_const', const=int)
>>> parser.parse_args('--str --int'.split())
Namespace(types=[<class 'str'>, <class 'int'>])
```

- `'count'` - This counts the number of times a keyword argument occurs. For example, this is useful for increasing verbosity levels:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--verbose', '-v', action='count')
>>> parser.parse_args(['-vvv'])
Namespace(verbose=3)
```

- `'help'` - This prints a complete help message for all the options in the current parser and then exits. By default a help action is automatically added to the parser. See *ArgumentParser* for details of how the output is created.

- `'version'` - This expects a `version=` keyword argument in the *add_argument()* call, and prints version information and exits when invoked:

```
>>> import argparse
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--version', action='version', version='%(prog)s 2.0')
>>> parser.parse_args(['--version'])
PROG 2.0
```

You may also specify an arbitrary action by passing an Action subclass or other object that implements the same interface. The recommended way to do this is to extend *Action*, overriding the `__call__` method and optionally the `__init__` method.

An example of a custom action:

```
>>> class FooAction(argparse.Action):
...     def __init__(self, option_strings, dest, nargs=None, **kwargs):
...         if nargs is not None:
...             raise ValueError("nargs not allowed")
...         super(FooAction, self).__init__(option_strings, dest, **kwargs)
...     def __call__(self, parser, namespace, values, option_string=None):
...         print('%r %r %r' % (namespace, values, option_string))
...         setattr(namespace, self.dest, values)
```

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```
...
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action=FooAction)
>>> parser.add_argument('bar', action=FooAction)
>>> args = parser.parse_args('1 --foo 2'.split())
Namespace(bar=None, foo=None) '1' None
Namespace(bar='1', foo=None) '2' '--foo'
>>> args
Namespace(bar='1', foo='2')
```

For more details, see *Action*.

nargs

ArgumentParser objects usually associate a single command-line argument with a single action to be taken. The `nargs` keyword argument associates a different number of command-line arguments with a single action. The supported values are:

- `N` (an integer). `N` arguments from the command line will be gathered together into a list. For example:

  ```
  >>> parser = argparse.ArgumentParser()
  >>> parser.add_argument('--foo', nargs=2)
  >>> parser.add_argument('bar', nargs=1)
  >>> parser.parse_args('c --foo a b'.split())
  Namespace(bar=['c'], foo=['a', 'b'])
  ```

  Note that `nargs=1` produces a list of one item. This is different from the default, in which the item is produced by itself.

- `'?'`. One argument will be consumed from the command line if possible, and produced as a single item. If no command-line argument is present, the value from *default* will be produced. Note that for optional arguments, there is an additional case - the option string is present but not followed by a command-line argument. In this case the value from *const* will be produced. Some examples to illustrate this:

  ```
  >>> parser = argparse.ArgumentParser()
  >>> parser.add_argument('--foo', nargs='?', const='c', default='d')
  >>> parser.add_argument('bar', nargs='?', default='d')
  >>> parser.parse_args(['XX', '--foo', 'YY'])
  Namespace(bar='XX', foo='YY')
  >>> parser.parse_args(['XX', '--foo'])
  Namespace(bar='XX', foo='c')
  >>> parser.parse_args([])
  Namespace(bar='d', foo='d')
  ```

  One of the more common uses of `nargs='?'` is to allow optional input and output files:

  ```
  >>> parser = argparse.ArgumentParser()
  >>> parser.add_argument('infile', nargs='?', type=argparse.FileType('r'),
  ...                     default=sys.stdin)
  >>> parser.add_argument('outfile', nargs='?', type=argparse.FileType('w'),
  ...                     default=sys.stdout)
  >>> parser.parse_args(['input.txt', 'output.txt'])
  Namespace(infile=<_io.TextIOWrapper name='input.txt' encoding='UTF-8'>,
            outfile=<_io.TextIOWrapper name='output.txt' encoding='UTF-8'>)
  >>> parser.parse_args([])
  ```

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```
Namespace(infile=<_io.TextIOWrapper name='<stdin>' encoding='UTF-8'>,
          outfile=<_io.TextIOWrapper name='<stdout>' encoding='UTF-8'>)
```

- `'*'`. All command-line arguments present are gathered into a list. Note that it generally doesn't make much sense to have more than one positional argument with `nargs='*'`, but multiple optional arguments with `nargs='*'` is possible. For example:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', nargs='*')
>>> parser.add_argument('--bar', nargs='*')
>>> parser.add_argument('baz', nargs='*')
>>> parser.parse_args('a b --foo x y --bar 1 2'.split())
Namespace(bar=['1', '2'], baz=['a', 'b'], foo=['x', 'y'])
```

- `'+'`. Just like `'*'`, all command-line args present are gathered into a list. Additionally, an error message will be generated if there wasn't at least one command-line argument present. For example:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', nargs='+')
>>> parser.parse_args(['a', 'b'])
Namespace(foo=['a', 'b'])
>>> parser.parse_args([])
usage: PROG [-h] foo [foo ...]
PROG: error: the following arguments are required: foo
```

- `argparse.REMAINDER`. All the remaining command-line arguments are gathered into a list. This is commonly useful for command line utilities that dispatch to other command line utilities:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo')
>>> parser.add_argument('command')
>>> parser.add_argument('args', nargs=argparse.REMAINDER)
>>> print(parser.parse_args('--foo B cmd --arg1 XX ZZ'.split()))
Namespace(args=['--arg1', 'XX', 'ZZ'], command='cmd', foo='B')
```

If the `nargs` keyword argument is not provided, the number of arguments consumed is determined by the *action*. Generally this means a single command-line argument will be consumed and a single item (not a list) will be produced.

const

The `const` argument of *add_argument()* is used to hold constant values that are not read from the command line but are required for the various *ArgumentParser* actions. The two most common uses of it are:

- When *add_argument()* is called with `action='store_const'` or `action='append_const'`. These actions add the `const` value to one of the attributes of the object returned by *parse_args()*. See the *action* description for examples.
- When *add_argument()* is called with option strings (like `-f` or `--foo`) and `nargs='?'`. This creates an optional argument that can be followed by zero or one command-line arguments. When parsing the command line, if the option string is encountered with no command-line argument following it, the value of `const` will be assumed instead. See the *nargs* description for examples.

With the `'store_const'` and `'append_const'` actions, the `const` keyword argument must be given. For other actions, it defaults to `None`.

default

All optional arguments and some positional arguments may be omitted at the command line. The `default` keyword argument of *add_argument()*, whose value defaults to `None`, specifies what value should be used if the command-line argument is not present. For optional arguments, the `default` value is used when the option string was not present at the command line:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default=42)
>>> parser.parse_args(['--foo', '2'])
Namespace(foo='2')
>>> parser.parse_args([])
Namespace(foo=42)
```

If the `default` value is a string, the parser parses the value as if it were a command-line argument. In particular, the parser applies any *type* conversion argument, if provided, before setting the attribute on the *Namespace* return value. Otherwise, the parser uses the value as is:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--length', default='10', type=int)
>>> parser.add_argument('--width', default=10.5, type=int)
>>> parser.parse_args()
Namespace(length=10, width=10.5)
```

For positional arguments with *nargs* equal to `?` or `*`, the `default` value is used when no command-line argument was present:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('foo', nargs='?', default=42)
>>> parser.parse_args(['a'])
Namespace(foo='a')
>>> parser.parse_args([])
Namespace(foo=42)
```

Providing `default=argparse.SUPPRESS` causes no attribute to be added if the command-line argument was not present:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default=argparse.SUPPRESS)
>>> parser.parse_args([])
Namespace()
>>> parser.parse_args(['--foo', '1'])
Namespace(foo='1')
```

type

By default, *ArgumentParser* objects read command-line arguments in as simple strings. However, quite often the command-line string should instead be interpreted as another type, like a *float* or *int*. The `type` keyword argument of *add_argument()* allows any necessary type-checking and type conversions to be performed. Common built-in types and functions can be used directly as the value of the `type` argument:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('foo', type=int)
>>> parser.add_argument('bar', type=open)
>>> parser.parse_args('2 temp.txt'.split())
Namespace(bar=<_io.TextIOWrapper name='temp.txt' encoding='UTF-8'>, foo=2)
```

See the section on the *default* keyword argument for information on when the `type` argument is applied to default arguments.

To ease the use of various types of files, the argparse module provides the factory FileType which takes the `mode=`, `bufsize=`, `encoding=` and `errors=` arguments of the *open()* function. For example, `FileType('w')` can be used to create a writable file:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('bar', type=argparse.FileType('w'))
>>> parser.parse_args(['out.txt'])
Namespace(bar=<_io.TextIOWrapper name='out.txt' encoding='UTF-8'>)
```

`type=` can take any callable that takes a single string argument and returns the converted value:

```
>>> def perfect_square(string):
...     value = int(string)
...     sqrt = math.sqrt(value)
...     if sqrt != int(sqrt):
...         msg = "%r is not a perfect square" % string
...         raise argparse.ArgumentTypeError(msg)
...     return value
...
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', type=perfect_square)
>>> parser.parse_args(['9'])
Namespace(foo=9)
>>> parser.parse_args(['7'])
usage: PROG [-h] foo
PROG: error: argument foo: '7' is not a perfect square
```

The *choices* keyword argument may be more convenient for type checkers that simply check against a range of values:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('foo', type=int, choices=range(5, 10))
>>> parser.parse_args(['7'])
Namespace(foo=7)
>>> parser.parse_args(['11'])
usage: PROG [-h] {5,6,7,8,9}
PROG: error: argument foo: invalid choice: 11 (choose from 5, 6, 7, 8, 9)
```

See the *choices* section for more details.

choices

Some command-line arguments should be selected from a restricted set of values. These can be handled by passing a container object as the *choices* keyword argument to *add_argument()*. When the command line is parsed, argument values will be checked, and an error message will be displayed if the argument was not one of the acceptable values:

```
>>> parser = argparse.ArgumentParser(prog='game.py')
>>> parser.add_argument('move', choices=['rock', 'paper', 'scissors'])
>>> parser.parse_args(['rock'])
Namespace(move='rock')
>>> parser.parse_args(['fire'])
usage: game.py [-h] {rock,paper,scissors}
game.py: error: argument move: invalid choice: 'fire' (choose from 'rock',
'paper', 'scissors')
```

Note that inclusion in the *choices* container is checked after any *type* conversions have been performed, so the type of the objects in the *choices* container should match the *type* specified:

```
>>> parser = argparse.ArgumentParser(prog='doors.py')
>>> parser.add_argument('door', type=int, choices=range(1, 4))
>>> print(parser.parse_args(['3']))
Namespace(door=3)
>>> parser.parse_args(['4'])
usage: doors.py [-h] {1,2,3}
doors.py: error: argument door: invalid choice: 4 (choose from 1, 2, 3)
```

Any object that supports the `in` operator can be passed as the *choices* value, so *dict* objects, *set* objects, custom containers, etc. are all supported.

required

In general, the *argparse* module assumes that flags like `-f` and `--bar` indicate *optional* arguments, which can always be omitted at the command line. To make an option *required*, `True` can be specified for the `required=` keyword argument to *add_argument()*:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', required=True)
>>> parser.parse_args(['--foo', 'BAR'])
Namespace(foo='BAR')
>>> parser.parse_args([])
usage: argparse.py [-h] [--foo FOO]
argparse.py: error: option --foo is required
```

As the example shows, if an option is marked as `required`, *parse_args()* will report an error if that option is not present at the command line.

Note: Required options are generally considered bad form because users expect *options* to be *optional*, and thus they should be avoided when possible.

---

help

The `help` value is a string containing a brief description of the argument. When a user requests help (usually by using `-h` or `--help` at the command line), these `help` descriptions will be displayed with each argument:

```
>>> parser = argparse.ArgumentParser(prog='frobble')
>>> parser.add_argument('--foo', action='store_true',
...                     help='foo the bars before frobbling')
>>> parser.add_argument('bar', nargs='+',
...                     help='one of the bars to be frobbled')
>>> parser.parse_args(['-h'])
usage: frobble [-h] [--foo] bar [bar ...]

positional arguments:
 bar     one of the bars to be frobbled

optional arguments:
 -h, --help  show this help message and exit
 --foo   foo the bars before frobbling
```

The help strings can include various format specifiers to avoid repetition of things like the program name or the argument *default*. The available specifiers include the program name, %(prog)s and most keyword arguments to *add_argument()*, e.g. %(default)s, %(type)s, etc.:

```
>>> parser = argparse.ArgumentParser(prog='frobble')
>>> parser.add_argument('bar', nargs='?', type=int, default=42,
...                     help='the bar to %(prog)s (default: %(default)s)')
>>> parser.print_help()
usage: frobble [-h] [bar]

positional arguments:
 bar     the bar to frobble (default: 42)

optional arguments:
 -h, --help  show this help message and exit
```

As the help string supports %-formatting, if you want a literal % to appear in the help string, you must escape it as %%.

argparse supports silencing the help entry for certain options, by setting the help value to argparse.SUPPRESS:

```
>>> parser = argparse.ArgumentParser(prog='frobble')
>>> parser.add_argument('--foo', help=argparse.SUPPRESS)
>>> parser.print_help()
usage: frobble [-h]

optional arguments:
  -h, --help  show this help message and exit
```

metavar

When *ArgumentParser* generates help messages, it needs some way to refer to each expected argument. By default, ArgumentParser objects use the *dest* value as the "name" of each object. By default, for positional argument actions, the *dest* value is used directly, and for optional argument actions, the *dest* value is uppercased. So, a single positional argument with dest='bar' will be referred to as bar. A single optional argument --foo that should be followed by a single command-line argument will be referred to as FOO. An example:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> parser.add_argument('bar')
>>> parser.parse_args('X --foo Y'.split())
Namespace(bar='X', foo='Y')
>>> parser.print_help()
usage:  [-h] [--foo FOO] bar

positional arguments:
 bar

optional arguments:
 -h, --help  show this help message and exit
 --foo FOO
```

An alternative name can be specified with metavar:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', metavar='YYY')
>>> parser.add_argument('bar', metavar='XXX')
>>> parser.parse_args('X --foo Y'.split())
Namespace(bar='X', foo='Y')
>>> parser.print_help()
usage:  [-h] [--foo YYY] XXX

positional arguments:
 XXX

optional arguments:
 -h, --help  show this help message and exit
 --foo YYY
```

Note that `metavar` only changes the *displayed* name - the name of the attribute on the *parse_args()* object is still determined by the *dest* value.

Different values of `nargs` may cause the metavar to be used multiple times. Providing a tuple to `metavar` specifies a different display for each of the arguments:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x', nargs=2)
>>> parser.add_argument('--foo', nargs=2, metavar=('bar', 'baz'))
>>> parser.print_help()
usage: PROG [-h] [-x X X] [--foo bar baz]

optional arguments:
 -h, --help     show this help message and exit
 -x X X
 --foo bar baz
```

dest

Most *ArgumentParser* actions add some value as an attribute of the object returned by *parse_args()*. The name of this attribute is determined by the `dest` keyword argument of *add_argument()*. For positional argument actions, `dest` is normally supplied as the first argument to *add_argument()*:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('bar')
>>> parser.parse_args(['XXX'])
Namespace(bar='XXX')
```

For optional argument actions, the value of `dest` is normally inferred from the option strings. *ArgumentParser* generates the value of `dest` by taking the first long option string and stripping away the initial `--` string. If no long option strings were supplied, `dest` will be derived from the first short option string by stripping the initial `-` character. Any internal `-` characters will be converted to `_` characters to make sure the string is a valid attribute name. The examples below illustrate this behavior:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('-f', '--foo-bar', '--foo')
>>> parser.add_argument('-x', '-y')
>>> parser.parse_args('-f 1 -x 2'.split())
Namespace(foo_bar='1', x='2')
>>> parser.parse_args('--foo 1 -y 2'.split())
Namespace(foo_bar='1', x='2')
```

dest allows a custom attribute name to be provided:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', dest='bar')
>>> parser.parse_args('--foo XXX'.split())
Namespace(bar='XXX')
```

Action classes

Action classes implement the Action API, a callable which returns a callable which processes arguments from the command-line. Any object which follows this API may be passed as the action parameter to add_argument().

class argparse.Action(*option_strings*, *dest*, *nargs=None*, *const=None*, *default=None*, *type=None*, *choices=None*, *required=False*, *help=None*, *metavar=None*)

Action objects are used by an ArgumentParser to represent the information needed to parse a single argument from one or more strings from the command line. The Action class must accept the two positional arguments plus any keyword arguments passed to *ArgumentParser.add_argument()* except for the action itself.

Instances of Action (or return value of any callable to the action parameter) should have attributes "dest", "option_strings", "default", "type", "required", "help", etc. defined. The easiest way to ensure these attributes are defined is to call Action.__init__.

Action instances should be callable, so subclasses must override the __call__ method, which should accept four parameters:

- parser - The ArgumentParser object which contains this action.
- namespace - The *Namespace* object that will be returned by *parse_args()*. Most actions add an attribute to this object using *setattr()*.
- values - The associated command-line arguments, with any type conversions applied. Type conversions are specified with the *type* keyword argument to *add_argument()*.
- option_string - The option string that was used to invoke this action. The option_string argument is optional, and will be absent if the action is associated with a positional argument.

The __call__ method may perform arbitrary actions, but will typically set attributes on the namespace based on dest and values.

16.4.4 The parse_args() method

ArgumentParser.parse_args(*args=None*, *namespace=None*)

Convert argument strings to objects and assign them as attributes of the namespace. Return the populated namespace.

Previous calls to *add_argument()* determine exactly what objects are created and how they are assigned. See the documentation for *add_argument()* for details.

- *args* - List of strings to parse. The default is taken from *sys.argv*.
- *namespace* - An object to take the attributes. The default is a new empty *Namespace* object.

Option value syntax

The *parse_args()* method supports several ways of specifying the value of an option (if it takes one). In the simplest case, the option and its value are passed as two separate arguments:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x')
>>> parser.add_argument('--foo')
>>> parser.parse_args(['-x', 'X'])
Namespace(foo=None, x='X')
>>> parser.parse_args(['--foo', 'FOO'])
Namespace(foo='FOO', x=None)
```

For long options (options with names longer than a single character), the option and value can also be passed as a single command-line argument, using = to separate them:

```
>>> parser.parse_args(['--foo=FOO'])
Namespace(foo='FOO', x=None)
```

For short options (options only one character long), the option and its value can be concatenated:

```
>>> parser.parse_args(['-xX'])
Namespace(foo=None, x='X')
```

Several short options can be joined together, using only a single - prefix, as long as only the last option (or none of them) requires a value:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x', action='store_true')
>>> parser.add_argument('-y', action='store_true')
>>> parser.add_argument('-z')
>>> parser.parse_args(['-xyzZ'])
Namespace(x=True, y=True, z='Z')
```

Invalid arguments

While parsing the command line, *parse_args()* checks for a variety of errors, including ambiguous options, invalid types, invalid options, wrong number of positional arguments, etc. When it encounters such an error, it exits and prints the error along with a usage message:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo', type=int)
>>> parser.add_argument('bar', nargs='?')

>>> # invalid type
>>> parser.parse_args(['--foo', 'spam'])
usage: PROG [-h] [--foo FOO] [bar]
PROG: error: argument --foo: invalid int value: 'spam'

>>> # invalid option
>>> parser.parse_args(['--bar'])
usage: PROG [-h] [--foo FOO] [bar]
PROG: error: no such option: --bar

>>> # wrong number of arguments
>>> parser.parse_args(['spam', 'badger'])
usage: PROG [-h] [--foo FOO] [bar]
PROG: error: extra arguments found: badger
```

Arguments containing -

The *parse_args()* method attempts to give errors whenever the user has clearly made a mistake, but some situations are inherently ambiguous. For example, the command-line argument `-1` could either be an attempt to specify an option or an attempt to provide a positional argument. The *parse_args()* method is cautious here: positional arguments may only begin with `-` if they look like negative numbers and there are no options in the parser that look like negative numbers:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-x')
>>> parser.add_argument('foo', nargs='?')

>>> # no negative number options, so -1 is a positional argument
>>> parser.parse_args(['-x', '-1'])
Namespace(foo=None, x='-1')

>>> # no negative number options, so -1 and -5 are positional arguments
>>> parser.parse_args(['-x', '-1', '-5'])
Namespace(foo='-5', x='-1')

>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-1', dest='one')
>>> parser.add_argument('foo', nargs='?')

>>> # negative number options present, so -1 is an option
>>> parser.parse_args(['-1', 'X'])
Namespace(foo=None, one='X')

>>> # negative number options present, so -2 is an option
>>> parser.parse_args(['-2'])
usage: PROG [-h] [-1 ONE] [foo]
PROG: error: no such option: -2

>>> # negative number options present, so both -1s are options
>>> parser.parse_args(['-1', '-1'])
usage: PROG [-h] [-1 ONE] [foo]
PROG: error: argument -1: expected one argument
```

If you have positional arguments that must begin with `-` and don't look like negative numbers, you can insert the pseudo-argument `'--'` which tells *parse_args()* that everything after that is a positional argument:

```
>>> parser.parse_args(['--', '-f'])
Namespace(foo='-f', one=None)
```

Argument abbreviations (prefix matching)

The *parse_args()* method *by default* allows long options to be abbreviated to a prefix, if the abbreviation is unambiguous (the prefix matches a unique option):

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('-bacon')
>>> parser.add_argument('-badger')
>>> parser.parse_args('-bac MMM'.split())
Namespace(bacon='MMM', badger=None)
>>> parser.parse_args('-bad WOOD'.split())
Namespace(bacon=None, badger='WOOD')
```

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```
>>> parser.parse_args('-ba BA'.split())
usage: PROG [-h] [-bacon BACON] [-badger BADGER]
PROG: error: ambiguous option: -ba could match -badger, -bacon
```

An error is produced for arguments that could produce more than one options. This feature can be disabled by setting *allow_abbrev* to `False`.

Beyond `sys.argv`

Sometimes it may be useful to have an ArgumentParser parse arguments other than those of *sys.argv*. This can be accomplished by passing a list of strings to *parse_args()*. This is useful for testing at the interactive prompt:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument(
...     'integers', metavar='int', type=int, choices=range(10),
...     nargs='+', help='an integer in the range 0..9')
>>> parser.add_argument(
...     '--sum', dest='accumulate', action='store_const', const=sum,
...     default=max, help='sum the integers (default: find the max)')
>>> parser.parse_args(['1', '2', '3', '4'])
Namespace(accumulate=<built-in function max>, integers=[1, 2, 3, 4])
>>> parser.parse_args(['1', '2', '3', '4', '--sum'])
Namespace(accumulate=<built-in function sum>, integers=[1, 2, 3, 4])
```

The Namespace object

class argparse.**Namespace**

Simple class used by default by *parse_args()* to create an object holding attributes and return it.

This class is deliberately simple, just an *object* subclass with a readable string representation. If you prefer to have dict-like view of the attributes, you can use the standard Python idiom, *vars()*:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> args = parser.parse_args(['--foo', 'BAR'])
>>> vars(args)
{'foo': 'BAR'}
```

It may also be useful to have an *ArgumentParser* assign attributes to an already existing object, rather than a new *Namespace* object. This can be achieved by specifying the `namespace=` keyword argument:

```
>>> class C:
...     pass
...
>>> c = C()
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> parser.parse_args(args=['--foo', 'BAR'], namespace=c)
>>> c.foo
'BAR'
```

16.4.5 Other utilities

Sub-commands

ArgumentParser.**add_subparsers**([*title*][, *description*][, *prog*][, *parser_class*][, *action*][, *option_string*][, *dest*][, *required] [help*][, *metavar*])

Many programs split up their functionality into a number of sub-commands, for example, the `svn` program can invoke sub-commands like `svn checkout`, `svn update`, and `svn commit`. Splitting up functionality this way can be a particularly good idea when a program performs several different functions which require different kinds of command-line arguments. *ArgumentParser* supports the creation of such sub-commands with the *add_subparsers()* method. The *add_subparsers()* method is normally called with no arguments and returns a special action object. This object has a single method, `add_parser()`, which takes a command name and any *ArgumentParser* constructor arguments, and returns an *ArgumentParser* object that can be modified as usual.

Description of parameters:

- title - title for the sub-parser group in help output; by default "subcommands" if description is provided, otherwise uses title for positional arguments
- description - description for the sub-parser group in help output, by default `None`
- prog - usage information that will be displayed with sub-command help, by default the name of the program and any positional arguments before the subparser argument
- parser_class - class which will be used to create sub-parser instances, by default the class of the current parser (e.g. ArgumentParser)
- *action* - the basic type of action to be taken when this argument is encountered at the command line
- *dest* - name of the attribute under which sub-command name will be stored; by default `None` and no value is stored
- *required* - Whether or not a subcommand must be provided, by default `False`.
- *help* - help for sub-parser group in help output, by default `None`
- *metavar* - string presenting available sub-commands in help; by default it is `None` and presents sub-commands in form {cmd1, cmd2, ..}

Some example usage:

```
>>> # create the top-level parser
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> parser.add_argument('--foo', action='store_true', help='foo help')
>>> subparsers = parser.add_subparsers(help='sub-command help')
>>>
>>> # create the parser for the "a" command
>>> parser_a = subparsers.add_parser('a', help='a help')
>>> parser_a.add_argument('bar', type=int, help='bar help')
>>>
>>> # create the parser for the "b" command
>>> parser_b = subparsers.add_parser('b', help='b help')
>>> parser_b.add_argument('--baz', choices='XYZ', help='baz help')
>>>
>>> # parse some argument lists
>>> parser.parse_args(['a', '12'])
Namespace(bar=12, foo=False)
>>> parser.parse_args(['--foo', 'b', '--baz', 'Z'])
Namespace(baz='Z', foo=True)
```

Note that the object returned by *parse_args()* will only contain attributes for the main parser and the subparser that was selected by the command line (and not any other subparsers). So in the example above, when the `a` command is specified, only the `foo` and `bar` attributes are present, and when the `b` command is specified, only the `foo` and `baz` attributes are present.

Similarly, when a help message is requested from a subparser, only the help for that particular parser will be printed. The help message will not include parent parser or sibling parser messages. (A help message for each subparser command, however, can be given by supplying the `help=` argument to `add_parser()` as above.)

```
>>> parser.parse_args(['--help'])
usage: PROG [-h] [--foo] {a,b} ...

positional arguments:
  {a,b}   sub-command help
    a     a help
    b     b help

optional arguments:
  -h, --help  show this help message and exit
  --foo   foo help

>>> parser.parse_args(['a', '--help'])
usage: PROG a [-h] bar

positional arguments:
  bar     bar help

optional arguments:
  -h, --help  show this help message and exit

>>> parser.parse_args(['b', '--help'])
usage: PROG b [-h] [--baz {X,Y,Z}]

optional arguments:
  -h, --help     show this help message and exit
  --baz {X,Y,Z}  baz help
```

The *add_subparsers()* method also supports `title` and `description` keyword arguments. When either is present, the subparser's commands will appear in their own group in the help output. For example:

```
>>> parser = argparse.ArgumentParser()
>>> subparsers = parser.add_subparsers(title='subcommands',
...                                    description='valid subcommands',
...                                    help='additional help')
>>> subparsers.add_parser('foo')
>>> subparsers.add_parser('bar')
>>> parser.parse_args(['-h'])
usage:  [-h] {foo,bar} ...

optional arguments:
  -h, --help  show this help message and exit

subcommands:
  valid subcommands

  {foo,bar}   additional help
```

Furthermore, `add_parser` supports an additional `aliases` argument, which allows multiple strings to refer to the same subparser. This example, like `svn`, aliases `co` as a shorthand for `checkout`:

```
>>> parser = argparse.ArgumentParser()
>>> subparsers = parser.add_subparsers()
>>> checkout = subparsers.add_parser('checkout', aliases=['co'])
>>> checkout.add_argument('foo')
>>> parser.parse_args(['co', 'bar'])
Namespace(foo='bar')
```

One particularly effective way of handling sub-commands is to combine the use of the *add_subparsers()* method with calls to *set_defaults()* so that each subparser knows which Python function it should execute. For example:

```
>>> # sub-command functions
>>> def foo(args):
...     print(args.x * args.y)
...
>>> def bar(args):
...     print('((%s))' % args.z)
...
>>> # create the top-level parser
>>> parser = argparse.ArgumentParser()
>>> subparsers = parser.add_subparsers()
>>>
>>> # create the parser for the "foo" command
>>> parser_foo = subparsers.add_parser('foo')
>>> parser_foo.add_argument('-x', type=int, default=1)
>>> parser_foo.add_argument('y', type=float)
>>> parser_foo.set_defaults(func=foo)
>>>
>>> # create the parser for the "bar" command
>>> parser_bar = subparsers.add_parser('bar')
>>> parser_bar.add_argument('z')
>>> parser_bar.set_defaults(func=bar)
>>>
>>> # parse the args and call whatever function was selected
>>> args = parser.parse_args('foo 1 -x 2'.split())
>>> args.func(args)
2.0
>>>
>>> # parse the args and call whatever function was selected
>>> args = parser.parse_args('bar XYZYX'.split())
>>> args.func(args)
((XYZYX))
```

This way, you can let *parse_args()* do the job of calling the appropriate function after argument parsing is complete. Associating functions with actions like this is typically the easiest way to handle the different actions for each of your subparsers. However, if it is necessary to check the name of the subparser that was invoked, the `dest` keyword argument to the *add_subparsers()* call will work:

```
>>> parser = argparse.ArgumentParser()
>>> subparsers = parser.add_subparsers(dest='subparser_name')
>>> subparser1 = subparsers.add_parser('1')
>>> subparser1.add_argument('-x')
>>> subparser2 = subparsers.add_parser('2')
>>> subparser2.add_argument('y')
>>> parser.parse_args(['2', 'frobble'])
```

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```
Namespace(subparser_name='2', y='frobble')
```

FileType objects

class argparse.FileType(*mode='r'*, *bufsize=-1*, *encoding=None*, *errors=None*)

The *FileType* factory creates objects that can be passed to the type argument of *ArgumentParser.add_argument()*. Arguments that have *FileType* objects as their type will open command-line arguments as files with the requested modes, buffer sizes, encodings and error handling (see the *open()* function for more details):

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--raw', type=argparse.FileType('wb', 0))
>>> parser.add_argument('out', type=argparse.FileType('w', encoding='UTF-8'))
>>> parser.parse_args(['--raw', 'raw.dat', 'file.txt'])
Namespace(out=<_io.TextIOWrapper name='file.txt' mode='w' encoding='UTF-8'>, raw=<_io.FileIO␣
↪name='raw.dat' mode='wb'>)
```

FileType objects understand the pseudo-argument `'-'` and automatically convert this into `sys.stdin` for readable *FileType* objects and `sys.stdout` for writable *FileType* objects:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('infile', type=argparse.FileType('r'))
>>> parser.parse_args(['-'])
Namespace(infile=<_io.TextIOWrapper name='<stdin>' encoding='UTF-8'>)
```

New in version 3.4: The *encodings* and *errors* keyword arguments.

Argument groups

ArgumentParser.add_argument_group(*title=None*, *description=None*)

By default, *ArgumentParser* groups command-line arguments into "positional arguments" and "optional arguments" when displaying help messages. When there is a better conceptual grouping of arguments than this default one, appropriate groups can be created using the *add_argument_group()* method:

```
>>> parser = argparse.ArgumentParser(prog='PROG', add_help=False)
>>> group = parser.add_argument_group('group')
>>> group.add_argument('--foo', help='foo help')
>>> group.add_argument('bar', help='bar help')
>>> parser.print_help()
usage: PROG [--foo FOO] bar

group:
  bar    bar help
  --foo FOO  foo help
```

The *add_argument_group()* method returns an argument group object which has an *add_argument()* method just like a regular *ArgumentParser*. When an argument is added to the group, the parser treats it just like a normal argument, but displays the argument in a separate group for help messages. The *add_argument_group()* method accepts *title* and *description* arguments which can be used to customize this display:

```
>>> parser = argparse.ArgumentParser(prog='PROG', add_help=False)
>>> group1 = parser.add_argument_group('group1', 'group1 description')
>>> group1.add_argument('foo', help='foo help')
>>> group2 = parser.add_argument_group('group2', 'group2 description')
>>> group2.add_argument('--bar', help='bar help')
>>> parser.print_help()
usage: PROG [--bar BAR] foo

group1:
  group1 description

  foo    foo help

group2:
  group2 description

  --bar BAR  bar help
```

Note that any arguments not in your user-defined groups will end up back in the usual "positional arguments" and "optional arguments" sections.

Mutual exclusion

`ArgumentParser.add_mutually_exclusive_group`(*required=False*)

Create a mutually exclusive group. *argparse* will make sure that only one of the arguments in the mutually exclusive group was present on the command line:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> group = parser.add_mutually_exclusive_group()
>>> group.add_argument('--foo', action='store_true')
>>> group.add_argument('--bar', action='store_false')
>>> parser.parse_args(['--foo'])
Namespace(bar=True, foo=True)
>>> parser.parse_args(['--bar'])
Namespace(bar=False, foo=False)
>>> parser.parse_args(['--foo', '--bar'])
usage: PROG [-h] [--foo | --bar]
PROG: error: argument --bar: not allowed with argument --foo
```

The *add_mutually_exclusive_group()* method also accepts a *required* argument, to indicate that at least one of the mutually exclusive arguments is required:

```
>>> parser = argparse.ArgumentParser(prog='PROG')
>>> group = parser.add_mutually_exclusive_group(required=True)
>>> group.add_argument('--foo', action='store_true')
>>> group.add_argument('--bar', action='store_false')
>>> parser.parse_args([])
usage: PROG [-h] (--foo | --bar)
PROG: error: one of the arguments --foo --bar is required
```

Note that currently mutually exclusive argument groups do not support the *title* and *description* arguments of *add_argument_group()*.

Parser defaults

ArgumentParser.set_defaults(***kwargs*)

Most of the time, the attributes of the object returned by *parse_args()* will be fully determined by inspecting the command-line arguments and the argument actions. *set_defaults()* allows some additional attributes that are determined without any inspection of the command line to be added:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('foo', type=int)
>>> parser.set_defaults(bar=42, baz='badger')
>>> parser.parse_args(['736'])
Namespace(bar=42, baz='badger', foo=736)
```

Note that parser-level defaults always override argument-level defaults:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default='bar')
>>> parser.set_defaults(foo='spam')
>>> parser.parse_args([])
Namespace(foo='spam')
```

Parser-level defaults can be particularly useful when working with multiple parsers. See the *add_subparsers()* method for an example of this type.

ArgumentParser.get_default(*dest*)

Get the default value for a namespace attribute, as set by either *add_argument()* or by *set_defaults()*:

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', default='badger')
>>> parser.get_default('foo')
'badger'
```

Printing help

In most typical applications, *parse_args()* will take care of formatting and printing any usage or error messages. However, several formatting methods are available:

ArgumentParser.print_usage(*file=None*)

Print a brief description of how the *ArgumentParser* should be invoked on the command line. If *file* is `None`, *sys.stdout* is assumed.

ArgumentParser.print_help(*file=None*)

Print a help message, including the program usage and information about the arguments registered with the *ArgumentParser*. If *file* is `None`, *sys.stdout* is assumed.

There are also variants of these methods that simply return a string instead of printing it:

ArgumentParser.format_usage()

Return a string containing a brief description of how the *ArgumentParser* should be invoked on the command line.

ArgumentParser.format_help()

Return a string containing a help message, including the program usage and information about the arguments registered with the *ArgumentParser*.

Partial parsing

ArgumentParser.**parse_known_args**(*args=None*, *namespace=None*)

Sometimes a script may only parse a few of the command-line arguments, passing the remaining arguments on to another script or program. In these cases, the *parse_known_args()* method can be useful. It works much like *parse_args()* except that it does not produce an error when extra arguments are present. Instead, it returns a two item tuple containing the populated namespace and the list of remaining argument strings.

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo', action='store_true')
>>> parser.add_argument('bar')
>>> parser.parse_known_args(['--foo', '--badger', 'BAR', 'spam'])
(Namespace(bar='BAR', foo=True), ['--badger', 'spam'])
```

Warning: *Prefix matching* rules apply to `parse_known_args()`. The parser may consume an option even if it's just a prefix of one of its known options, instead of leaving it in the remaining arguments list.

Customizing file parsing

ArgumentParser.**convert_arg_line_to_args**(*arg_line*)

Arguments that are read from a file (see the *fromfile_prefix_chars* keyword argument to the *ArgumentParser* constructor) are read one argument per line. *convert_arg_line_to_args()* can be overridden for fancier reading.

This method takes a single argument *arg_line* which is a string read from the argument file. It returns a list of arguments parsed from this string. The method is called once per line read from the argument file, in order.

A useful override of this method is one that treats each space-separated word as an argument. The following example demonstrates how to do this:

```
class MyArgumentParser(argparse.ArgumentParser):
    def convert_arg_line_to_args(self, arg_line):
        return arg_line.split()
```

Exiting methods

ArgumentParser.**exit**(*status=0*, *message=None*)

This method terminates the program, exiting with the specified *status* and, if given, it prints a *message* before that.

ArgumentParser.**error**(*message*)

This method prints a usage message including the *message* to the standard error and terminates the program with a status code of 2.

Intermixed parsing

ArgumentParser.**parse_intermixed_args**(*args=None*, *namespace=None*)

ArgumentParser.**parse_known_intermixed_args**(*args=None*, *namespace=None*)

A number of Unix commands allow the user to intermix optional arguments with positional arguments. The *parse_intermixed_args()* and *parse_known_intermixed_args()* methods support this parsing style.

These parsers do not support all the argparse features, and will raise exceptions if unsupported features are used. In particular, subparsers, `argparse.REMAINDER`, and mutually exclusive groups that include both optionals and positionals are not supported.

The following example shows the difference between *parse_known_args()* and *parse_intermixed_args()*: the former returns `['2', '3']` as unparsed arguments, while the latter collects all the positionals into `rest`.

```
>>> parser = argparse.ArgumentParser()
>>> parser.add_argument('--foo')
>>> parser.add_argument('cmd')
>>> parser.add_argument('rest', nargs='*', type=int)
>>> parser.parse_known_args('doit 1 --foo bar 2 3'.split())
(Namespace(cmd='doit', foo='bar', rest=[1]), ['2', '3'])
>>> parser.parse_intermixed_args('doit 1 --foo bar 2 3'.split())
Namespace(cmd='doit', foo='bar', rest=[1, 2, 3])
```

parse_known_intermixed_args() returns a two item tuple containing the populated namespace and the list of remaining argument strings. *parse_intermixed_args()* raises an error if there are any remaining unparsed argument strings.

New in version 3.7.

16.4.6 Upgrading optparse code

Originally, the *argparse* module had attempted to maintain compatibility with *optparse*. However, *optparse* was difficult to extend transparently, particularly with the changes required to support the new `nargs=` specifiers and better usage messages. When most everything in *optparse* had either been copy-pasted over or monkey-patched, it no longer seemed practical to try to maintain the backwards compatibility.

The *argparse* module improves on the standard library *optparse* module in a number of ways including:

- Handling positional arguments.
- Supporting sub-commands.
- Allowing alternative option prefixes like `+` and `/`.
- Handling zero-or-more and one-or-more style arguments.
- Producing more informative usage messages.
- Providing a much simpler interface for custom `type` and `action`.

A partial upgrade path from *optparse* to *argparse*:

- Replace all *optparse.OptionParser.add_option()* calls with *ArgumentParser.add_argument()* calls.
- Replace `(options, args) = parser.parse_args()` with `args = parser.parse_args()` and add additional *ArgumentParser.add_argument()* calls for the positional arguments. Keep in mind that what was previously called `options`, now in the *argparse* context is called `args`.
- Replace *optparse.OptionParser.disable_interspersed_args()* by using *parse_intermixed_args()* instead of *parse_args()*.
- Replace callback actions and the `callback_*` keyword arguments with `type` or `action` arguments.
- Replace string names for `type` keyword arguments with the corresponding type objects (e.g. int, float, complex, etc).
- Replace `optparse.Values` with *Namespace* and `optparse.OptionError` and `optparse.OptionValueError` with `ArgumentError`.

- Replace strings with implicit arguments such as `%default` or `%prog` with the standard Python syntax to use dictionaries to format strings, that is, `%(default)s` and `%(prog)s`.
- Replace the OptionParser constructor `version` argument with a call to `parser.add_argument('--version', action='version', version='<the version>')`.

16.5 getopt — C-style parser for command line options

Source code: Lib/getopt.py

Note: The *getopt* module is a parser for command line options whose API is designed to be familiar to users of the C `getopt()` function. Users who are unfamiliar with the C `getopt()` function or who would like to write less code and get better help and error messages should consider using the *argparse* module instead.

This module helps scripts to parse the command line arguments in `sys.argv`. It supports the same conventions as the Unix `getopt()` function (including the special meanings of arguments of the form '`-`' and '`--`'). Long options similar to those supported by GNU software may be used as well via an optional third argument.

This module provides two functions and an exception:

`getopt.getopt(`*args*, *shortopts*, *longopts=[]*`)`

Parses command line options and parameter list. *args* is the argument list to be parsed, without the leading reference to the running program. Typically, this means `sys.argv[1:]`. *shortopts* is the string of option letters that the script wants to recognize, with options that require an argument followed by a colon (`':'`; i.e., the same format that Unix `getopt()` uses).

Note: Unlike GNU `getopt()`, after a non-option argument, all further arguments are considered also non-options. This is similar to the way non-GNU Unix systems work.

---

longopts, if specified, must be a list of strings with the names of the long options which should be supported. The leading `'--'` characters should not be included in the option name. Long options which require an argument should be followed by an equal sign (`'='`). Optional arguments are not supported. To accept only long options, *shortopts* should be an empty string. Long options on the command line can be recognized so long as they provide a prefix of the option name that matches exactly one of the accepted options. For example, if *longopts* is `['foo', 'frob']`, the option `--fo` will match as `--foo`, but `--f` will not match uniquely, so *GetoptError* will be raised.

The return value consists of two elements: the first is a list of `(option, value)` pairs; the second is the list of program arguments left after the option list was stripped (this is a trailing slice of *args*). Each option-and-value pair returned has the option as its first element, prefixed with a hyphen for short options (e.g., `'-x'`) or two hyphens for long options (e.g., `'--long-option'`), and the option argument as its second element, or an empty string if the option has no argument. The options occur in the list in the same order in which they were found, thus allowing multiple occurrences. Long and short options may be mixed.

`getopt.gnu_getopt(`*args*, *shortopts*, *longopts=[]*`)`

This function works like *getopt()*, except that GNU style scanning mode is used by default. This means that option and non-option arguments may be intermixed. The *getopt()* function stops processing options as soon as a non-option argument is encountered.

If the first character of the option string is `'+'`, or if the environment variable `POSIXLY_CORRECT` is set, then option processing stops as soon as a non-option argument is encountered.

exception getopt.GetoptError

This is raised when an unrecognized option is found in the argument list or when an option requiring an argument is given none. The argument to the exception is a string indicating the cause of the error. For long options, an argument given to an option which does not require one will also cause this exception to be raised. The attributes `msg` and `opt` give the error message and related option; if there is no specific option to which the exception relates, `opt` is an empty string.

exception getopt.error

Alias for *GetoptError*; for backward compatibility.

An example using only Unix style options:

```
>>> import getopt
>>> args = '-a -b -cfoo -d bar a1 a2'.split()
>>> args
['-a', '-b', '-cfoo', '-d', 'bar', 'a1', 'a2']
>>> optlist, args = getopt.getopt(args, 'abc:d:')
>>> optlist
[('-a', ''), ('-b', ''), ('-c', 'foo'), ('-d', 'bar')]
>>> args
['a1', 'a2']
```

Using long option names is equally easy:

```
>>> s = '--condition=foo --testing --output-file abc.def -x a1 a2'
>>> args = s.split()
>>> args
['--condition=foo', '--testing', '--output-file', 'abc.def', '-x', 'a1', 'a2']
>>> optlist, args = getopt.getopt(args, 'x', [
...     'condition=', 'output-file=', 'testing'])
>>> optlist
[('--condition', 'foo'), ('--testing', ''), ('--output-file', 'abc.def'), ('-x', '')]
>>> args
['a1', 'a2']
```

In a script, typical usage is something like this:

```
import getopt, sys

def main():
    try:
        opts, args = getopt.getopt(sys.argv[1:], "ho:v", ["help", "output="])
    except getopt.GetoptError as err:
        # print help information and exit:
        print(err)  # will print something like "option -a not recognized"
        usage()
        sys.exit(2)
    output = None
    verbose = False
    for o, a in opts:
        if o == "-v":
            verbose = True
        elif o in ("-h", "--help"):
            usage()
            sys.exit()
        elif o in ("-o", "--output"):
```

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```
            output = a
        else:
            assert False, "unhandled option"
    # ...

if __name__ == "__main__":
    main()
```

Note that an equivalent command line interface could be produced with less code and more informative help and error messages by using the *argparse* module:

```
import argparse

if __name__ == '__main__':
    parser = argparse.ArgumentParser()
    parser.add_argument('-o', '--output')
    parser.add_argument('-v', dest='verbose', action='store_true')
    args = parser.parse_args()
    # ... do something with args.output ...
    # ... do something with args.verbose ..
```

See also:

Module *argparse* Alternative command line option and argument parsing library.

16.6 `logging` — Logging facility for Python

Source code: Lib/logging/__init__.py

Important

This page contains the API reference information. For tutorial information and discussion of more advanced topics, see

- Basic Tutorial
- Advanced Tutorial
- Logging Cookbook

This module defines functions and classes which implement a flexible event logging system for applications and libraries.

The key benefit of having the logging API provided by a standard library module is that all Python modules can participate in logging, so your application log can include your own messages integrated with messages from third-party modules.

The module provides a lot of functionality and flexibility. If you are unfamiliar with logging, the best way to get to grips with it is to see the tutorials (see the links on the right).

The basic classes defined by the module, together with their functions, are listed below.

- Loggers expose the interface that application code directly uses.
- Handlers send the log records (created by loggers) to the appropriate destination.

- Filters provide a finer grained facility for determining which log records to output.
- Formatters specify the layout of log records in the final output.

16.6.1 Logger Objects

Loggers have the following attributes and methods. Note that Loggers are never instantiated directly, but always through the module-level function `logging.getLogger(name)`. Multiple calls to *getLogger()* with the same name will always return a reference to the same Logger object.

The `name` is potentially a period-separated hierarchical value, like `foo.bar.baz` (though it could also be just plain `foo`, for example). Loggers that are further down in the hierarchical list are children of loggers higher up in the list. For example, given a logger with a name of `foo`, loggers with names of `foo.bar`, `foo.bar.baz`, and `foo.bam` are all descendants of `foo`. The logger name hierarchy is analogous to the Python package hierarchy, and identical to it if you organise your loggers on a per-module basis using the recommended construction `logging.getLogger(__name__)`. That's because in a module, `__name__` is the module's name in the Python package namespace.

class logging.**Logger**

propagate
If this attribute evaluates to true, events logged to this logger will be passed to the handlers of higher level (ancestor) loggers, in addition to any handlers attached to this logger. Messages are passed directly to the ancestor loggers' handlers - neither the level nor filters of the ancestor loggers in question are considered.

If this evaluates to false, logging messages are not passed to the handlers of ancestor loggers.

The constructor sets this attribute to `True`.

Note: If you attach a handler to a logger *and* one or more of its ancestors, it may emit the same record multiple times. In general, you should not need to attach a handler to more than one logger - if you just attach it to the appropriate logger which is highest in the logger hierarchy, then it will see all events logged by all descendant loggers, provided that their propagate setting is left set to `True`. A common scenario is to attach handlers only to the root logger, and to let propagation take care of the rest.

---

setLevel(*level*)
Sets the threshold for this logger to *level*. Logging messages which are less severe than *level* will be ignored; logging messages which have severity *level* or higher will be emitted by whichever handler or handlers service this logger, unless a handler's level has been set to a higher severity level than *level*.

When a logger is created, the level is set to `NOTSET` (which causes all messages to be processed when the logger is the root logger, or delegation to the parent when the logger is a non-root logger). Note that the root logger is created with level `WARNING`.

The term 'delegation to the parent' means that if a logger has a level of NOTSET, its chain of ancestor loggers is traversed until either an ancestor with a level other than NOTSET is found, or the root is reached.

If an ancestor is found with a level other than NOTSET, then that ancestor's level is treated as the effective level of the logger where the ancestor search began, and is used to determine how a logging event is handled.

If the root is reached, and it has a level of NOTSET, then all messages will be processed. Otherwise, the root's level will be used as the effective level.

See *Logging Levels* for a list of levels.

Changed in version 3.2: The *level* parameter now accepts a string representation of the level such as 'INFO' as an alternative to the integer constants such as `INFO`. Note, however, that levels are internally stored as integers, and methods such as e.g. *getEffectiveLevel()* and *isEnabledFor()* will return/expect to be passed integers.

`isEnabledFor`(*lvl*)
Indicates if a message of severity *lvl* would be processed by this logger. This method checks first the module-level level set by `logging.disable(lvl)` and then the logger's effective level as determined by *getEffectiveLevel()*.

`getEffectiveLevel`()
Indicates the effective level for this logger. If a value other than `NOTSET` has been set using *setLevel()*, it is returned. Otherwise, the hierarchy is traversed towards the root until a value other than `NOTSET` is found, and that value is returned. The value returned is an integer, typically one of `logging.DEBUG`, `logging.INFO` etc.

`getChild`(*suffix*)
Returns a logger which is a descendant to this logger, as determined by the suffix. Thus, `logging.getLogger('abc').getChild('def.ghi')` would return the same logger as would be returned by `logging.getLogger('abc.def.ghi')`. This is a convenience method, useful when the parent logger is named using e.g. `__name__` rather than a literal string.

New in version 3.2.

`debug`(*msg*, **args*, ***kwargs*)
Logs a message with level `DEBUG` on this logger. The *msg* is the message format string, and the *args* are the arguments which are merged into *msg* using the string formatting operator. (Note that this means that you can use keywords in the format string, together with a single dictionary argument.)

There are three keyword arguments in *kwargs* which are inspected: *exc_info*, *stack_info*, and *extra*.

If *exc_info* does not evaluate as false, it causes exception information to be added to the logging message. If an exception tuple (in the format returned by *sys.exc_info()*) or an exception instance is provided, it is used; otherwise, *sys.exc_info()* is called to get the exception information.

The second optional keyword argument is *stack_info*, which defaults to `False`. If true, stack information is added to the logging message, including the actual logging call. Note that this is not the same stack information as that displayed through specifying *exc_info*: The former is stack frames from the bottom of the stack up to the logging call in the current thread, whereas the latter is information about stack frames which have been unwound, following an exception, while searching for exception handlers.

You can specify *stack_info* independently of *exc_info*, e.g. to just show how you got to a certain point in your code, even when no exceptions were raised. The stack frames are printed following a header line which says:

```
Stack (most recent call last):
```

This mimics the `Traceback (most recent call last):` which is used when displaying exception frames.

The third keyword argument is *extra* which can be used to pass a dictionary which is used to populate the ___dict___ of the LogRecord created for the logging event with user-defined attributes. These custom attributes can then be used as you like. For example, they could be incorporated into logged messages. For example:

```
FORMAT = '%(asctime)-15s %(clientip)s %(user)-8s %(message)s'
logging.basicConfig(format=FORMAT)
d = {'clientip': '192.168.0.1', 'user': 'fbloggs'}
logger = logging.getLogger('tcpserver')
logger.warning('Protocol problem: %s', 'connection reset', extra=d)
```

would print something like

```
2006-02-08 22:20:02,165 192.168.0.1 fbloggs  Protocol problem: connection reset
```

The keys in the dictionary passed in *extra* should not clash with the keys used by the logging system. (See the *Formatter* documentation for more information on which keys are used by the logging system.)

If you choose to use these attributes in logged messages, you need to exercise some care. In the above example, for instance, the *Formatter* has been set up with a format string which expects 'clientip' and 'user' in the attribute dictionary of the LogRecord. If these are missing, the message will not be logged because a string formatting exception will occur. So in this case, you always need to pass the *extra* dictionary with these keys.

While this might be annoying, this feature is intended for use in specialized circumstances, such as multi-threaded servers where the same code executes in many contexts, and interesting conditions which arise are dependent on this context (such as remote client IP address and authenticated user name, in the above example). In such circumstances, it is likely that specialized *Formatter*s would be used with particular *Handler*s.

New in version 3.2: The *stack_info* parameter was added.

Changed in version 3.5: The *exc_info* parameter can now accept exception instances.

info(*msg*, **args*, ***kwargs*)
Logs a message with level `INFO` on this logger. The arguments are interpreted as for *debug()*.

warning(*msg*, **args*, ***kwargs*)
Logs a message with level `WARNING` on this logger. The arguments are interpreted as for *debug()*.

Note: There is an obsolete method `warn` which is functionally identical to `warning`. As `warn` is deprecated, please do not use it - use `warning` instead.

---

error(*msg*, **args*, ***kwargs*)
Logs a message with level `ERROR` on this logger. The arguments are interpreted as for *debug()*.

critical(*msg*, **args*, ***kwargs*)
Logs a message with level `CRITICAL` on this logger. The arguments are interpreted as for *debug()*.

log(*lvl*, *msg*, **args*, ***kwargs*)
Logs a message with integer level *lvl* on this logger. The other arguments are interpreted as for *debug()*.

exception(*msg*, **args*, ***kwargs*)
Logs a message with level `ERROR` on this logger. The arguments are interpreted as for *debug()*. Exception info is added to the logging message. This method should only be called from an exception handler.

addFilter(*filter*)
Adds the specified filter *filter* to this logger.

removeFilter(*filter*)
Removes the specified filter *filter* from this logger.

filter(*record*)
Applies this logger's filters to the record and returns a true value if the record is to be processed. The filters are consulted in turn, until one of them returns a false value. If none of them return a false value, the record will be processed (passed to handlers). If one returns a false value, no further processing of the record occurs.

addHandler(*hdlr*)
Adds the specified handler *hdlr* to this logger.

removeHandler(*hdlr*)
Removes the specified handler *hdlr* from this logger.

findCaller(*stack_info=False*)
Finds the caller's source filename and line number. Returns the filename, line number, function name and stack information as a 4-element tuple. The stack information is returned as `None` unless *stack_info* is `True`.

handle(*record*)
Handles a record by passing it to all handlers associated with this logger and its ancestors (until a false value of *propagate* is found). This method is used for unpickled records received from a socket, as well as those created locally. Logger-level filtering is applied using *filter()*.

makeRecord(*name*, *lvl*, *fn*, *lno*, *msg*, *args*, *exc_info*, *func=None*, *extra=None*, *sinfo=None*)
This is a factory method which can be overridden in subclasses to create specialized *LogRecord* instances.

hasHandlers()
Checks to see if this logger has any handlers configured. This is done by looking for handlers in this logger and its parents in the logger hierarchy. Returns `True` if a handler was found, else `False`. The method stops searching up the hierarchy whenever a logger with the 'propagate' attribute set to false is found - that will be the last logger which is checked for the existence of handlers.

New in version 3.2.

Changed in version 3.7: Loggers can now be pickled and unpickled.

16.6.2 Logging Levels

The numeric values of logging levels are given in the following table. These are primarily of interest if you want to define your own levels, and need them to have specific values relative to the predefined levels. If you define a level with the same numeric value, it overwrites the predefined value; the predefined name is lost.

Level	Numeric value
CRITICAL	50
ERROR	40
WARNING	30
INFO	20
DEBUG	10
NOTSET	0

16.6.3 Handler Objects

Handlers have the following attributes and methods. Note that *Handler* is never instantiated directly; this class acts as a base for more useful subclasses. However, the `__init__()` method in subclasses needs to call *Handler.__init__()*.

class logging.**Handler**

__init__(*level=NOTSET*)
Initializes the *Handler* instance by setting its level, setting the list of filters to the empty list and creating a lock (using *createLock()*) for serializing access to an I/O mechanism.

createLock()
Initializes a thread lock which can be used to serialize access to underlying I/O functionality which may not be threadsafe.

acquire()
Acquires the thread lock created with *createLock()*.

release()
Releases the thread lock acquired with *acquire()*.

setLevel(*level*)
Sets the threshold for this handler to *level*. Logging messages which are less severe than *level* will be ignored. When a handler is created, the level is set to `NOTSET` (which causes all messages to be processed).

See *Logging Levels* for a list of levels.

Changed in version 3.2: The *level* parameter now accepts a string representation of the level such as 'INFO' as an alternative to the integer constants such as `INFO`.

setFormatter(*fmt*)
Sets the *Formatter* for this handler to *fmt*.

addFilter(*filter*)
Adds the specified filter *filter* to this handler.

removeFilter(*filter*)
Removes the specified filter *filter* from this handler.

filter(*record*)
Applies this handler's filters to the record and returns a true value if the record is to be processed. The filters are consulted in turn, until one of them returns a false value. If none of them return a false value, the record will be emitted. If one returns a false value, the handler will not emit the record.

flush()
Ensure all logging output has been flushed. This version does nothing and is intended to be implemented by subclasses.

close()
Tidy up any resources used by the handler. This version does no output but removes the handler from an internal list of handlers which is closed when *shutdown()* is called. Subclasses should ensure that this gets called from overridden *close()* methods.

handle(*record*)
Conditionally emits the specified logging record, depending on filters which may have been added to the handler. Wraps the actual emission of the record with acquisition/release of the I/O thread lock.

handleError(*record*)
This method should be called from handlers when an exception is encountered during an *emit()* call. If the module-level attribute `raiseExceptions` is `False`, exceptions get silently ignored. This is what is mostly wanted for a logging system - most users will not care about errors in the logging system, they are more interested in application errors. You could, however, replace this with a custom handler if you wish. The specified record is the one which was being processed

when the exception occurred. (The default value of `raiseExceptions` is `True`, as that is more useful during development).

`format`(*record*)
Do formatting for a record - if a formatter is set, use it. Otherwise, use the default formatter for the module.

`emit`(*record*)
Do whatever it takes to actually log the specified logging record. This version is intended to be implemented by subclasses and so raises a *NotImplementedError*.

For a list of handlers included as standard, see *logging.handlers*.

16.6.4 Formatter Objects

Formatter objects have the following attributes and methods. They are responsible for converting a *LogRecord* to (usually) a string which can be interpreted by either a human or an external system. The base *Formatter* allows a formatting string to be specified. If none is supplied, the default value of `'%(message)s'` is used, which just includes the message in the logging call. To have additional items of information in the formatted output (such as a timestamp), keep reading.

A Formatter can be initialized with a format string which makes use of knowledge of the *LogRecord* attributes - such as the default value mentioned above making use of the fact that the user's message and arguments are pre-formatted into a *LogRecord*'s *message* attribute. This format string contains standard Python %-style mapping keys. See section *printf-style String Formatting* for more information on string formatting.

The useful mapping keys in a *LogRecord* are given in the section on *LogRecord attributes*.

`class logging.Formatter`(*fmt=None*, *datefmt=None*, *style='%'*)
Returns a new instance of the *Formatter* class. The instance is initialized with a format string for the message as a whole, as well as a format string for the date/time portion of a message. If no *fmt* is specified, `'%(message)s'` is used. If no *datefmt* is specified, a format is used which is described in the *formatTime()* documentation.

The *style* parameter can be one of '%', '{' or '$' and determines how the format string will be merged with its data: using one of %-formatting, *str.format()* or *string.Template*. See formatting-styles for more information on using {- and $-formatting for log messages.

Changed in version 3.2: The *style* parameter was added.

`format`(*record*)
The record's attribute dictionary is used as the operand to a string formatting operation. Returns the resulting string. Before formatting the dictionary, a couple of preparatory steps are carried out. The *message* attribute of the record is computed using *msg* % *args*. If the formatting string contains `'(asctime)'`, *formatTime()* is called to format the event time. If there is exception information, it is formatted using *formatException()* and appended to the message. Note that the formatted exception information is cached in attribute *exc_text*. This is useful because the exception information can be pickled and sent across the wire, but you should be careful if you have more than one *Formatter* subclass which customizes the formatting of exception information. In this case, you will have to clear the cached value after a formatter has done its formatting, so that the next formatter to handle the event doesn't use the cached value but recalculates it afresh.

If stack information is available, it's appended after the exception information, using *formatStack()* to transform it if necessary.

`formatTime`(*record*, *datefmt=None*)
This method should be called from *format()* by a formatter which wants to make use of a formatted time. This method can be overridden in formatters to provide for any specific requirement, but the basic behavior is as follows: if *datefmt* (a string) is specified, it is used with *time.strftime()* to format the creation time of the record. Otherwise, the format '%Y-%m-%d %H:%M:%S,uuu'

is used, where the uuu part is a millisecond value and the other letters are as per the *time.strftime()* documentation. An example time in this format is `2003-01-23 00:29:50,411`. The resulting string is returned.

This function uses a user-configurable function to convert the creation time to a tuple. By default, *time.localtime()* is used; to change this for a particular formatter instance, set the `converter` attribute to a function with the same signature as *time.localtime()* or *time.gmtime()*. To change it for all formatters, for example if you want all logging times to be shown in GMT, set the `converter` attribute in the `Formatter` class.

Changed in version 3.3: Previously, the default format was hard-coded as in this example: `2010-09-06 22:38:15,292` where the part before the comma is handled by a strptime format string (`'%Y-%m-%d %H:%M:%S'`), and the part after the comma is a millisecond value. Because strptime does not have a format placeholder for milliseconds, the millisecond value is appended using another format string, `'%s,%03d'` — and both of these format strings have been hardcoded into this method. With the change, these strings are defined as class-level attributes which can be overridden at the instance level when desired. The names of the attributes are `default_time_format` (for the strptime format string) and `default_msec_format` (for appending the millisecond value).

formatException(*exc_info*)
Formats the specified exception information (a standard exception tuple as returned by *sys.exc_info()*) as a string. This default implementation just uses *traceback.print_exception()*. The resulting string is returned.

formatStack(*stack_info*)
Formats the specified stack information (a string as returned by *traceback.print_stack()*, but with the last newline removed) as a string. This default implementation just returns the input value.

16.6.5 Filter Objects

`Filters` can be used by `Handlers` and `Loggers` for more sophisticated filtering than is provided by levels. The base filter class only allows events which are below a certain point in the logger hierarchy. For example, a filter initialized with 'A.B' will allow events logged by loggers 'A.B', 'A.B.C', 'A.B.C.D', 'A.B.D' etc. but not 'A.BB', 'B.A.B' etc. If initialized with the empty string, all events are passed.

class logging.Filter(*name=''*)
Returns an instance of the *Filter* class. If *name* is specified, it names a logger which, together with its children, will have its events allowed through the filter. If *name* is the empty string, allows every event.

filter(*record*)
Is the specified record to be logged? Returns zero for no, nonzero for yes. If deemed appropriate, the record may be modified in-place by this method.

Note that filters attached to handlers are consulted before an event is emitted by the handler, whereas filters attached to loggers are consulted whenever an event is logged (using *debug()*, *info()*, etc.), before sending an event to handlers. This means that events which have been generated by descendant loggers will not be filtered by a logger's filter setting, unless the filter has also been applied to those descendant loggers.

You don't actually need to subclass `Filter`: you can pass any instance which has a `filter` method with the same semantics.

Changed in version 3.2: You don't need to create specialized `Filter` classes, or use other classes with a `filter` method: you can use a function (or other callable) as a filter. The filtering logic will check to see if the filter object has a `filter` attribute: if it does, it's assumed to be a `Filter` and its *filter()* method is called. Otherwise, it's assumed to be a callable and called with the record as the single parameter. The returned value should conform to that returned by *filter()*.

Although filters are used primarily to filter records based on more sophisticated criteria than levels, they get to see every record which is processed by the handler or logger they're attached to: this can be useful if you want to do things like counting how many records were processed by a particular logger or handler, or adding, changing or removing attributes in the LogRecord being processed. Obviously changing the LogRecord needs to be done with some care, but it does allow the injection of contextual information into logs (see filters-contextual).

16.6.6 LogRecord Objects

LogRecord instances are created automatically by the *Logger* every time something is logged, and can be created manually via *makeLogRecord()* (for example, from a pickled event received over the wire).

class logging.**LogRecord**(*name*, *level*, *pathname*, *lineno*, *msg*, *args*, *exc_info*, *func=None*, *sinfo=None*)

Contains all the information pertinent to the event being logged.

The primary information is passed in `msg` and `args`, which are combined using `msg % args` to create the `message` field of the record.

Parameters

- **name** – The name of the logger used to log the event represented by this LogRecord. Note that this name will always have this value, even though it may be emitted by a handler attached to a different (ancestor) logger.
- **level** – The numeric level of the logging event (one of DEBUG, INFO etc.) Note that this is converted to *two* attributes of the LogRecord: `levelno` for the numeric value and `levelname` for the corresponding level name.
- **pathname** – The full pathname of the source file where the logging call was made.
- **lineno** – The line number in the source file where the logging call was made.
- **msg** – The event description message, possibly a format string with placeholders for variable data.
- **args** – Variable data to merge into the *msg* argument to obtain the event description.
- **exc_info** – An exception tuple with the current exception information, or `None` if no exception information is available.
- **func** – The name of the function or method from which the logging call was invoked.
- **sinfo** – A text string representing stack information from the base of the stack in the current thread, up to the logging call.

getMessage()

Returns the message for this *LogRecord* instance after merging any user-supplied arguments with the message. If the user-supplied message argument to the logging call is not a string, *str()* is called on it to convert it to a string. This allows use of user-defined classes as messages, whose `__str__` method can return the actual format string to be used.

Changed in version 3.2: The creation of a `LogRecord` has been made more configurable by providing a factory which is used to create the record. The factory can be set using *getLogRecordFactory()* and *setLogRecordFactory()* (see this for the factory's signature).

This functionality can be used to inject your own values into a LogRecord at creation time. You can use the following pattern:

```
old_factory = logging.getLogRecordFactory()

def record_factory(*args, **kwargs):
```

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```
    record = old_factory(*args, **kwargs)
    record.custom_attribute = 0xdecafbad
    return record

logging.setLogRecordFactory(record_factory)
```

With this pattern, multiple factories could be chained, and as long as they don't overwrite each other's attributes or unintentionally overwrite the standard attributes listed above, there should be no surprises.

16.6.7 LogRecord attributes

The LogRecord has a number of attributes, most of which are derived from the parameters to the constructor. (Note that the names do not always correspond exactly between the LogRecord constructor parameters and the LogRecord attributes.) These attributes can be used to merge data from the record into the format string. The following table lists (in alphabetical order) the attribute names, their meanings and the corresponding placeholder in a %-style format string.

If you are using {}-formatting (*str.format()*), you can use `{attrname}` as the placeholder in the format string. If you are using $-formatting (*string.Template*), use the form `${attrname}`. In both cases, of course, replace `attrname` with the actual attribute name you want to use.

In the case of {}-formatting, you can specify formatting flags by placing them after the attribute name, separated from it with a colon. For example: a placeholder of `{msecs:03d}` would format a millisecond value of `4` as `004`. Refer to the *str.format()* documentation for full details on the options available to you.

Attribute name	Format	Description
args	You shouldn't need to format this yourself.	The tuple of arguments merged into `msg` to produce `message`, or a dict whose values are used for the merge (when there is only one argument, and it is a dictionary).
asctime	`%(asctime)s`	Human-readable time when the *LogRecord* was created. By default this is of the form '2003-07-08 16:49:45,896' (the numbers after the comma are millisecond portion of the time).
created	`%(created)f`	Time when the *LogRecord* was created (as returned by *time.time()*).
exc_info	You shouldn't need to format this yourself.	Exception tuple (à la `sys.exc_info`) or, if no exception has occurred, `None`.
filename	`%(filename)s`	Filename portion of `pathname`.
funcName	`%(funcName)s`	Name of function containing the logging call.
levelname	`%(levelname)s`	Text logging level for the message (`'DEBUG'`, `'INFO'`, `'WARNING'`, `'ERROR'`, `'CRITICAL'`).
levelno	`%(levelno)s`	Numeric logging level for the message (`DEBUG`, `INFO`, `WARNING`, `ERROR`, `CRITICAL`).
lineno	`%(lineno)d`	Source line number where the logging call was issued (if available).
message	`%(message)s`	The logged message, computed as `msg % args`. This is set when *Formatter.format()* is invoked.
module	`%(module)s`	Module (name portion of `filename`).
msecs	`%(msecs)d`	Millisecond portion of the time when the *LogRecord* was created.
msg	You shouldn't need to format this yourself.	The format string passed in the original logging call. Merged with `args` to produce `message`, or an arbitrary object (see arbitrary-object-messages).
name	`%(name)s`	Name of the logger used to log the call.
pathname	`%(pathname)s`	Full pathname of the source file where the logging call was issued (if available).
process	`%(process)d`	Process ID (if available).
processName	`%(processName)s`	Process name (if available).
relativeCreated	`%(relativeCreated)d`	Time in milliseconds when the LogRecord was created, relative to the time the logging module was loaded.
stack_info	You shouldn't need to format this yourself.	Stack frame information (where available) from the bottom of the stack in the current thread, up to and including the stack frame of the logging call which resulted in the creation of this record.
thread	`%(thread)d`	Thread ID (if available).
threadName	`%(threadName)s`	Thread name (if available).

Changed in version 3.1: *processName* was added.

16.6.8 LoggerAdapter Objects

LoggerAdapter instances are used to conveniently pass contextual information into logging calls. For a usage example, see the section on adding contextual information to your logging output.

class logging.LoggerAdapter(*logger*, *extra*)

Returns an instance of *LoggerAdapter* initialized with an underlying *Logger* instance and a dict-like object.

process(*msg*, *kwargs*)

Modifies the message and/or keyword arguments passed to a logging call in order to insert contextual information. This implementation takes the object passed as *extra* to the constructor and adds it to *kwargs* using key 'extra'. The return value is a (*msg*, *kwargs*) tuple which has the (possibly modified) versions of the arguments passed in.

In addition to the above, *LoggerAdapter* supports the following methods of *Logger*: *debug()*, *info()*, *warning()*, *error()*, *exception()*, *critical()*, *log()*, *isEnabledFor()*, *getEffectiveLevel()*, *setLevel()* and *hasHandlers()*. These methods have the same signatures as their counterparts in *Logger*, so you can use the two types of instances interchangeably.

Changed in version 3.2: The *isEnabledFor()*, *getEffectiveLevel()*, *setLevel()* and *hasHandlers()* methods were added to *LoggerAdapter*. These methods delegate to the underlying logger.

16.6.9 Thread Safety

The logging module is intended to be thread-safe without any special work needing to be done by its clients. It achieves this though using threading locks; there is one lock to serialize access to the module's shared data, and each handler also creates a lock to serialize access to its underlying I/O.

If you are implementing asynchronous signal handlers using the *signal* module, you may not be able to use logging from within such handlers. This is because lock implementations in the *threading* module are not always re-entrant, and so cannot be invoked from such signal handlers.

16.6.10 Module-Level Functions

In addition to the classes described above, there are a number of module- level functions.

logging.getLogger(*name=None*)

Return a logger with the specified name or, if name is `None`, return a logger which is the root logger of the hierarchy. If specified, the name is typically a dot-separated hierarchical name like *'a'*, *'a.b'* or *'a.b.c.d'*. Choice of these names is entirely up to the developer who is using logging.

All calls to this function with a given name return the same logger instance. This means that logger instances never need to be passed between different parts of an application.

logging.getLoggerClass()

Return either the standard *Logger* class, or the last class passed to *setLoggerClass()*. This function may be called from within a new class definition, to ensure that installing a customized *Logger* class will not undo customizations already applied by other code. For example:

```
class MyLogger(logging.getLoggerClass()):
    # ... override behaviour here
```

logging.getLogRecordFactory()

Return a callable which is used to create a *LogRecord*.

New in version 3.2: This function has been provided, along with *setLogRecordFactory()*, to allow developers more control over how the *LogRecord* representing a logging event is constructed.

See *setLogRecordFactory()* for more information about the how the factory is called.

logging.**debug**(*msg*, **args*, ***kwargs*)

Logs a message with level DEBUG on the root logger. The *msg* is the message format string, and the *args* are the arguments which are merged into *msg* using the string formatting operator. (Note that this means that you can use keywords in the format string, together with a single dictionary argument.)

There are three keyword arguments in *kwargs* which are inspected: *exc_info* which, if it does not evaluate as false, causes exception information to be added to the logging message. If an exception tuple (in the format returned by *sys.exc_info()*) is provided, it is used; otherwise, *sys.exc_info()* is called to get the exception information.

The second optional keyword argument is *stack_info*, which defaults to False. If true, stack information is added to the logging message, including the actual logging call. Note that this is not the same stack information as that displayed through specifying *exc_info*: The former is stack frames from the bottom of the stack up to the logging call in the current thread, whereas the latter is information about stack frames which have been unwound, following an exception, while searching for exception handlers.

You can specify *stack_info* independently of *exc_info*, e.g. to just show how you got to a certain point in your code, even when no exceptions were raised. The stack frames are printed following a header line which says:

```
Stack (most recent call last):
```

This mimics the Traceback (most recent call last): which is used when displaying exception frames.

The third optional keyword argument is *extra* which can be used to pass a dictionary which is used to populate the ___dict___ of the LogRecord created for the logging event with user-defined attributes. These custom attributes can then be used as you like. For example, they could be incorporated into logged messages. For example:

```
FORMAT = '%(asctime)-15s %(clientip)s %(user)-8s %(message)s'
logging.basicConfig(format=FORMAT)
d = {'clientip': '192.168.0.1', 'user': 'fbloggs'}
logging.warning('Protocol problem: %s', 'connection reset', extra=d)
```

would print something like:

```
2006-02-08 22:20:02,165 192.168.0.1 fbloggs  Protocol problem: connection reset
```

The keys in the dictionary passed in *extra* should not clash with the keys used by the logging system. (See the *Formatter* documentation for more information on which keys are used by the logging system.)

If you choose to use these attributes in logged messages, you need to exercise some care. In the above example, for instance, the *Formatter* has been set up with a format string which expects 'clientip' and 'user' in the attribute dictionary of the LogRecord. If these are missing, the message will not be logged because a string formatting exception will occur. So in this case, you always need to pass the *extra* dictionary with these keys.

While this might be annoying, this feature is intended for use in specialized circumstances, such as multi-threaded servers where the same code executes in many contexts, and interesting conditions which arise are dependent on this context (such as remote client IP address and authenticated user name, in the above example). In such circumstances, it is likely that specialized *Formatter*s would be used with particular *Handler*s.

New in version 3.2: The *stack_info* parameter was added.

logging.**info**(*msg*, **args*, ***kwargs*)

Logs a message with level INFO on the root logger. The arguments are interpreted as for *debug()*.

logging.**warning**(*msg*, **args*, ***kwargs*)
Logs a message with level WARNING on the root logger. The arguments are interpreted as for *debug()*.

Note: There is an obsolete function **warn** which is functionally identical to **warning**. As **warn** is deprecated, please do not use it - use **warning** instead.

---

logging.**error**(*msg*, **args*, ***kwargs*)
Logs a message with level ERROR on the root logger. The arguments are interpreted as for *debug()*.

logging.**critical**(*msg*, **args*, ***kwargs*)
Logs a message with level CRITICAL on the root logger. The arguments are interpreted as for *debug()*.

logging.**exception**(*msg*, **args*, ***kwargs*)
Logs a message with level ERROR on the root logger. The arguments are interpreted as for *debug()*. Exception info is added to the logging message. This function should only be called from an exception handler.

logging.**log**(*level*, *msg*, **args*, ***kwargs*)
Logs a message with level *level* on the root logger. The other arguments are interpreted as for *debug()*.

Note: The above module-level convenience functions, which delegate to the root logger, call *basicConfig()* to ensure that at least one handler is available. Because of this, they should *not* be used in threads, in versions of Python earlier than 2.7.1 and 3.2, unless at least one handler has been added to the root logger *before* the threads are started. In earlier versions of Python, due to a thread safety shortcoming in *basicConfig()*, this can (under rare circumstances) lead to handlers being added multiple times to the root logger, which can in turn lead to multiple messages for the same event.

---

logging.**disable**(*lvl=CRITICAL*)
Provides an overriding level *lvl* for all loggers which takes precedence over the logger's own level. When the need arises to temporarily throttle logging output down across the whole application, this function can be useful. Its effect is to disable all logging calls of severity *lvl* and below, so that if you call it with a value of INFO, then all INFO and DEBUG events would be discarded, whereas those of severity WARNING and above would be processed according to the logger's effective level. If `logging.disable(logging.NOTSET)` is called, it effectively removes this overriding level, so that logging output again depends on the effective levels of individual loggers.

Note that if you have defined any custom logging level higher than CRITICAL (this is not recommended), you won't be able to rely on the default value for the *lvl* parameter, but will have to explicitly supply a suitable value.

Changed in version 3.7: The *lvl* parameter was defaulted to level CRITICAL. See Issue #28524 for more information about this change.

logging.**addLevelName**(*lvl*, *levelName*)
Associates level *lvl* with text *levelName* in an internal dictionary, which is used to map numeric levels to a textual representation, for example when a *Formatter* formats a message. This function can also be used to define your own levels. The only constraints are that all levels used must be registered using this function, levels should be positive integers and they should increase in increasing order of severity.

Note: If you are thinking of defining your own levels, please see the section on custom-levels.

---

logging.**getLevelName**(*lvl*)
Returns the textual representation of logging level *lvl*. If the level is one of the predefined levels CRITICAL, ERROR, WARNING, INFO or DEBUG then you get the corresponding string. If you have associated

levels with names using *addLevelName()* then the name you have associated with *lvl* is returned. If a numeric value corresponding to one of the defined levels is passed in, the corresponding string representation is returned. Otherwise, the string 'Level %s' % lvl is returned.

Note: Levels are internally integers (as they need to be compared in the logging logic). This function is used to convert between an integer level and the level name displayed in the formatted log output by means of the `%(levelname)s` format specifier (see *LogRecord attributes*).

Changed in version 3.4: In Python versions earlier than 3.4, this function could also be passed a text level, and would return the corresponding numeric value of the level. This undocumented behaviour was considered a mistake, and was removed in Python 3.4, but reinstated in 3.4.2 due to retain backward compatibility.

`logging.makeLogRecord(`*attrdict*`)`

Creates and returns a new *LogRecord* instance whose attributes are defined by *attrdict*. This function is useful for taking a pickled *LogRecord* attribute dictionary, sent over a socket, and reconstituting it as a *LogRecord* instance at the receiving end.

`logging.basicConfig(`***kwargs*`)`

Does basic configuration for the logging system by creating a *StreamHandler* with a default *Formatter* and adding it to the root logger. The functions *debug()*, *info()*, *warning()*, *error()* and *critical()* will call *basicConfig()* automatically if no handlers are defined for the root logger.

This function does nothing if the root logger already has handlers configured for it.

Note: This function should be called from the main thread before other threads are started. In versions of Python prior to 2.7.1 and 3.2, if this function is called from multiple threads, it is possible (in rare circumstances) that a handler will be added to the root logger more than once, leading to unexpected results such as messages being duplicated in the log.

The following keyword arguments are supported.

Format	Description
filename	Specifies that a FileHandler be created, using the specified filename, rather than a StreamHandler.
filemode	If *filename* is specified, open the file in this *mode*. Defaults to `'a'`.
format	Use the specified format string for the handler.
datefmt	Use the specified date/time format, as accepted by *time.strftime()*.
style	If *format* is specified, use this style for the format string. One of `'%'`, `'{'` or `'$'` for *printf-style*, *str.format()* or *string.Template* respectively. Defaults to `'%'`.
level	Set the root logger level to the specified *level*.
stream	Use the specified stream to initialize the StreamHandler. Note that this argument is incompatible with *filename* - if both are present, a `ValueError` is raised.
handlers	If specified, this should be an iterable of already created handlers to add to the root logger. Any handlers which don't already have a formatter set will be assigned the default formatter created in this function. Note that this argument is incompatible with *filename* or *stream* - if both are present, a `ValueError` is raised.

Changed in version 3.2: The `style` argument was added.

Changed in version 3.3: The `handlers` argument was added. Additional checks were added to catch situations where incompatible arguments are specified (e.g. `handlers` together with `stream` or `filename`, or `stream` together with `filename`).

logging.**shutdown**()
Informs the logging system to perform an orderly shutdown by flushing and closing all handlers. This should be called at application exit and no further use of the logging system should be made after this call.

logging.**setLoggerClass**(*klass*)
Tells the logging system to use the class *klass* when instantiating a logger. The class should define `__init__()` such that only a name argument is required, and the `__init__()` should call `Logger.__init__()`. This function is typically called before any loggers are instantiated by applications which need to use custom logger behavior.

logging.**setLogRecordFactory**(*factory*)
Set a callable which is used to create a *LogRecord*.

Parameters `factory` – The factory callable to be used to instantiate a log record.

New in version 3.2: This function has been provided, along with *getLogRecordFactory()*, to allow developers more control over how the *LogRecord* representing a logging event is constructed.

The factory has the following signature:

```
factory(name, level, fn, lno, msg, args, exc_info, func=None, sinfo=None, **kwargs)
```

name The logger name.

level The logging level (numeric).

fn The full pathname of the file where the logging call was made.

lno The line number in the file where the logging call was made.

msg The logging message.

args The arguments for the logging message.

exc_info An exception tuple, or `None`.

func The name of the function or method which invoked the logging call.

sinfo A stack traceback such as is provided by *traceback.print_stack()*, showing the call hierarchy.

kwargs Additional keyword arguments.

16.6.11 Module-Level Attributes

logging.**lastResort**
A "handler of last resort" is available through this attribute. This is a *StreamHandler* writing to `sys.stderr` with a level of `WARNING`, and is used to handle logging events in the absence of any logging configuration. The end result is to just print the message to `sys.stderr`. This replaces the earlier error message saying that "no handlers could be found for logger XYZ". If you need the earlier behaviour for some reason, `lastResort` can be set to `None`.

New in version 3.2.

16.6.12 Integration with the warnings module

The *captureWarnings()* function can be used to integrate *logging* with the *warnings* module.

logging.**captureWarnings**(*capture*)
This function is used to turn the capture of warnings by logging on and off.

If *capture* is `True`, warnings issued by the *warnings* module will be redirected to the logging system. Specifically, a warning will be formatted using *warnings.formatwarning()* and the resulting string logged to a logger named `'py.warnings'` with a severity of `WARNING`.

If *capture* is `False`, the redirection of warnings to the logging system will stop, and warnings will be redirected to their original destinations (i.e. those in effect before `captureWarnings(True)` was called).

See also:

Module *logging.config* Configuration API for the logging module.

Module *logging.handlers* Useful handlers included with the logging module.

PEP 282 - A Logging System The proposal which described this feature for inclusion in the Python standard library.

Original Python logging package This is the original source for the *logging* package. The version of the package available from this site is suitable for use with Python 1.5.2, 2.1.x and 2.2.x, which do not include the *logging* package in the standard library.

16.7 `logging.config` — Logging configuration

Source code: Lib/logging/config.py

Important

This page contains only reference information. For tutorials, please see

- Basic Tutorial
- Advanced Tutorial
- Logging Cookbook

This section describes the API for configuring the logging module.

16.7.1 Configuration functions

The following functions configure the logging module. They are located in the *logging.config* module. Their use is optional — you can configure the logging module using these functions or by making calls to the main API (defined in *logging* itself) and defining handlers which are declared either in *logging* or *logging.handlers*.

`logging.config.dictConfig(`*config*`)`

Takes the logging configuration from a dictionary. The contents of this dictionary are described in *Configuration dictionary schema* below.

If an error is encountered during configuration, this function will raise a *ValueError*, *TypeError*, *AttributeError* or *ImportError* with a suitably descriptive message. The following is a (possibly incomplete) list of conditions which will raise an error:

- A `level` which is not a string or which is a string not corresponding to an actual logging level.
- A `propagate` value which is not a boolean.

- An id which does not have a corresponding destination.
- A non-existent handler id found during an incremental call.
- An invalid logger name.
- Inability to resolve to an internal or external object.

Parsing is performed by the `DictConfigurator` class, whose constructor is passed the dictionary used for configuration, and has a `configure()` method. The *logging.config* module has a callable attribute `dictConfigClass` which is initially set to `DictConfigurator`. You can replace the value of `dictConfigClass` with a suitable implementation of your own.

dictConfig() calls `dictConfigClass` passing the specified dictionary, and then calls the `configure()` method on the returned object to put the configuration into effect:

```
def dictConfig(config):
    dictConfigClass(config).configure()
```

For example, a subclass of `DictConfigurator` could call `DictConfigurator.__init__()` in its own `__init__()`, then set up custom prefixes which would be usable in the subsequent `configure()` call. `dictConfigClass` would be bound to this new subclass, and then *dictConfig()* could be called exactly as in the default, uncustomized state.

New in version 3.2.

`logging.config.fileConfig`(*fname*, *defaults=None*, *disable_existing_loggers=True*)

Reads the logging configuration from a *configparser*-format file. The format of the file should be as described in *Configuration file format*. This function can be called several times from an application, allowing an end user to select from various pre-canned configurations (if the developer provides a mechanism to present the choices and load the chosen configuration).

Parameters

- **fname** – A filename, or a file-like object, or an instance derived from *RawConfigParser*. If a `RawConfigParser`-derived instance is passed, it is used as is. Otherwise, a `Configparser` is instantiated, and the configuration read by it from the object passed in `fname`. If that has a *readline()* method, it is assumed to be a file-like object and read using *read_file()*; otherwise, it is assumed to be a filename and passed to *read()*.
- **defaults** – Defaults to be passed to the ConfigParser can be specified in this argument.
- **disable_existing_loggers** – If specified as `False`, loggers which exist when this call is made are left enabled. The default is `True` because this enables old behaviour in a backward-compatible way. This behaviour is to disable any existing loggers unless they or their ancestors are explicitly named in the logging configuration.

Changed in version 3.4: An instance of a subclass of *RawConfigParser* is now accepted as a value for `fname`. This facilitates:

- Use of a configuration file where logging configuration is just part of the overall application configuration.
- Use of a configuration read from a file, and then modified by the using application (e.g. based on command-line parameters or other aspects of the runtime environment) before being passed to `fileConfig`.

`logging.config.listen`(*port=DEFAULT_LOGGING_CONFIG_PORT*, *verify=None*)

Starts up a socket server on the specified port, and listens for new configurations. If no port is specified, the module's default `DEFAULT_LOGGING_CONFIG_PORT` is used. Logging configurations will be sent as a file suitable for processing by *dictConfig()* or *fileConfig()*. Returns a *Thread* instance on which

you can call *start()* to start the server, and which you can *join()* when appropriate. To stop the server, call *stopListening()*.

The `verify` argument, if specified, should be a callable which should verify whether bytes received across the socket are valid and should be processed. This could be done by encrypting and/or signing what is sent across the socket, such that the `verify` callable can perform signature verification and/or decryption. The `verify` callable is called with a single argument - the bytes received across the socket - and should return the bytes to be processed, or `None` to indicate that the bytes should be discarded. The returned bytes could be the same as the passed in bytes (e.g. when only verification is done), or they could be completely different (perhaps if decryption were performed).

To send a configuration to the socket, read in the configuration file and send it to the socket as a sequence of bytes preceded by a four-byte length string packed in binary using `struct.pack('>L', n)`.

Note: Because portions of the configuration are passed through *eval()*, use of this function may open its users to a security risk. While the function only binds to a socket on `localhost`, and so does not accept connections from remote machines, there are scenarios where untrusted code could be run under the account of the process which calls *listen()*. Specifically, if the process calling *listen()* runs on a multi-user machine where users cannot trust each other, then a malicious user could arrange to run essentially arbitrary code in a victim user's process, simply by connecting to the victim's *listen()* socket and sending a configuration which runs whatever code the attacker wants to have executed in the victim's process. This is especially easy to do if the default port is used, but not hard even if a different port is used). To avoid the risk of this happening, use the `verify` argument to *listen()* to prevent unrecognised configurations from being applied.

Changed in version 3.4: The `verify` argument was added.

Note: If you want to send configurations to the listener which don't disable existing loggers, you will need to use a JSON format for the configuration, which will use *dictConfig()* for configuration. This method allows you to specify `disable_existing_loggers` as `False` in the configuration you send.

`logging.config.stopListening()`
Stops the listening server which was created with a call to *listen()*. This is typically called before calling `join()` on the return value from *listen()*.

16.7.2 Configuration dictionary schema

Describing a logging configuration requires listing the various objects to create and the connections between them; for example, you may create a handler named 'console' and then say that the logger named 'startup' will send its messages to the 'console' handler. These objects aren't limited to those provided by the *logging* module because you might write your own formatter or handler class. The parameters to these classes may also need to include external objects such as `sys.stderr`. The syntax for describing these objects and connections is defined in *Object connections* below.

Dictionary Schema Details

The dictionary passed to *dictConfig()* must contain the following keys:

- *version* - to be set to an integer value representing the schema version. The only valid value at present is 1, but having this key allows the schema to evolve while still preserving backwards compatibility.

All other keys are optional, but if present they will be interpreted as described below. In all cases below where a 'configuring dict' is mentioned, it will be checked for the special `'()'` key to see if a custom instantiation is required. If so, the mechanism described in *User-defined objects* below is used to create an instance; otherwise, the context is used to determine what to instantiate.

- *formatters* - the corresponding value will be a dict in which each key is a formatter id and each value is a dict describing how to configure the corresponding *Formatter* instance.

  The configuring dict is searched for keys `format` and `datefmt` (with defaults of `None`) and these are used to construct a *Formatter* instance.

- *filters* - the corresponding value will be a dict in which each key is a filter id and each value is a dict describing how to configure the corresponding Filter instance.

  The configuring dict is searched for the key `name` (defaulting to the empty string) and this is used to construct a *logging.Filter* instance.

- *handlers* - the corresponding value will be a dict in which each key is a handler id and each value is a dict describing how to configure the corresponding Handler instance.

  The configuring dict is searched for the following keys:

  – `class` (mandatory). This is the fully qualified name of the handler class.

  – `level` (optional). The level of the handler.

  – `formatter` (optional). The id of the formatter for this handler.

  – `filters` (optional). A list of ids of the filters for this handler.

  All *other* keys are passed through as keyword arguments to the handler's constructor. For example, given the snippet:

  ```
  handlers:
    console:
      class : logging.StreamHandler
      formatter: brief
      level   : INFO
      filters: [allow_foo]
      stream  : ext://sys.stdout
    file:
      class : logging.handlers.RotatingFileHandler
      formatter: precise
      filename: logconfig.log
      maxBytes: 1024
      backupCount: 3
  ```

  the handler with id `console` is instantiated as a *logging.StreamHandler*, using `sys.stdout` as the underlying stream. The handler with id `file` is instantiated as a *logging.handlers.RotatingFileHandler* with the keyword arguments `filename='logconfig.log', maxBytes=1024, backupCount=3`.

- *loggers* - the corresponding value will be a dict in which each key is a logger name and each value is a dict describing how to configure the corresponding Logger instance.

  The configuring dict is searched for the following keys:

  – `level` (optional). The level of the logger.

  – `propagate` (optional). The propagation setting of the logger.

  – `filters` (optional). A list of ids of the filters for this logger.

  – `handlers` (optional). A list of ids of the handlers for this logger.

The specified loggers will be configured according to the level, propagation, filters and handlers specified.

- *root* - this will be the configuration for the root logger. Processing of the configuration will be as for any logger, except that the `propagate` setting will not be applicable.
- *incremental* - whether the configuration is to be interpreted as incremental to the existing configuration. This value defaults to `False`, which means that the specified configuration replaces the existing configuration with the same semantics as used by the existing *`fileConfig()`* API.

  If the specified value is `True`, the configuration is processed as described in the section on *Incremental Configuration*.
- *disable_existing_loggers* - whether any existing loggers are to be disabled. This setting mirrors the parameter of the same name in *`fileConfig()`*. If absent, this parameter defaults to `True`. This value is ignored if *incremental* is `True`.

Incremental Configuration

It is difficult to provide complete flexibility for incremental configuration. For example, because objects such as filters and formatters are anonymous, once a configuration is set up, it is not possible to refer to such anonymous objects when augmenting a configuration.

Furthermore, there is not a compelling case for arbitrarily altering the object graph of loggers, handlers, filters, formatters at run-time, once a configuration is set up; the verbosity of loggers and handlers can be controlled just by setting levels (and, in the case of loggers, propagation flags). Changing the object graph arbitrarily in a safe way is problematic in a multi-threaded environment; while not impossible, the benefits are not worth the complexity it adds to the implementation.

Thus, when the `incremental` key of a configuration dict is present and is `True`, the system will completely ignore any `formatters` and `filters` entries, and process only the `level` settings in the `handlers` entries, and the `level` and `propagate` settings in the `loggers` and `root` entries.

Using a value in the configuration dict lets configurations to be sent over the wire as pickled dicts to a socket listener. Thus, the logging verbosity of a long-running application can be altered over time with no need to stop and restart the application.

Object connections

The schema describes a set of logging objects - loggers, handlers, formatters, filters - which are connected to each other in an object graph. Thus, the schema needs to represent connections between the objects. For example, say that, once configured, a particular logger has attached to it a particular handler. For the purposes of this discussion, we can say that the logger represents the source, and the handler the destination, of a connection between the two. Of course in the configured objects this is represented by the logger holding a reference to the handler. In the configuration dict, this is done by giving each destination object an id which identifies it unambiguously, and then using the id in the source object's configuration to indicate that a connection exists between the source and the destination object with that id.

So, for example, consider the following YAML snippet:

```
formatters:
  brief:
    # configuration for formatter with id 'brief' goes here
  precise:
    # configuration for formatter with id 'precise' goes here
handlers:
  h1: #This is an id
```

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```
   # configuration of handler with id 'h1' goes here
   formatter: brief
  h2: #This is another id
   # configuration of handler with id 'h2' goes here
   formatter: precise
loggers:
  foo.bar.baz:
    # other configuration for logger 'foo.bar.baz'
    handlers: [h1, h2]
```

(Note: YAML used here because it's a little more readable than the equivalent Python source form for the dictionary.)

The ids for loggers are the logger names which would be used programmatically to obtain a reference to those loggers, e.g. `foo.bar.baz`. The ids for Formatters and Filters can be any string value (such as `brief`, `precise` above) and they are transient, in that they are only meaningful for processing the configuration dictionary and used to determine connections between objects, and are not persisted anywhere when the configuration call is complete.

The above snippet indicates that logger named `foo.bar.baz` should have two handlers attached to it, which are described by the handler ids `h1` and `h2`. The formatter for `h1` is that described by id `brief`, and the formatter for `h2` is that described by id `precise`.

User-defined objects

The schema supports user-defined objects for handlers, filters and formatters. (Loggers do not need to have different types for different instances, so there is no support in this configuration schema for user-defined logger classes.)

Objects to be configured are described by dictionaries which detail their configuration. In some places, the logging system will be able to infer from the context how an object is to be instantiated, but when a user-defined object is to be instantiated, the system will not know how to do this. In order to provide complete flexibility for user-defined object instantiation, the user needs to provide a 'factory' - a callable which is called with a configuration dictionary and which returns the instantiated object. This is signalled by an absolute import path to the factory being made available under the special key `'()'`. Here's a concrete example:

```
formatters:
  brief:
    format: '%(message)s'
  default:
    format: '%(asctime)s %(levelname)-8s %(name)-15s %(message)s'
    datefmt: '%Y-%m-%d %H:%M:%S'
  custom:
      (): my.package.customFormatterFactory
      bar: baz
      spam: 99.9
      answer: 42
```

The above YAML snippet defines three formatters. The first, with id `brief`, is a standard *logging.Formatter* instance with the specified format string. The second, with id `default`, has a longer format and also defines the time format explicitly, and will result in a *logging.Formatter* initialized with those two format strings. Shown in Python source form, the `brief` and `default` formatters have configuration sub-dictionaries:

```
{
  'format' : '%(message)s'
}
```

and:

```
{
  'format' : '%(asctime)s %(levelname)-8s %(name)-15s %(message)s',
  'datefmt' : '%Y-%m-%d %H:%M:%S'
}
```

respectively, and as these dictionaries do not contain the special key `'()'`, the instantiation is inferred from the context: as a result, standard *logging.Formatter* instances are created. The configuration sub-dictionary for the third formatter, with id `custom`, is:

```
{
  '()' : 'my.package.customFormatterFactory',
  'bar' : 'baz',
  'spam' : 99.9,
  'answer' : 42
}
```

and this contains the special key `'()'`, which means that user-defined instantiation is wanted. In this case, the specified factory callable will be used. If it is an actual callable it will be used directly - otherwise, if you specify a string (as in the example) the actual callable will be located using normal import mechanisms. The callable will be called with the **remaining** items in the configuration sub-dictionary as keyword arguments. In the above example, the formatter with id `custom` will be assumed to be returned by the call:

```
my.package.customFormatterFactory(bar='baz', spam=99.9, answer=42)
```

The key `'()'` has been used as the special key because it is not a valid keyword parameter name, and so will not clash with the names of the keyword arguments used in the call. The `'()'` also serves as a mnemonic that the corresponding value is a callable.

Access to external objects

There are times where a configuration needs to refer to objects external to the configuration, for example `sys.stderr`. If the configuration dict is constructed using Python code, this is straightforward, but a problem arises when the configuration is provided via a text file (e.g. JSON, YAML). In a text file, there is no standard way to distinguish `sys.stderr` from the literal string `'sys.stderr'`. To facilitate this distinction, the configuration system looks for certain special prefixes in string values and treat them specially. For example, if the literal string `'ext://sys.stderr'` is provided as a value in the configuration, then the `ext://` will be stripped off and the remainder of the value processed using normal import mechanisms.

The handling of such prefixes is done in a way analogous to protocol handling: there is a generic mechanism to look for prefixes which match the regular expression `^(?P<prefix>[a-z]+)://(?P<suffix>.*)$` whereby, if the `prefix` is recognised, the `suffix` is processed in a prefix-dependent manner and the result of the processing replaces the string value. If the prefix is not recognised, then the string value will be left as-is.

Access to internal objects

As well as external objects, there is sometimes also a need to refer to objects in the configuration. This will be done implicitly by the configuration system for things that it knows about. For example, the string value `'DEBUG'` for a `level` in a logger or handler will automatically be converted to the value `logging.DEBUG`,

and the handlers, filters and formatter entries will take an object id and resolve to the appropriate destination object.

However, a more generic mechanism is needed for user-defined objects which are not known to the *logging* module. For example, consider *logging.handlers.MemoryHandler*, which takes a target argument which is another handler to delegate to. Since the system already knows about this class, then in the configuration, the given target just needs to be the object id of the relevant target handler, and the system will resolve to the handler from the id. If, however, a user defines a my.package.MyHandler which has an alternate handler, the configuration system would not know that the alternate referred to a handler. To cater for this, a generic resolution system allows the user to specify:

```
handlers:
  file:
    # configuration of file handler goes here

  custom:
    (): my.package.MyHandler
    alternate: cfg://handlers.file
```

The literal string 'cfg://handlers.file' will be resolved in an analogous way to strings with the ext:// prefix, but looking in the configuration itself rather than the import namespace. The mechanism allows access by dot or by index, in a similar way to that provided by str.format. Thus, given the following snippet:

```
handlers:
  email:
    class: logging.handlers.SMTPHandler
    mailhost: localhost
    fromaddr: my_app@domain.tld
    toaddrs:
      - support_team@domain.tld
      - dev_team@domain.tld
    subject: Houston, we have a problem.
```

in the configuration, the string 'cfg://handlers' would resolve to the dict with key handlers, the string 'cfg://handlers.email would resolve to the dict with key email in the handlers dict, and so on. The string 'cfg://handlers.email.toaddrs[1] would resolve to 'dev_team.domain.tld' and the string 'cfg://handlers.email.toaddrs[0]' would resolve to the value 'support_team@domain.tld'. The subject value could be accessed using either 'cfg://handlers.email.subject' or, equivalently, 'cfg://handlers.email[subject]'. The latter form only needs to be used if the key contains spaces or non-alphanumeric characters. If an index value consists only of decimal digits, access will be attempted using the corresponding integer value, falling back to the string value if needed.

Given a string cfg://handlers.myhandler.mykey.123, this will resolve to config_dict['handlers']['myhandler']['mykey']['123']. If the string is specified as cfg://handlers.myhandler.mykey[123], the system will attempt to retrieve the value from config_dict['handlers']['myhandler']['mykey'][123], and fall back to config_dict['handlers']['myhandler']['mykey']['123'] if that fails.

Import resolution and custom importers

Import resolution, by default, uses the builtin *__import__()* function to do its importing. You may want to replace this with your own importing mechanism: if so, you can replace the importer attribute of the DictConfigurator or its superclass, the BaseConfigurator class. However, you need to be careful because of the way functions are accessed from classes via descriptors. If you are using a Python callable to do your imports, and you want to define it at class level rather than instance level, you need to wrap it with *staticmethod()*. For example:

```
from importlib import import_module
from logging.config import BaseConfigurator

BaseConfigurator.importer = staticmethod(import_module)
```

You don't need to wrap with *staticmethod()* if you're setting the import callable on a configurator *instance*.

16.7.3 Configuration file format

The configuration file format understood by *fileConfig()* is based on *configparser* functionality. The file must contain sections called `[loggers]`, `[handlers]` and `[formatters]` which identify by name the entities of each type which are defined in the file. For each such entity, there is a separate section which identifies how that entity is configured. Thus, for a logger named `log01` in the `[loggers]` section, the relevant configuration details are held in a section `[logger_log01]`. Similarly, a handler called `hand01` in the `[handlers]` section will have its configuration held in a section called `[handler_hand01]`, while a formatter called `form01` in the `[formatters]` section will have its configuration specified in a section called `[formatter_form01]`. The root logger configuration must be specified in a section called `[logger_root]`.

Note: The *fileConfig()* API is older than the *dictConfig()* API and does not provide functionality to cover certain aspects of logging. For example, you cannot configure *Filter* objects, which provide for filtering of messages beyond simple integer levels, using *fileConfig()*. If you need to have instances of *Filter* in your logging configuration, you will need to use *dictConfig()*. Note that future enhancements to configuration functionality will be added to *dictConfig()*, so it's worth considering transitioning to this newer API when it's convenient to do so.

Examples of these sections in the file are given below.

```
[loggers]
keys=root,log02,log03,log04,log05,log06,log07

[handlers]
keys=hand01,hand02,hand03,hand04,hand05,hand06,hand07,hand08,hand09

[formatters]
keys=form01,form02,form03,form04,form05,form06,form07,form08,form09
```

The root logger must specify a level and a list of handlers. An example of a root logger section is given below.

```
[logger_root]
level=NOTSET
handlers=hand01
```

The `level` entry can be one of `DEBUG, INFO, WARNING, ERROR, CRITICAL` or `NOTSET`. For the root logger only, `NOTSET` means that all messages will be logged. Level values are *eval()*uated in the context of the `logging` package's namespace.

The `handlers` entry is a comma-separated list of handler names, which must appear in the `[handlers]` section. These names must appear in the `[handlers]` section and have corresponding sections in the configuration file.

For loggers other than the root logger, some additional information is required. This is illustrated by the following example.

```
[logger_parser]
level=DEBUG
handlers=hand01
propagate=1
qualname=compiler.parser
```

The `level` and `handlers` entries are interpreted as for the root logger, except that if a non-root logger's level is specified as `NOTSET`, the system consults loggers higher up the hierarchy to determine the effective level of the logger. The `propagate` entry is set to 1 to indicate that messages must propagate to handlers higher up the logger hierarchy from this logger, or 0 to indicate that messages are **not** propagated to handlers up the hierarchy. The `qualname` entry is the hierarchical channel name of the logger, that is to say the name used by the application to get the logger.

Sections which specify handler configuration are exemplified by the following.

```
[handler_hand01]
class=StreamHandler
level=NOTSET
formatter=form01
args=(sys.stdout,)
```

The `class` entry indicates the handler's class (as determined by *eval()* in the `logging` package's namespace). The `level` is interpreted as for loggers, and `NOTSET` is taken to mean 'log everything'.

The `formatter` entry indicates the key name of the formatter for this handler. If blank, a default formatter (`logging._defaultFormatter`) is used. If a name is specified, it must appear in the `[formatters]` section and have a corresponding section in the configuration file.

The `args` entry, when *eval()*uated in the context of the `logging` package's namespace, is the list of arguments to the constructor for the handler class. Refer to the constructors for the relevant handlers, or to the examples below, to see how typical entries are constructed. If not provided, it defaults to `()`.

The optional `kwargs` entry, when *eval()*uated in the context of the `logging` package's namespace, is the keyword argument dict to the constructor for the handler class. If not provided, it defaults to `{}`.

```
[handler_hand02]
class=FileHandler
level=DEBUG
formatter=form02
args=('python.log', 'w')

[handler_hand03]
class=handlers.SocketHandler
level=INFO
formatter=form03
args=('localhost', handlers.DEFAULT_TCP_LOGGING_PORT)

[handler_hand04]
class=handlers.DatagramHandler
level=WARN
formatter=form04
args=('localhost', handlers.DEFAULT_UDP_LOGGING_PORT)

[handler_hand05]
class=handlers.SysLogHandler
level=ERROR
formatter=form05
args=(('localhost', handlers.SYSLOG_UDP_PORT), handlers.SysLogHandler.LOG_USER)
```

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```
[handler_hand06]
class=handlers.NTEventLogHandler
level=CRITICAL
formatter=form06
args=('Python Application', '', 'Application')

[handler_hand07]
class=handlers.SMTPHandler
level=WARN
formatter=form07
args=('localhost', 'from@abc', ['user1@abc', 'user2@xyz'], 'Logger Subject')
kwargs={'timeout': 10.0}

[handler_hand08]
class=handlers.MemoryHandler
level=NOTSET
formatter=form08
target=
args=(10, ERROR)

[handler_hand09]
class=handlers.HTTPHandler
level=NOTSET
formatter=form09
args=('localhost:9022', '/log', 'GET')
kwargs={'secure': True}
```

Sections which specify formatter configuration are typified by the following.

```
[formatter_form01]
format=F1 %(asctime)s %(levelname)s %(message)s
datefmt=
class=logging.Formatter
```

The `format` entry is the overall format string, and the `datefmt` entry is the `strftime()`-compatible date/time format string. If empty, the package substitutes something which is almost equivalent to specifying the date format string `'%Y-%m-%d %H:%M:%S'`. This format also specifies milliseconds, which are appended to the result of using the above format string, with a comma separator. An example time in this format is `2003-01-23 00:29:50,411`.

The `class` entry is optional. It indicates the name of the formatter's class (as a dotted module and class name.) This option is useful for instantiating a *Formatter* subclass. Subclasses of *Formatter* can present exception tracebacks in an expanded or condensed format.

Note: Due to the use of *eval()* as described above, there are potential security risks which result from using the *listen()* to send and receive configurations via sockets. The risks are limited to where multiple users with no mutual trust run code on the same machine; see the *listen()* documentation for more information.

See also:

Module *logging* API reference for the logging module.

Module *logging.handlers* Useful handlers included with the logging module.

16.8 logging.handlers — Logging handlers

Source code: Lib/logging/handlers.py

Important

This page contains only reference information. For tutorials, please see

- Basic Tutorial
- Advanced Tutorial
- Logging Cookbook

The following useful handlers are provided in the package. Note that three of the handlers (*StreamHandler*, *FileHandler* and *NullHandler*) are actually defined in the *logging* module itself, but have been documented here along with the other handlers.

16.8.1 StreamHandler

The *StreamHandler* class, located in the core *logging* package, sends logging output to streams such as *sys.stdout*, *sys.stderr* or any file-like object (or, more precisely, any object which supports `write()` and `flush()` methods).

class logging.**StreamHandler**(*stream=None*)

Returns a new instance of the *StreamHandler* class. If *stream* is specified, the instance will use it for logging output; otherwise, *sys.stderr* will be used.

emit(*record*)

If a formatter is specified, it is used to format the record. The record is then written to the stream with a terminator. If exception information is present, it is formatted using *traceback.print_exception()* and appended to the stream.

flush()

Flushes the stream by calling its *flush()* method. Note that the `close()` method is inherited from *Handler* and so does no output, so an explicit *flush()* call may be needed at times.

setStream(*stream*)

Sets the instance's stream to the specified value, if it is different. The old stream is flushed before the new stream is set.

Parameters **stream** – The stream that the handler should use.

Returns the old stream, if the stream was changed, or *None* if it wasn't.

New in version 3.7.

Changed in version 3.2: The `StreamHandler` class now has a `terminator` attribute, default value `'\n'`, which is used as the terminator when writing a formatted record to a stream. If you don't want this newline termination, you can set the handler instance's `terminator` attribute to the empty string. In earlier versions, the terminator was hardcoded as `'\n'`.

16.8.2 FileHandler

The *FileHandler* class, located in the core *logging* package, sends logging output to a disk file. It inherits the output functionality from *StreamHandler*.

class logging.FileHandler(*filename*, *mode='a'*, *encoding=None*, *delay=False*)
Returns a new instance of the *FileHandler* class. The specified file is opened and used as the stream for logging. If *mode* is not specified, `'a'` is used. If *encoding* is not `None`, it is used to open the file with that encoding. If *delay* is true, then file opening is deferred until the first call to *emit()*. By default, the file grows indefinitely.

Changed in version 3.6: As well as string values, *Path* objects are also accepted for the *filename* argument.

close()
Closes the file.

emit(*record*)
Outputs the record to the file.

16.8.3 NullHandler

New in version 3.1.

The *NullHandler* class, located in the core *logging* package, does not do any formatting or output. It is essentially a 'no-op' handler for use by library developers.

class logging.NullHandler
Returns a new instance of the *NullHandler* class.

emit(*record*)
This method does nothing.

handle(*record*)
This method does nothing.

createLock()
This method returns `None` for the lock, since there is no underlying I/O to which access needs to be serialized.

See library-config for more information on how to use *NullHandler*.

16.8.4 WatchedFileHandler

The *WatchedFileHandler* class, located in the *logging.handlers* module, is a `FileHandler` which watches the file it is logging to. If the file changes, it is closed and reopened using the file name.

A file change can happen because of usage of programs such as *newsyslog* and *logrotate* which perform log file rotation. This handler, intended for use under Unix/Linux, watches the file to see if it has changed since the last emit. (A file is deemed to have changed if its device or inode have changed.) If the file has changed, the old file stream is closed, and the file opened to get a new stream.

This handler is not appropriate for use under Windows, because under Windows open log files cannot be moved or renamed - logging opens the files with exclusive locks - and so there is no need for such a handler. Furthermore, *ST_INO* is not supported under Windows; *stat()* always returns zero for this value.

class logging.handlers.WatchedFileHandler(*filename*, *mode='a'*, *encoding=None*, *delay=False*)
Returns a new instance of the *WatchedFileHandler* class. The specified file is opened and used as the stream for logging. If *mode* is not specified, `'a'` is used. If *encoding* is not `None`, it is used to open the file with that encoding. If *delay* is true, then file opening is deferred until the first call to *emit()*. By default, the file grows indefinitely.

Changed in version 3.6: As well as string values, *Path* objects are also accepted for the *filename* argument.

reopenIfNeeded()
Checks to see if the file has changed. If it has, the existing stream is flushed and closed and the file opened again, typically as a precursor to outputting the record to the file.

New in version 3.6.

emit(*record*)
Outputs the record to the file, but first calls *reopenIfNeeded()* to reopen the file if it has changed.

16.8.5 BaseRotatingHandler

The *BaseRotatingHandler* class, located in the *logging.handlers* module, is the base class for the rotating file handlers, *RotatingFileHandler* and *TimedRotatingFileHandler*. You should not need to instantiate this class, but it has attributes and methods you may need to override.

class logging.handlers.BaseRotatingHandler(*filename*, *mode*, *encoding=None*, *delay=False*)
The parameters are as for **FileHandler**. The attributes are:

namer
If this attribute is set to a callable, the *rotation_filename()* method delegates to this callable. The parameters passed to the callable are those passed to *rotation_filename()*.

Note: The namer function is called quite a few times during rollover, so it should be as simple and as fast as possible. It should also return the same output every time for a given input, otherwise the rollover behaviour may not work as expected.

New in version 3.3.

rotator
If this attribute is set to a callable, the *rotate()* method delegates to this callable. The parameters passed to the callable are those passed to *rotate()*.

New in version 3.3.

rotation_filename(*default_name*)
Modify the filename of a log file when rotating.

This is provided so that a custom filename can be provided.

The default implementation calls the 'namer' attribute of the handler, if it's callable, passing the default name to it. If the attribute isn't callable (the default is **None**), the name is returned unchanged.

Parameters **default_name** – The default name for the log file.

New in version 3.3.

rotate(*source*, *dest*)
When rotating, rotate the current log.

The default implementation calls the 'rotator' attribute of the handler, if it's callable, passing the source and dest arguments to it. If the attribute isn't callable (the default is **None**), the source is simply renamed to the destination.

Parameters

- **source** – The source filename. This is normally the base filename, e.g. 'test.log'.
- **dest** – The destination filename. This is normally what the source is rotated to, e.g. 'test.log.1'.

New in version 3.3.

The reason the attributes exist is to save you having to subclass - you can use the same callables for instances of *RotatingFileHandler* and *TimedRotatingFileHandler*. If either the namer or rotator callable raises an exception, this will be handled in the same way as any other exception during an `emit()` call, i.e. via the `handleError()` method of the handler.

If you need to make more significant changes to rotation processing, you can override the methods.

For an example, see cookbook-rotator-namer.

16.8.6 RotatingFileHandler

The *RotatingFileHandler* class, located in the *logging.handlers* module, supports rotation of disk log files.

class logging.handlers.**RotatingFileHandler**(*filename*, *mode='a'*, *maxBytes=0*, *backupCount=0*, *encoding=None*, *delay=False*)

Returns a new instance of the *RotatingFileHandler* class. The specified file is opened and used as the stream for logging. If *mode* is not specified, `'a'` is used. If *encoding* is not `None`, it is used to open the file with that encoding. If *delay* is true, then file opening is deferred until the first call to *emit()*. By default, the file grows indefinitely.

You can use the *maxBytes* and *backupCount* values to allow the file to *rollover* at a predetermined size. When the size is about to be exceeded, the file is closed and a new file is silently opened for output. Rollover occurs whenever the current log file is nearly *maxBytes* in length; but if either of *maxBytes* or *backupCount* is zero, rollover never occurs, so you generally want to set *backupCount* to at least 1, and have a non-zero *maxBytes*. When *backupCount* is non-zero, the system will save old log files by appending the extensions '.1', '.2' etc., to the filename. For example, with a *backupCount* of 5 and a base file name of `app.log`, you would get `app.log`, `app.log.1`, `app.log.2`, up to `app.log.5`. The file being written to is always `app.log`. When this file is filled, it is closed and renamed to `app.log.1`, and if files `app.log.1`, `app.log.2`, etc. exist, then they are renamed to `app.log.2`, `app.log.3` etc. respectively.

Changed in version 3.6: As well as string values, *Path* objects are also accepted for the *filename* argument.

doRollover()

Does a rollover, as described above.

emit(*record*)

Outputs the record to the file, catering for rollover as described previously.

16.8.7 TimedRotatingFileHandler

The *TimedRotatingFileHandler* class, located in the *logging.handlers* module, supports rotation of disk log files at certain timed intervals.

class logging.handlers.**TimedRotatingFileHandler**(*filename*, *when='h'*, *interval=1*, *backupCount=0*, *encoding=None*, *delay=False*, *utc=False*, *atTime=None*)

Returns a new instance of the *TimedRotatingFileHandler* class. The specified file is opened and used as the stream for logging. On rotating it also sets the filename suffix. Rotating happens based on the product of *when* and *interval*.

You can use the *when* to specify the type of *interval*. The list of possible values is below. Note that they are not case sensitive.

Value	Type of interval	If/how *atTime* is used
`'S'`	Seconds	Ignored
`'M'`	Minutes	Ignored
`'H'`	Hours	Ignored
`'D'`	Days	Ignored
`'W0'-'W6'`	Weekday (0=Monday)	Used to compute initial rollover time
`'midnight'`	Roll over at midnight, if *atTime* not specified, else at time *atTime*	Used to compute initial rollover time

When using weekday-based rotation, specify 'W0' for Monday, 'W1' for Tuesday, and so on up to 'W6' for Sunday. In this case, the value passed for *interval* isn't used.

The system will save old log files by appending extensions to the filename. The extensions are date-and-time based, using the strftime format `%Y-%m-%d_%H-%M-%S` or a leading portion thereof, depending on the rollover interval.

When computing the next rollover time for the first time (when the handler is created), the last modification time of an existing log file, or else the current time, is used to compute when the next rotation will occur.

If the *utc* argument is true, times in UTC will be used; otherwise local time is used.

If *backupCount* is nonzero, at most *backupCount* files will be kept, and if more would be created when rollover occurs, the oldest one is deleted. The deletion logic uses the interval to determine which files to delete, so changing the interval may leave old files lying around.

If *delay* is true, then file opening is deferred until the first call to *emit()*.

If *atTime* is not `None`, it must be a `datetime.time` instance which specifies the time of day when rollover occurs, for the cases where rollover is set to happen "at midnight" or "on a particular weekday". Note that in these cases, the *atTime* value is effectively used to compute the *initial* rollover, and subsequent rollovers would be calculated via the normal interval calculation.

Note: Calculation of the initial rollover time is done when the handler is initialised. Calculation of subsequent rollover times is done only when rollover occurs, and rollover occurs only when emitting output. If this is not kept in mind, it might lead to some confusion. For example, if an interval of "every minute" is set, that does not mean you will always see log files with times (in the filename) separated by a minute; if, during application execution, logging output is generated more frequently than once a minute, *then* you can expect to see log files with times separated by a minute. If, on the other hand, logging messages are only output once every five minutes (say), then there will be gaps in the file times corresponding to the minutes where no output (and hence no rollover) occurred.

Changed in version 3.4: *atTime* parameter was added.

Changed in version 3.6: As well as string values, *Path* objects are also accepted for the *filename* argument.

`doRollover()`
Does a rollover, as described above.

`emit(`*record***`)`**
Outputs the record to the file, catering for rollover as described above.

16.8.8 SocketHandler

The *SocketHandler* class, located in the *logging.handlers* module, sends logging output to a network socket. The base class uses a TCP socket.

class logging.handlers.SocketHandler(*host*, *port*)

Returns a new instance of the *SocketHandler* class intended to communicate with a remote machine whose address is given by *host* and *port*.

Changed in version 3.4: If `port` is specified as `None`, a Unix domain socket is created using the value in `host` - otherwise, a TCP socket is created.

close()

Closes the socket.

emit()

Pickles the record's attribute dictionary and writes it to the socket in binary format. If there is an error with the socket, silently drops the packet. If the connection was previously lost, re-establishes the connection. To unpickle the record at the receiving end into a *LogRecord*, use the *makeLogRecord()* function.

handleError()

Handles an error which has occurred during *emit()*. The most likely cause is a lost connection. Closes the socket so that we can retry on the next event.

makeSocket()

This is a factory method which allows subclasses to define the precise type of socket they want. The default implementation creates a TCP socket (*socket.SOCK_STREAM*).

makePickle(*record*)

Pickles the record's attribute dictionary in binary format with a length prefix, and returns it ready for transmission across the socket.

Note that pickles aren't completely secure. If you are concerned about security, you may want to override this method to implement a more secure mechanism. For example, you can sign pickles using HMAC and then verify them on the receiving end, or alternatively you can disable unpickling of global objects on the receiving end.

send(*packet*)

Send a pickled string *packet* to the socket. This function allows for partial sends which can happen when the network is busy.

createSocket()

Tries to create a socket; on failure, uses an exponential back-off algorithm. On initial failure, the handler will drop the message it was trying to send. When subsequent messages are handled by the same instance, it will not try connecting until some time has passed. The default parameters are such that the initial delay is one second, and if after that delay the connection still can't be made, the handler will double the delay each time up to a maximum of 30 seconds.

This behaviour is controlled by the following handler attributes:

- `retryStart` (initial delay, defaulting to 1.0 seconds).
- `retryFactor` (multiplier, defaulting to 2.0).
- `retryMax` (maximum delay, defaulting to 30.0 seconds).

This means that if the remote listener starts up *after* the handler has been used, you could lose messages (since the handler won't even attempt a connection until the delay has elapsed, but just silently drop messages during the delay period).

16.8.9 DatagramHandler

The *DatagramHandler* class, located in the *logging.handlers* module, inherits from *SocketHandler* to support sending logging messages over UDP sockets.

class logging.handlers.DatagramHandler(*host*, *port*)

Returns a new instance of the *DatagramHandler* class intended to communicate with a remote machine whose address is given by *host* and *port*.

Changed in version 3.4: If `port` is specified as `None`, a Unix domain socket is created using the value in `host` - otherwise, a UDP socket is created.

emit()

Pickles the record's attribute dictionary and writes it to the socket in binary format. If there is an error with the socket, silently drops the packet. To unpickle the record at the receiving end into a *LogRecord*, use the *makeLogRecord()* function.

makeSocket()

The factory method of *SocketHandler* is here overridden to create a UDP socket (*socket.SOCK_DGRAM*).

send(*s*)

Send a pickled string to a socket.

16.8.10 SysLogHandler

The *SysLogHandler* class, located in the *logging.handlers* module, supports sending logging messages to a remote or local Unix syslog.

class logging.handlers.SysLogHandler(*address=('localhost', SYSLOG_UDP_PORT)*, *facility=LOG_USER*, *socktype=socket.SOCK_DGRAM*)

Returns a new instance of the *SysLogHandler* class intended to communicate with a remote Unix machine whose address is given by *address* in the form of a `(host, port)` tuple. If *address* is not specified, `('localhost', 514)` is used. The address is used to open a socket. An alternative to providing a `(host, port)` tuple is providing an address as a string, for example '/dev/log'. In this case, a Unix domain socket is used to send the message to the syslog. If *facility* is not specified, `LOG_USER` is used. The type of socket opened depends on the *socktype* argument, which defaults to *socket.SOCK_DGRAM* and thus opens a UDP socket. To open a TCP socket (for use with the newer syslog daemons such as rsyslog), specify a value of *socket.SOCK_STREAM*.

Note that if your server is not listening on UDP port 514, *SysLogHandler* may appear not to work. In that case, check what address you should be using for a domain socket - it's system dependent. For example, on Linux it's usually '/dev/log' but on OS/X it's '/var/run/syslog'. You'll need to check your platform and use the appropriate address (you may need to do this check at runtime if your application needs to run on several platforms). On Windows, you pretty much have to use the UDP option.

Changed in version 3.2: *socktype* was added.

close()

Closes the socket to the remote host.

emit(*record*)

The record is formatted, and then sent to the syslog server. If exception information is present, it is *not* sent to the server.

Changed in version 3.2.1: (See: bpo-12168.) In earlier versions, the message sent to the syslog daemons was always terminated with a NUL byte, because early versions of these daemons expected a NUL terminated message - even though it's not in the relevant specification (**RFC 5424**). More recent versions of these daemons don't expect the NUL byte but strip it off if it's

there, and even more recent daemons (which adhere more closely to RFC 5424) pass the NUL byte on as part of the message.

To enable easier handling of syslog messages in the face of all these differing daemon behaviours, the appending of the NUL byte has been made configurable, through the use of a class-level attribute, `append_nul`. This defaults to `True` (preserving the existing behaviour) but can be set to `False` on a `SysLogHandler` instance in order for that instance to *not* append the NUL terminator.

Changed in version 3.3: (See: bpo-12419.) In earlier versions, there was no facility for an "ident" or "tag" prefix to identify the source of the message. This can now be specified using a class-level attribute, defaulting to `""` to preserve existing behaviour, but which can be overridden on a `SysLogHandler` instance in order for that instance to prepend the ident to every message handled. Note that the provided ident must be text, not bytes, and is prepended to the message exactly as is.

`encodePriority`(*facility*, *priority*)

Encodes the facility and priority into an integer. You can pass in strings or integers - if strings are passed, internal mapping dictionaries are used to convert them to integers.

The symbolic `LOG_` values are defined in *SysLogHandler* and mirror the values defined in the `sys/syslog.h` header file.

Priorities

Name (string)	Symbolic value
`alert`	LOG_ALERT
`crit` or `critical`	LOG_CRIT
`debug`	LOG_DEBUG
`emerg` or `panic`	LOG_EMERG
`err` or `error`	LOG_ERR
`info`	LOG_INFO
`notice`	LOG_NOTICE
`warn` or `warning`	LOG_WARNING

Facilities

Name (string)	Symbolic value
auth	LOG_AUTH
authpriv	LOG_AUTHPRIV
cron	LOG_CRON
daemon	LOG_DAEMON
ftp	LOG_FTP
kern	LOG_KERN
lpr	LOG_LPR
mail	LOG_MAIL
news	LOG_NEWS
syslog	LOG_SYSLOG
user	LOG_USER
uucp	LOG_UUCP
local0	LOG_LOCAL0
local1	LOG_LOCAL1
local2	LOG_LOCAL2
local3	LOG_LOCAL3
local4	LOG_LOCAL4
local5	LOG_LOCAL5
local6	LOG_LOCAL6
local7	LOG_LOCAL7

mapPriority(*levelname*)

Maps a logging level name to a syslog priority name. You may need to override this if you are using custom levels, or if the default algorithm is not suitable for your needs. The default algorithm maps `DEBUG`, `INFO`, `WARNING`, `ERROR` and `CRITICAL` to the equivalent syslog names, and all other level names to 'warning'.

16.8.11 NTEventLogHandler

The *NTEventLogHandler* class, located in the *logging.handlers* module, supports sending logging messages to a local Windows NT, Windows 2000 or Windows XP event log. Before you can use it, you need Mark Hammond's Win32 extensions for Python installed.

class logging.handlers.**NTEventLogHandler**(*appname*, *dllname=None*, *logtype='Application'*)

Returns a new instance of the *NTEventLogHandler* class. The *appname* is used to define the application name as it appears in the event log. An appropriate registry entry is created using this name. The *dllname* should give the fully qualified pathname of a .dll or .exe which contains message definitions to hold in the log (if not specified, `'win32service.pyd'` is used - this is installed with the Win32 extensions and contains some basic placeholder message definitions. Note that use of these placeholders will make your event logs big, as the entire message source is held in the log. If you want slimmer logs, you have to pass in the name of your own .dll or .exe which contains the message definitions you want to use in the event log). The *logtype* is one of `'Application'`, `'System'` or `'Security'`, and defaults to `'Application'`.

close()

At this point, you can remove the application name from the registry as a source of event log entries. However, if you do this, you will not be able to see the events as you intended in the Event Log Viewer - it needs to be able to access the registry to get the .dll name. The current version does not do this.

emit(*record*)

Determines the message ID, event category and event type, and then logs the message in the NT event log.

`getEventCategory`(*record*)
Returns the event category for the record. Override this if you want to specify your own categories. This version returns 0.

`getEventType`(*record*)
Returns the event type for the record. Override this if you want to specify your own types. This version does a mapping using the handler's typemap attribute, which is set up in `__init__()` to a dictionary which contains mappings for `DEBUG`, `INFO`, `WARNING`, `ERROR` and `CRITICAL`. If you are using your own levels, you will either need to override this method or place a suitable dictionary in the handler's *typemap* attribute.

`getMessageID`(*record*)
Returns the message ID for the record. If you are using your own messages, you could do this by having the *msg* passed to the logger being an ID rather than a format string. Then, in here, you could use a dictionary lookup to get the message ID. This version returns 1, which is the base message ID in `win32service.pyd`.

16.8.12 SMTPHandler

The *SMTPHandler* class, located in the *logging.handlers* module, supports sending logging messages to an email address via SMTP.

`class logging.handlers.SMTPHandler`(*mailhost*, *fromaddr*, *toaddrs*, *subject*, *credentials=None*, *secure=None*, *timeout=1.0*)
Returns a new instance of the *SMTPHandler* class. The instance is initialized with the from and to addresses and subject line of the email. The *toaddrs* should be a list of strings. To specify a non-standard SMTP port, use the (host, port) tuple format for the *mailhost* argument. If you use a string, the standard SMTP port is used. If your SMTP server requires authentication, you can specify a (username, password) tuple for the *credentials* argument.

To specify the use of a secure protocol (TLS), pass in a tuple to the *secure* argument. This will only be used when authentication credentials are supplied. The tuple should be either an empty tuple, or a single-value tuple with the name of a keyfile, or a 2-value tuple with the names of the keyfile and certificate file. (This tuple is passed to the *smtplib.SMTP.starttls()* method.)

A timeout can be specified for communication with the SMTP server using the *timeout* argument.

New in version 3.3: The *timeout* argument was added.

`emit`(*record*)
Formats the record and sends it to the specified addressees.

`getSubject`(*record*)
If you want to specify a subject line which is record-dependent, override this method.

16.8.13 MemoryHandler

The *MemoryHandler* class, located in the *logging.handlers* module, supports buffering of logging records in memory, periodically flushing them to a *target* handler. Flushing occurs whenever the buffer is full, or when an event of a certain severity or greater is seen.

MemoryHandler is a subclass of the more general *BufferingHandler*, which is an abstract class. This buffers logging records in memory. Whenever each record is added to the buffer, a check is made by calling `shouldFlush()` to see if the buffer should be flushed. If it should, then `flush()` is expected to do the flushing.

`class logging.handlers.BufferingHandler`(*capacity*)
Initializes the handler with a buffer of the specified capacity.

emit(*record*)
Appends the record to the buffer. If *shouldFlush()* returns true, calls *flush()* to process the buffer.

flush()
You can override this to implement custom flushing behavior. This version just zaps the buffer to empty.

shouldFlush(*record*)
Returns true if the buffer is up to capacity. This method can be overridden to implement custom flushing strategies.

class logging.handlers.**MemoryHandler**(*capacity*, *flushLevel=ERROR*, *target=None*, *flushOnClose=True*)
Returns a new instance of the *MemoryHandler* class. The instance is initialized with a buffer size of *capacity*. If *flushLevel* is not specified, `ERROR` is used. If no *target* is specified, the target will need to be set using *setTarget()* before this handler does anything useful. If *flushOnClose* is specified as `False`, then the buffer is *not* flushed when the handler is closed. If not specified or specified as `True`, the previous behaviour of flushing the buffer will occur when the handler is closed.

Changed in version 3.6: The *flushOnClose* parameter was added.

close()
Calls *flush()*, sets the target to `None` and clears the buffer.

flush()
For a *MemoryHandler*, flushing means just sending the buffered records to the target, if there is one. The buffer is also cleared when this happens. Override if you want different behavior.

setTarget(*target*)
Sets the target handler for this handler.

shouldFlush(*record*)
Checks for buffer full or a record at the *flushLevel* or higher.

16.8.14 HTTPHandler

The *HTTPHandler* class, located in the *logging.handlers* module, supports sending logging messages to a Web server, using either `GET` or `POST` semantics.

class logging.handlers.**HTTPHandler**(*host*, *url*, *method='GET'*, *secure=False*, *credentials=None*, *context=None*)
Returns a new instance of the *HTTPHandler* class. The *host* can be of the form `host:port`, should you need to use a specific port number. If no *method* is specified, `GET` is used. If *secure* is true, a HTTPS connection will be used. The *context* parameter may be set to a *ssl.SSLContext* instance to configure the SSL settings used for the HTTPS connection. If *credentials* is specified, it should be a 2-tuple consisting of userid and password, which will be placed in a HTTP 'Authorization' header using Basic authentication. If you specify credentials, you should also specify secure=True so that your userid and password are not passed in cleartext across the wire.

Changed in version 3.5: The *context* parameter was added.

mapLogRecord(*record*)
Provides a dictionary, based on `record`, which is to be URL-encoded and sent to the web server. The default implementation just returns `record.__dict__`. This method can be overridden if e.g. only a subset of *LogRecord* is to be sent to the web server, or if more specific customization of what's sent to the server is required.

emit(*record*)
Sends the record to the Web server as a URL-encoded dictionary. The *mapLogRecord()* method is used to convert the record to the dictionary to be sent.

Note: Since preparing a record for sending it to a Web server is not the same as a generic formatting operation, using *setFormatter()* to specify a *Formatter* for a *HTTPHandler* has no effect. Instead of calling *format()*, this handler calls *mapLogRecord()* and then *urllib.parse.urlencode()* to encode the dictionary in a form suitable for sending to a Web server.

16.8.15 QueueHandler

New in version 3.2.

The *QueueHandler* class, located in the *logging.handlers* module, supports sending logging messages to a queue, such as those implemented in the *queue* or *multiprocessing* modules.

Along with the *QueueListener* class, *QueueHandler* can be used to let handlers do their work on a separate thread from the one which does the logging. This is important in Web applications and also other service applications where threads servicing clients need to respond as quickly as possible, while any potentially slow operations (such as sending an email via *SMTPHandler*) are done on a separate thread.

class logging.handlers.**QueueHandler**(*queue*)

Returns a new instance of the *QueueHandler* class. The instance is initialized with the queue to send messages to. The queue can be any queue-like object; it's used as-is by the *enqueue()* method, which needs to know how to send messages to it.

emit(*record*)

Enqueues the result of preparing the LogRecord.

prepare(*record*)

Prepares a record for queuing. The object returned by this method is enqueued.

The base implementation formats the record to merge the message and arguments, and removes unpickleable items from the record in-place.

You might want to override this method if you want to convert the record to a dict or JSON string, or send a modified copy of the record while leaving the original intact.

enqueue(*record*)

Enqueues the record on the queue using `put_nowait()`; you may want to override this if you want to use blocking behaviour, or a timeout, or a customized queue implementation.

16.8.16 QueueListener

New in version 3.2.

The *QueueListener* class, located in the *logging.handlers* module, supports receiving logging messages from a queue, such as those implemented in the *queue* or *multiprocessing* modules. The messages are received from a queue in an internal thread and passed, on the same thread, to one or more handlers for processing. While *QueueListener* is not itself a handler, it is documented here because it works hand-in-hand with *QueueHandler*.

Along with the *QueueHandler* class, *QueueListener* can be used to let handlers do their work on a separate thread from the one which does the logging. This is important in Web applications and also other service applications where threads servicing clients need to respond as quickly as possible, while any potentially slow operations (such as sending an email via *SMTPHandler*) are done on a separate thread.

class logging.handlers.**QueueListener**(*queue*, **handlers*, *respect_handler_level=False*)

Returns a new instance of the *QueueListener* class. The instance is initialized with the queue to send messages to and a list of handlers which will handle entries placed on the queue. The queue can be any queue-like object; it's passed as-is to the *dequeue()* method, which needs to know how to get messages

from it. If `respect_handler_level` is `True`, a handler's level is respected (compared with the level for the message) when deciding whether to pass messages to that handler; otherwise, the behaviour is as in previous Python versions - to always pass each message to each handler.

Changed in version 3.5: The `respect_handler_levels` argument was added.

`dequeue`(*block*)
Dequeues a record and return it, optionally blocking.

The base implementation uses `get()`. You may want to override this method if you want to use timeouts or work with custom queue implementations.

`prepare`(*record*)
Prepare a record for handling.

This implementation just returns the passed-in record. You may want to override this method if you need to do any custom marshalling or manipulation of the record before passing it to the handlers.

`handle`(*record*)
Handle a record.

This just loops through the handlers offering them the record to handle. The actual object passed to the handlers is that which is returned from *prepare()*.

`start()`
Starts the listener.

This starts up a background thread to monitor the queue for LogRecords to process.

`stop()`
Stops the listener.

This asks the thread to terminate, and then waits for it to do so. Note that if you don't call this before your application exits, there may be some records still left on the queue, which won't be processed.

`enqueue_sentinel()`
Writes a sentinel to the queue to tell the listener to quit. This implementation uses `put_nowait()`. You may want to override this method if you want to use timeouts or work with custom queue implementations.

New in version 3.3.

See also:

Module *logging* API reference for the logging module.

Module *logging.config* Configuration API for the logging module.

16.9 getpass — Portable password input

Source code: Lib/getpass.py

The *getpass* module provides two functions:

`getpass.getpass`(*prompt='Password: ', stream=None*)
Prompt the user for a password without echoing. The user is prompted using the string *prompt*, which defaults to `'Password: '`. On Unix, the prompt is written to the file-like object *stream* using the replace error handler if needed. *stream* defaults to the controlling terminal (`/dev/tty`) or if that is unavailable to `sys.stderr` (this argument is ignored on Windows).

If echo free input is unavailable getpass() falls back to printing a warning message to *stream* and reading from `sys.stdin` and issuing a *GetPassWarning*.

Note: If you call getpass from within IDLE, the input may be done in the terminal you launched IDLE from rather than the idle window itself.

exception getpass.GetPassWarning
A *UserWarning* subclass issued when password input may be echoed.

getpass.getuser()
Return the "login name" of the user.

This function checks the environment variables `LOGNAME`, `USER`, `LNAME` and `USERNAME`, in order, and returns the value of the first one which is set to a non-empty string. If none are set, the login name from the password database is returned on systems which support the *pwd* module, otherwise, an exception is raised.

In general, this function should be preferred over *os.getlogin()*.

16.10 curses — Terminal handling for character-cell displays

The *curses* module provides an interface to the curses library, the de-facto standard for portable advanced terminal handling.

While curses is most widely used in the Unix environment, versions are available for Windows, DOS, and possibly other systems as well. This extension module is designed to match the API of ncurses, an open-source curses library hosted on Linux and the BSD variants of Unix.

Note: Whenever the documentation mentions a *character* it can be specified as an integer, a one-character Unicode string or a one-byte byte string.

Whenever the documentation mentions a *character string* it can be specified as a Unicode string or a byte string.

Note: Since version 5.4, the ncurses library decides how to interpret non-ASCII data using the `nl_langinfo` function. That means that you have to call *locale.setlocale()* in the application and encode Unicode strings using one of the system's available encodings. This example uses the system's default encoding:

```
import locale
locale.setlocale(locale.LC_ALL, '')
code = locale.getpreferredencoding()
```

Then use *code* as the encoding for *str.encode()* calls.

See also:

Module *curses.ascii* Utilities for working with ASCII characters, regardless of your locale settings.

Module *curses.panel* A panel stack extension that adds depth to curses windows.

Module *curses.textpad* Editable text widget for curses supporting **Emacs**-like bindings.

curses-howto Tutorial material on using curses with Python, by Andrew Kuchling and Eric Raymond.

The Tools/demo/ directory in the Python source distribution contains some example programs using the curses bindings provided by this module.

16.10.1 Functions

The module *curses* defines the following exception:

exception curses.error
Exception raised when a curses library function returns an error.

Note: Whenever *x* or *y* arguments to a function or a method are optional, they default to the current cursor location. Whenever *attr* is optional, it defaults to `A_NORMAL`.

The module *curses* defines the following functions:

curses.baudrate()
Return the output speed of the terminal in bits per second. On software terminal emulators it will have a fixed high value. Included for historical reasons; in former times, it was used to write output loops for time delays and occasionally to change interfaces depending on the line speed.

curses.beep()
Emit a short attention sound.

curses.can_change_color()
Return `True` or `False`, depending on whether the programmer can change the colors displayed by the terminal.

curses.cbreak()
Enter cbreak mode. In cbreak mode (sometimes called "rare" mode) normal tty line buffering is turned off and characters are available to be read one by one. However, unlike raw mode, special characters (interrupt, quit, suspend, and flow control) retain their effects on the tty driver and calling program. Calling first *raw()* then *cbreak()* leaves the terminal in cbreak mode.

curses.color_content(*color_number***)**
Return the intensity of the red, green, and blue (RGB) components in the color *color_number*, which must be between `0` and `COLORS`. Return a 3-tuple, containing the R,G,B values for the given color, which will be between `0` (no component) and `1000` (maximum amount of component).

curses.color_pair(*color_number***)**
Return the attribute value for displaying text in the specified color. This attribute value can be combined with `A_STANDOUT`, `A_REVERSE`, and the other `A_*` attributes. *pair_number()* is the counterpart to this function.

curses.curs_set(*visibility***)**
Set the cursor state. *visibility* can be set to `0`, `1`, or `2`, for invisible, normal, or very visible. If the terminal supports the visibility requested, return the previous cursor state; otherwise raise an exception. On many terminals, the "visible" mode is an underline cursor and the "very visible" mode is a block cursor.

curses.def_prog_mode()
Save the current terminal mode as the "program" mode, the mode when the running program is using curses. (Its counterpart is the "shell" mode, for when the program is not in curses.) Subsequent calls to *reset_prog_mode()* will restore this mode.

curses.def_shell_mode()
Save the current terminal mode as the "shell" mode, the mode when the running program is not using curses. (Its counterpart is the "program" mode, when the program is using curses capabilities.) Subsequent calls to *reset_shell_mode()* will restore this mode.

curses.delay_output(*ms*)
Insert an *ms* millisecond pause in output.

curses.doupdate()
Update the physical screen. The curses library keeps two data structures, one representing the current physical screen contents and a virtual screen representing the desired next state. The *doupdate()* ground updates the physical screen to match the virtual screen.

The virtual screen may be updated by a *noutrefresh()* call after write operations such as *addstr()* have been performed on a window. The normal *refresh()* call is simply noutrefresh() followed by doupdate(); if you have to update multiple windows, you can speed performance and perhaps reduce screen flicker by issuing noutrefresh() calls on all windows, followed by a single doupdate().

curses.echo()
Enter echo mode. In echo mode, each character input is echoed to the screen as it is entered.

curses.endwin()
De-initialize the library, and return terminal to normal status.

curses.erasechar()
Return the user's current erase character as a one-byte bytes object. Under Unix operating systems this is a property of the controlling tty of the curses program, and is not set by the curses library itself.

curses.filter()
The *filter()* routine, if used, must be called before *initscr()* is called. The effect is that, during those calls, LINES is set to 1; the capabilities clear, cup, cud, cud1, cuu1, cuu, vpa are disabled; and the home string is set to the value of cr. The effect is that the cursor is confined to the current line, and so are screen updates. This may be used for enabling character-at-a-time line editing without touching the rest of the screen.

curses.flash()
Flash the screen. That is, change it to reverse-video and then change it back in a short interval. Some people prefer such as 'visible bell' to the audible attention signal produced by *beep()*.

curses.flushinp()
Flush all input buffers. This throws away any typeahead that has been typed by the user and has not yet been processed by the program.

curses.getmouse()
After *getch()* returns KEY_MOUSE to signal a mouse event, this method should be call to retrieve the queued mouse event, represented as a 5-tuple (id, x, y, z, bstate). *id* is an ID value used to distinguish multiple devices, and *x*, *y*, *z* are the event's coordinates. (*z* is currently unused.) *bstate* is an integer value whose bits will be set to indicate the type of event, and will be the bitwise OR of one or more of the following constants, where *n* is the button number from 1 to 4: BUTTONn_PRESSED, BUTTONn_RELEASED, BUTTONn_CLICKED, BUTTONn_DOUBLE_CLICKED, BUTTONn_TRIPLE_CLICKED, BUTTON_SHIFT, BUTTON_CTRL, BUTTON_ALT.

curses.getsyx()
Return the current coordinates of the virtual screen cursor as a tuple (y, x). If *leaveok* is currently True, then return (-1, -1).

curses.getwin(*file*)
Read window related data stored in the file by an earlier putwin() call. The routine then creates and initializes a new window using that data, returning the new window object.

curses.has_colors()
Return True if the terminal can display colors; otherwise, return False.

curses.has_ic()
Return True if the terminal has insert- and delete-character capabilities. This function is included for historical reasons only, as all modern software terminal emulators have such capabilities.

curses.**has_il**()
Return True if the terminal has insert- and delete-line capabilities, or can simulate them using scrolling regions. This function is included for historical reasons only, as all modern software terminal emulators have such capabilities.

curses.**has_key**(*ch*)
Take a key value *ch*, and return True if the current terminal type recognizes a key with that value.

curses.**halfdelay**(*tenths*)
Used for half-delay mode, which is similar to cbreak mode in that characters typed by the user are immediately available to the program. However, after blocking for *tenths* tenths of seconds, raise an exception if nothing has been typed. The value of *tenths* must be a number between 1 and 255. Use *nocbreak()* to leave half-delay mode.

curses.**init_color**(*color_number*, *r*, *g*, *b*)
Change the definition of a color, taking the number of the color to be changed followed by three RGB values (for the amounts of red, green, and blue components). The value of *color_number* must be between 0 and COLORS. Each of *r*, *g*, *b*, must be a value between 0 and 1000. When *init_color()* is used, all occurrences of that color on the screen immediately change to the new definition. This function is a no-op on most terminals; it is active only if *can_change_color()* returns True.

curses.**init_pair**(*pair_number*, *fg*, *bg*)
Change the definition of a color-pair. It takes three arguments: the number of the color-pair to be changed, the foreground color number, and the background color number. The value of *pair_number* must be between 1 and COLOR_PAIRS - 1 (the 0 color pair is wired to white on black and cannot be changed). The value of *fg* and *bg* arguments must be between 0 and COLORS. If the color-pair was previously initialized, the screen is refreshed and all occurrences of that color-pair are changed to the new definition.

curses.**initscr**()
Initialize the library. Return a *window* object which represents the whole screen.

Note: If there is an error opening the terminal, the underlying curses library may cause the interpreter to exit.

---

curses.**is_term_resized**(*nlines*, *ncols*)
Return True if *resize_term()* would modify the window structure, False otherwise.

curses.**isendwin**()
Return True if *endwin()* has been called (that is, the curses library has been deinitialized).

curses.**keyname**(*k*)
Return the name of the key numbered *k* as a bytes object. The name of a key generating printable ASCII character is the key's character. The name of a control-key combination is a two-byte bytes object consisting of a caret (b'^') followed by the corresponding printable ASCII character. The name of an alt-key combination (128–255) is a bytes object consisting of the prefix b'M-' followed by the name of the corresponding ASCII character.

curses.**killchar**()
Return the user's current line kill character as a one-byte bytes object. Under Unix operating systems this is a property of the controlling tty of the curses program, and is not set by the curses library itself.

curses.**longname**()
Return a bytes object containing the terminfo long name field describing the current terminal. The maximum length of a verbose description is 128 characters. It is defined only after the call to *initscr()*.

curses.**meta**(*flag*)
If *flag* is True, allow 8-bit characters to be input. If *flag* is False, allow only 7-bit chars.

curses.**mouseinterval**(*interval*)
Set the maximum time in milliseconds that can elapse between press and release events in order for them to be recognized as a click, and return the previous interval value. The default value is 200 msec, or one fifth of a second.

curses.**mousemask**(*mousemask*)
Set the mouse events to be reported, and return a tuple `(availmask, oldmask)`. *availmask* indicates which of the specified mouse events can be reported; on complete failure it returns `0`. *oldmask* is the previous value of the given window's mouse event mask. If this function is never called, no mouse events are ever reported.

curses.**napms**(*ms*)
Sleep for *ms* milliseconds.

curses.**newpad**(*nlines*, *ncols*)
Create and return a pointer to a new pad data structure with the given number of lines and columns. Return a pad as a window object.

A pad is like a window, except that it is not restricted by the screen size, and is not necessarily associated with a particular part of the screen. Pads can be used when a large window is needed, and only a part of the window will be on the screen at one time. Automatic refreshes of pads (such as from scrolling or echoing of input) do not occur. The *refresh()* and *noutrefresh()* methods of a pad require 6 arguments to specify the part of the pad to be displayed and the location on the screen to be used for the display. The arguments are *pminrow*, *pmincol*, *sminrow*, *smincol*, *smaxrow*, *smaxcol*; the *p* arguments refer to the upper left corner of the pad region to be displayed and the *s* arguments define a clipping box on the screen within which the pad region is to be displayed.

curses.**newwin**(*nlines*, *ncols*)
curses.**newwin**(*nlines*, *ncols*, *begin_y*, *begin_x*)
Return a new *window*, whose left-upper corner is at `(begin_y, begin_x)`, and whose height/width is *nlines*/*ncols*.

By default, the window will extend from the specified position to the lower right corner of the screen.

curses.**nl**()
Enter newline mode. This mode translates the return key into newline on input, and translates newline into return and line-feed on output. Newline mode is initially on.

curses.**nocbreak**()
Leave cbreak mode. Return to normal "cooked" mode with line buffering.

curses.**noecho**()
Leave echo mode. Echoing of input characters is turned off.

curses.**nonl**()
Leave newline mode. Disable translation of return into newline on input, and disable low-level translation of newline into newline/return on output (but this does not change the behavior of `addch('\n')`, which always does the equivalent of return and line feed on the virtual screen). With translation off, curses can sometimes speed up vertical motion a little; also, it will be able to detect the return key on input.

curses.**noqiflush**()
When the `noqiflush()` routine is used, normal flush of input and output queues associated with the `INTR`, `QUIT` and `SUSP` characters will not be done. You may want to call `noqiflush()` in a signal handler if you want output to continue as though the interrupt had not occurred, after the handler exits.

curses.**noraw**()
Leave raw mode. Return to normal "cooked" mode with line buffering.

curses.**pair_content**(*pair_number*)
Return a tuple `(fg, bg)` containing the colors for the requested color pair. The value of *pair_number* must be between `1` and `COLOR_PAIRS - 1`.

curses.**pair_number**(*attr*)
Return the number of the color-pair set by the attribute value *attr*. *color_pair()* is the counterpart to this function.

curses.**putp**(*str*)
Equivalent to `tputs(str, 1, putchar)`; emit the value of a specified terminfo capability for the current terminal. Note that the output of *putp()* always goes to standard output.

curses.**qiflush**([*flag*])
If *flag* is `False`, the effect is the same as calling *noqiflush()*. If *flag* is `True`, or no argument is provided, the queues will be flushed when these control characters are read.

curses.**raw**()
Enter raw mode. In raw mode, normal line buffering and processing of interrupt, quit, suspend, and flow control keys are turned off; characters are presented to curses input functions one by one.

curses.**reset_prog_mode**()
Restore the terminal to "program" mode, as previously saved by *def_prog_mode()*.

curses.**reset_shell_mode**()
Restore the terminal to "shell" mode, as previously saved by *def_shell_mode()*.

curses.**resetty**()
Restore the state of the terminal modes to what it was at the last call to *savetty()*.

curses.**resize_term**(*nlines*, *ncols*)
Backend function used by *resizeterm()*, performing most of the work; when resizing the windows, *resize_term()* blank-fills the areas that are extended. The calling application should fill in these areas with appropriate data. The `resize_term()` function attempts to resize all windows. However, due to the calling convention of pads, it is not possible to resize these without additional interaction with the application.

curses.**resizeterm**(*nlines*, *ncols*)
Resize the standard and current windows to the specified dimensions, and adjusts other bookkeeping data used by the curses library that record the window dimensions (in particular the SIGWINCH handler).

curses.**savetty**()
Save the current state of the terminal modes in a buffer, usable by *resetty()*.

curses.**setsyx**(*y*, *x*)
Set the virtual screen cursor to *y*, *x*. If *y* and *x* are both `-1`, then *leaveok* is set `True`.

curses.**setupterm**(*term=None*, *fd=-1*)
Initialize the terminal. *term* is a string giving the terminal name, or `None`; if omitted or `None`, the value of the `TERM` environment variable will be used. *fd* is the file descriptor to which any initialization sequences will be sent; if not supplied or `-1`, the file descriptor for `sys.stdout` will be used.

curses.**start_color**()
Must be called if the programmer wants to use colors, and before any other color manipulation routine is called. It is good practice to call this routine right after *initscr()*.

start_color() initializes eight basic colors (black, red, green, yellow, blue, magenta, cyan, and white), and two global variables in the *curses* module, `COLORS` and `COLOR_PAIRS`, containing the maximum number of colors and color-pairs the terminal can support. It also restores the colors on the terminal to the values they had when the terminal was just turned on.

curses.**termattrs**()
Return a logical OR of all video attributes supported by the terminal. This information is useful when a curses program needs complete control over the appearance of the screen.

curses.**termname**()
Return the value of the environment variable TERM, as a bytes object, truncated to 14 characters.

curses.**tigetflag**(*capname*)
Return the value of the Boolean capability corresponding to the terminfo capability name *capname* as an integer. Return the value -1 if *capname* is not a Boolean capability, or 0 if it is canceled or absent from the terminal description.

curses.**tigetnum**(*capname*)
Return the value of the numeric capability corresponding to the terminfo capability name *capname* as an integer. Return the value -2 if *capname* is not a numeric capability, or -1 if it is canceled or absent from the terminal description.

curses.**tigetstr**(*capname*)
Return the value of the string capability corresponding to the terminfo capability name *capname* as a bytes object. Return None if *capname* is not a terminfo "string capability", or is canceled or absent from the terminal description.

curses.**tparm**(*str*[, *...*])
Instantiate the bytes object *str* with the supplied parameters, where *str* should be a parameterized string obtained from the terminfo database. E.g. `tparm(tigetstr("cup"), 5, 3)` could result in `b'\033[6;4H'`, the exact result depending on terminal type.

curses.**typeahead**(*fd*)
Specify that the file descriptor *fd* be used for typeahead checking. If *fd* is -1, then no typeahead checking is done.

The curses library does "line-breakout optimization" by looking for typeahead periodically while updating the screen. If input is found, and it is coming from a tty, the current update is postponed until refresh or doupdate is called again, allowing faster response to commands typed in advance. This function allows specifying a different file descriptor for typeahead checking.

curses.**unctrl**(*ch*)
Return a bytes object which is a printable representation of the character *ch*. Control characters are represented as a caret followed by the character, for example as `b'^C'`. Printing characters are left as they are.

curses.**ungetch**(*ch*)
Push *ch* so the next *getch()* will return it.

Note: Only one *ch* can be pushed before `getch()` is called.

---

curses.**update_lines_cols**()
Update LINES and COLS. Useful for detecting manual screen resize.

New in version 3.5.

curses.**unget_wch**(*ch*)
Push *ch* so the next *get_wch()* will return it.

Note: Only one *ch* can be pushed before `get_wch()` is called.

New in version 3.3.

curses.**ungetmouse**(*id*, *x*, *y*, *z*, *bstate*)
Push a KEY_MOUSE event onto the input queue, associating the given state data with it.

curses.**use_env**(*flag*)
If used, this function should be called before *initscr()* or newterm are called. When *flag* is False, the values of lines and columns specified in the terminfo database will be used, even if environment variables LINES and COLUMNS (used by default) are set, or if curses is running in a window (in which case default behavior would be to use the window size if LINES and COLUMNS are not set).

curses.**use_default_colors**()
Allow use of default values for colors on terminals supporting this feature. Use this to support transparency in your application. The default color is assigned to the color number -1. After calling this function, init_pair(x, curses.COLOR_RED, -1) initializes, for instance, color pair *x* to a red foreground color on the default background.

curses.**wrapper**(*func*, ...)
Initialize curses and call another callable object, *func*, which should be the rest of your curses-using application. If the application raises an exception, this function will restore the terminal to a sane state before re-raising the exception and generating a traceback. The callable object *func* is then passed the main window 'stdscr' as its first argument, followed by any other arguments passed to wrapper(). Before calling *func*, wrapper() turns on cbreak mode, turns off echo, enables the terminal keypad, and initializes colors if the terminal has color support. On exit (whether normally or by exception) it restores cooked mode, turns on echo, and disables the terminal keypad.

16.10.2 Window Objects

Window objects, as returned by *initscr()* and *newwin()* above, have the following methods and attributes:

window.**addch**(*ch*[, *attr*])
window.**addch**(*y*, *x*, *ch*[, *attr*])
Paint character *ch* at (y, x) with attributes *attr*, overwriting any character previously painter at that location. By default, the character position and attributes are the current settings for the window object.

Note: Writing outside the window, subwindow, or pad raises a *curses.error*. Attempting to write to the lower right corner of a window, subwindow, or pad will cause an exception to be raised after the character is printed.

---

window.**addnstr**(*str*, *n*[, *attr*])
window.**addnstr**(*y*, *x*, *str*, *n*[, *attr*])
Paint at most *n* characters of the character string *str* at (y, x) with attributes *attr*, overwriting anything previously on the display.

window.**addstr**(*str*[, *attr*])
window.**addstr**(*y*, *x*, *str*[, *attr*])
Paint the character string *str* at (y, x) with attributes *attr*, overwriting anything previously on the display.

Note: Writing outside the window, subwindow, or pad raises *curses.error*. Attempting to write to the lower right corner of a window, subwindow, or pad will cause an exception to be raised after the string is printed.

`window.attroff(`*attr*`)`
Remove attribute *attr* from the "background" set applied to all writes to the current window.

`window.attron(`*attr*`)`
Add attribute *attr* from the "background" set applied to all writes to the current window.

`window.attrset(`*attr*`)`
Set the "background" set of attributes to *attr*. This set is initially `0` (no attributes).

`window.bkgd(`*ch*[, *attr*]`)`
Set the background property of the window to the character *ch*, with attributes *attr*. The change is then applied to every character position in that window:

- The attribute of every character in the window is changed to the new background attribute.
- Wherever the former background character appears, it is changed to the new background character.

`window.bkgdset(`*ch*[, *attr*]`)`
Set the window's background. A window's background consists of a character and any combination of attributes. The attribute part of the background is combined (OR'ed) with all non-blank characters that are written into the window. Both the character and attribute parts of the background are combined with the blank characters. The background becomes a property of the character and moves with the character through any scrolling and insert/delete line/character operations.

`window.border(`[*ls*[, *rs*[, *ts*[, *bs*[, *tl*[, *tr*[, *bl*[, *br*]]]]]]]]`)`
Draw a border around the edges of the window. Each parameter specifies the character to use for a specific part of the border; see the table below for more details.

Note: A `0` value for any parameter will cause the default character to be used for that parameter. Keyword parameters can *not* be used. The defaults are listed in this table:

Parameter	Description	Default value
ls	Left side	`ACS_VLINE`
rs	Right side	`ACS_VLINE`
ts	Top	`ACS_HLINE`
bs	Bottom	`ACS_HLINE`
tl	Upper-left corner	`ACS_ULCORNER`
tr	Upper-right corner	`ACS_URCORNER`
bl	Bottom-left corner	`ACS_LLCORNER`
br	Bottom-right corner	`ACS_LRCORNER`

`window.box(`[*vertch*, *horch*]`)`
Similar to *border()*, but both *ls* and *rs* are *vertch* and both *ts* and *bs* are *horch*. The default corner characters are always used by this function.

`window.chgat(`*attr*`)`
`window.chgat(`*num*, *attr*`)`
`window.chgat(`*y*, *x*, *attr*`)`
`window.chgat(`*y*, *x*, *num*, *attr*`)`
Set the attributes of *num* characters at the current cursor position, or at position `(y, x)` if supplied. If *num* is not given or is `-1`, the attribute will be set on all the characters to the end of the line. This function moves cursor to position `(y, x)` if supplied. The changed line will be touched using the *touchline()* method so that the contents will be redisplayed by the next window refresh.

`window.clear()`
Like *erase()*, but also cause the whole window to be repainted upon next call to *refresh()*.

window.**clearok**(*flag*)
If *flag* is `True`, the next call to *refresh()* will clear the window completely.

window.**clrtobot**()
Erase from cursor to the end of the window: all lines below the cursor are deleted, and then the equivalent of *clrtoeol()* is performed.

window.**clrtoeol**()
Erase from cursor to the end of the line.

window.**cursyncup**()
Update the current cursor position of all the ancestors of the window to reflect the current cursor position of the window.

window.**delch**([*y*, *x*])
Delete any character at `(y, x)`.

window.**deleteln**()
Delete the line under the cursor. All following lines are moved up by one line.

window.**derwin**(*begin_y*, *begin_x*)
window.**derwin**(*nlines*, *ncols*, *begin_y*, *begin_x*)
An abbreviation for "derive window", *derwin()* is the same as calling *subwin()*, except that *begin_y* and *begin_x* are relative to the origin of the window, rather than relative to the entire screen. Return a window object for the derived window.

window.**echochar**(*ch*[, *attr*])
Add character *ch* with attribute *attr*, and immediately call *refresh()* on the window.

window.**enclose**(*y*, *x*)
Test whether the given pair of screen-relative character-cell coordinates are enclosed by the given window, returning `True` or `False`. It is useful for determining what subset of the screen windows enclose the location of a mouse event.

window.**encoding**
Encoding used to encode method arguments (Unicode strings and characters). The encoding attribute is inherited from the parent window when a subwindow is created, for example with *window.subwin()*. By default, the locale encoding is used (see *locale.getpreferredencoding()*).

New in version 3.3.

window.**erase**()
Clear the window.

window.**getbegyx**()
Return a tuple `(y, x)` of co-ordinates of upper-left corner.

window.**getbkgd**()
Return the given window's current background character/attribute pair.

window.**getch**([*y*, *x*])
Get a character. Note that the integer returned does *not* have to be in ASCII range: function keys, keypad keys and so on are represented by numbers higher than 255. In no-delay mode, return `-1` if there is no input, otherwise wait until a key is pressed.

window.**get_wch**([*y*, *x*])
Get a wide character. Return a character for most keys, or an integer for function keys, keypad keys, and other special keys. In no-delay mode, raise an exception if there is no input.

New in version 3.3.

window.**getkey**([*y*, *x*])
Get a character, returning a string instead of an integer, as *getch()* does. Function keys, keypad keys

and other special keys return a multibyte string containing the key name. In no-delay mode, raise an exception if there is no input.

window.getmaxyx()
Return a tuple `(y, x)` of the height and width of the window.

window.getparyx()
Return the beginning coordinates of this window relative to its parent window as a tuple `(y, x)`. Return `(-1, -1)` if this window has no parent.

window.getstr()
window.getstr(*n***)**
window.getstr(*y*, *x***)**
window.getstr(*y*, *x*, *n***)**
Read a bytes object from the user, with primitive line editing capacity.

window.getyx()
Return a tuple `(y, x)` of current cursor position relative to the window's upper-left corner.

window.hline(*ch*, *n***)**
window.hline(*y*, *x*, *ch*, *n***)**
Display a horizontal line starting at `(y, x)` with length *n* consisting of the character *ch*.

window.idcok(*flag***)**
If *flag* is `False`, curses no longer considers using the hardware insert/delete character feature of the terminal; if *flag* is `True`, use of character insertion and deletion is enabled. When curses is first initialized, use of character insert/delete is enabled by default.

window.idlok(*flag***)**
If *flag* is `True`, *curses* will try and use hardware line editing facilities. Otherwise, line insertion/deletion are disabled.

window.immedok(*flag***)**
If *flag* is `True`, any change in the window image automatically causes the window to be refreshed; you no longer have to call *refresh()* yourself. However, it may degrade performance considerably, due to repeated calls to wrefresh. This option is disabled by default.

window.inch([*y*, *x*]**)**
Return the character at the given position in the window. The bottom 8 bits are the character proper, and upper bits are the attributes.

window.insch(*ch*[, *attr*]**)**
window.insch(*y*, *x*, *ch*[, *attr*]**)**
Paint character *ch* at `(y, x)` with attributes *attr*, moving the line from position *x* right by one character.

window.insdelln(*nlines***)**
Insert *nlines* lines into the specified window above the current line. The *nlines* bottom lines are lost. For negative *nlines*, delete *nlines* lines starting with the one under the cursor, and move the remaining lines up. The bottom *nlines* lines are cleared. The current cursor position remains the same.

window.insertln()
Insert a blank line under the cursor. All following lines are moved down by one line.

window.insnstr(*str*, *n*[, *attr*]**)**
window.insnstr(*y*, *x*, *str*, *n*[, *attr*]**)**
Insert a character string (as many characters as will fit on the line) before the character under the cursor, up to *n* characters. If *n* is zero or negative, the entire string is inserted. All characters to the right of the cursor are shifted right, with the rightmost characters on the line being lost. The cursor position does not change (after moving to *y*, *x*, if specified).

window.insstr(*str*[, *attr*]**)**

window.insstr(*y*, *x*, *str*[, *attr*])
Insert a character string (as many characters as will fit on the line) before the character under the cursor. All characters to the right of the cursor are shifted right, with the rightmost characters on the line being lost. The cursor position does not change (after moving to *y*, *x*, if specified).

window.instr([*n*])
window.instr(*y*, *x*[, *n*])
Return a bytes object of characters, extracted from the window starting at the current cursor position, or at *y*, *x* if specified. Attributes are stripped from the characters. If *n* is specified, *instr()* returns a string at most *n* characters long (exclusive of the trailing NUL).

window.is_linetouched(*line*)
Return `True` if the specified line was modified since the last call to *refresh()*; otherwise return `False`. Raise a *curses.error* exception if *line* is not valid for the given window.

window.is_wintouched()
Return `True` if the specified window was modified since the last call to *refresh()*; otherwise return `False`.

window.keypad(*flag*)
If *flag* is `True`, escape sequences generated by some keys (keypad, function keys) will be interpreted by *curses*. If *flag* is `False`, escape sequences will be left as is in the input stream.

window.leaveok(*flag*)
If *flag* is `True`, cursor is left where it is on update, instead of being at "cursor position." This reduces cursor movement where possible. If possible the cursor will be made invisible.

If *flag* is `False`, cursor will always be at "cursor position" after an update.

window.move(*new_y*, *new_x*)
Move cursor to `(new_y, new_x)`.

window.mvderwin(*y*, *x*)
Move the window inside its parent window. The screen-relative parameters of the window are not changed. This routine is used to display different parts of the parent window at the same physical position on the screen.

window.mvwin(*new_y*, *new_x*)
Move the window so its upper-left corner is at `(new_y, new_x)`.

window.nodelay(*flag*)
If *flag* is `True`, *getch()* will be non-blocking.

window.notimeout(*flag*)
If *flag* is `True`, escape sequences will not be timed out.

If *flag* is `False`, after a few milliseconds, an escape sequence will not be interpreted, and will be left in the input stream as is.

window.noutrefresh()
Mark for refresh but wait. This function updates the data structure representing the desired state of the window, but does not force an update of the physical screen. To accomplish that, call *doupdate()*.

window.overlay(*destwin*[, *sminrow*, *smincol*, *dminrow*, *dmincol*, *dmaxrow*, *dmaxcol*])
Overlay the window on top of *destwin*. The windows need not be the same size, only the overlapping region is copied. This copy is non-destructive, which means that the current background character does not overwrite the old contents of *destwin*.

To get fine-grained control over the copied region, the second form of *overlay()* can be used. *sminrow* and *smincol* are the upper-left coordinates of the source window, and the other variables mark a rectangle in the destination window.

window.overwrite(*destwin*[, *sminrow*, *smincol*, *dminrow*, *dmincol*, *dmaxrow*, *dmaxcol*])
Overwrite the window on top of *destwin*. The windows need not be the same size, in which case only the overlapping region is copied. This copy is destructive, which means that the current background character overwrites the old contents of *destwin*.

To get fine-grained control over the copied region, the second form of *overwrite()* can be used. *sminrow* and *smincol* are the upper-left coordinates of the source window, the other variables mark a rectangle in the destination window.

window.putwin(*file*)
Write all data associated with the window into the provided file object. This information can be later retrieved using the *getwin()* function.

window.redrawln(*beg*, *num*)
Indicate that the *num* screen lines, starting at line *beg*, are corrupted and should be completely redrawn on the next *refresh()* call.

window.redrawwin()
Touch the entire window, causing it to be completely redrawn on the next *refresh()* call.

window.refresh([*pminrow*, *pmincol*, *sminrow*, *smincol*, *smaxrow*, *smaxcol*])
Update the display immediately (sync actual screen with previous drawing/deleting methods).

The 6 optional arguments can only be specified when the window is a pad created with *newpad()*. The additional parameters are needed to indicate what part of the pad and screen are involved. *pminrow* and *pmincol* specify the upper left-hand corner of the rectangle to be displayed in the pad. *sminrow*, *smincol*, *smaxrow*, and *smaxcol* specify the edges of the rectangle to be displayed on the screen. The lower right-hand corner of the rectangle to be displayed in the pad is calculated from the screen coordinates, since the rectangles must be the same size. Both rectangles must be entirely contained within their respective structures. Negative values of *pminrow*, *pmincol*, *sminrow*, or *smincol* are treated as if they were zero.

window.resize(*nlines*, *ncols*)
Reallocate storage for a curses window to adjust its dimensions to the specified values. If either dimension is larger than the current values, the window's data is filled with blanks that have the current background rendition (as set by *bkgdset()*) merged into them.

window.scroll([*lines=1*])
Scroll the screen or scrolling region upward by *lines* lines.

window.scrollok(*flag*)
Control what happens when the cursor of a window is moved off the edge of the window or scrolling region, either as a result of a newline action on the bottom line, or typing the last character of the last line. If *flag* is `False`, the cursor is left on the bottom line. If *flag* is `True`, the window is scrolled up one line. Note that in order to get the physical scrolling effect on the terminal, it is also necessary to call *idlok()*.

window.setscrreg(*top*, *bottom*)
Set the scrolling region from line *top* to line *bottom*. All scrolling actions will take place in this region.

window.standend()
Turn off the standout attribute. On some terminals this has the side effect of turning off all attributes.

window.standout()
Turn on attribute *A_STANDOUT*.

window.subpad(*begin_y*, *begin_x*)
window.subpad(*nlines*, *ncols*, *begin_y*, *begin_x*)
Return a sub-window, whose upper-left corner is at `(begin_y, begin_x)`, and whose width/height is *ncols*/*nlines*.

window.subwin(*begin_y*, *begin_x*)

window.subwin(*nlines*, *ncols*, *begin_y*, *begin_x*)
Return a sub-window, whose upper-left corner is at `(begin_y, begin_x)`, and whose width/height is *ncols*/*nlines*.

By default, the sub-window will extend from the specified position to the lower right corner of the window.

window.syncdown()
Touch each location in the window that has been touched in any of its ancestor windows. This routine is called by *refresh()*, so it should almost never be necessary to call it manually.

window.syncok(*flag*)
If *flag* is `True`, then *syncup()* is called automatically whenever there is a change in the window.

window.syncup()
Touch all locations in ancestors of the window that have been changed in the window.

window.timeout(*delay*)
Set blocking or non-blocking read behavior for the window. If *delay* is negative, blocking read is used (which will wait indefinitely for input). If *delay* is zero, then non-blocking read is used, and *getch()* will return `-1` if no input is waiting. If *delay* is positive, then *getch()* will block for *delay* milliseconds, and return `-1` if there is still no input at the end of that time.

window.touchline(*start*, *count*[, *changed*])
Pretend *count* lines have been changed, starting with line *start*. If *changed* is supplied, it specifies whether the affected lines are marked as having been changed (*changed*=`True`) or unchanged (*changed*=`False`).

window.touchwin()
Pretend the whole window has been changed, for purposes of drawing optimizations.

window.untouchwin()
Mark all lines in the window as unchanged since the last call to *refresh()*.

window.vline(*ch*, *n*)
window.vline(*y*, *x*, *ch*, *n*)
Display a vertical line starting at `(y, x)` with length *n* consisting of the character *ch*.

16.10.3 Constants

The *curses* module defines the following data members:

curses.ERR
Some curses routines that return an integer, such as `getch()`, return *ERR* upon failure.

curses.OK
Some curses routines that return an integer, such as *napms()*, return *OK* upon success.

curses.version
A bytes object representing the current version of the module. Also available as `__version__`.

Some constants are available to specify character cell attributes. The exact constants available are system dependent.

Attribute	Meaning
A_ALTCHARSET	Alternate character set mode
A_BLINK	Blink mode
A_BOLD	Bold mode
A_DIM	Dim mode
A_INVIS	Invisible or blank mode
A_ITALIC	Italic mode
A_NORMAL	Normal attribute
A_PROTECT	Protected mode
A_REVERSE	Reverse background and foreground colors
A_STANDOUT	Standout mode
A_UNDERLINE	Underline mode
A_HORIZONTAL	Horizontal highlight
A_LEFT	Left highlight
A_LOW	Low highlight
A_RIGHT	Right highlight
A_TOP	Top highlight
A_VERTICAL	Vertical highlight
A_CHARTEXT	Bit-mask to extract a character

New in version 3.7: A_ITALIC was added.

Several constants are available to extract corresponding attributes returned by some methods.

Bit-mask	Meaning
A_ATTRIBUTES	Bit-mask to extract attributes
A_CHARTEXT	Bit-mask to extract a character
A_COLOR	Bit-mask to extract color-pair field information

Keys are referred to by integer constants with names starting with KEY_. The exact keycaps available are system dependent.

Key constant	Key
KEY_MIN	Minimum key value
KEY_BREAK	Break key (unreliable)
KEY_DOWN	Down-arrow
KEY_UP	Up-arrow
KEY_LEFT	Left-arrow
KEY_RIGHT	Right-arrow
KEY_HOME	Home key (upward+left arrow)
KEY_BACKSPACE	Backspace (unreliable)
KEY_F0	Function keys. Up to 64 function keys are supported.
KEY_Fn	Value of function key n
KEY_DL	Delete line
KEY_IL	Insert line
KEY_DC	Delete character
KEY_IC	Insert char or enter insert mode
KEY_EIC	Exit insert char mode
KEY_CLEAR	Clear screen
KEY_EOS	Clear to end of screen
KEY_EOL	Clear to end of line

Continued on next page

Table 1 – continued from previous page

Key constant	Key
KEY_SF	Scroll 1 line forward
KEY_SR	Scroll 1 line backward (reverse)
KEY_NPAGE	Next page
KEY_PPAGE	Previous page
KEY_STAB	Set tab
KEY_CTAB	Clear tab
KEY_CATAB	Clear all tabs
KEY_ENTER	Enter or send (unreliable)
KEY_SRESET	Soft (partial) reset (unreliable)
KEY_RESET	Reset or hard reset (unreliable)
KEY_PRINT	Print
KEY_LL	Home down or bottom (lower left)
KEY_A1	Upper left of keypad
KEY_A3	Upper right of keypad
KEY_B2	Center of keypad
KEY_C1	Lower left of keypad
KEY_C3	Lower right of keypad
KEY_BTAB	Back tab
KEY_BEG	Beg (beginning)
KEY_CANCEL	Cancel
KEY_CLOSE	Close
KEY_COMMAND	Cmd (command)
KEY_COPY	Copy
KEY_CREATE	Create
KEY_END	End
KEY_EXIT	Exit
KEY_FIND	Find
KEY_HELP	Help
KEY_MARK	Mark
KEY_MESSAGE	Message
KEY_MOVE	Move
KEY_NEXT	Next
KEY_OPEN	Open
KEY_OPTIONS	Options
KEY_PREVIOUS	Prev (previous)
KEY_REDO	Redo
KEY_REFERENCE	Ref (reference)
KEY_REFRESH	Refresh
KEY_REPLACE	Replace
KEY_RESTART	Restart
KEY_RESUME	Resume
KEY_SAVE	Save
KEY_SBEG	Shifted Beg (beginning)
KEY_SCANCEL	Shifted Cancel
KEY_SCOMMAND	Shifted Command
KEY_SCOPY	Shifted Copy
KEY_SCREATE	Shifted Create
KEY_SDC	Shifted Delete char
KEY_SDL	Shifted Delete line

Continued on next page

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Key constant	Key
KEY_SELECT	Select
KEY_SEND	Shifted End
KEY_SEOL	Shifted Clear line
KEY_SEXIT	Shifted Exit
KEY_SFIND	Shifted Find
KEY_SHELP	Shifted Help
KEY_SHOME	Shifted Home
KEY_SIC	Shifted Input
KEY_SLEFT	Shifted Left arrow
KEY_SMESSAGE	Shifted Message
KEY_SMOVE	Shifted Move
KEY_SNEXT	Shifted Next
KEY_SOPTIONS	Shifted Options
KEY_SPREVIOUS	Shifted Prev
KEY_SPRINT	Shifted Print
KEY_SREDO	Shifted Redo
KEY_SREPLACE	Shifted Replace
KEY_SRIGHT	Shifted Right arrow
KEY_SRSUME	Shifted Resume
KEY_SSAVE	Shifted Save
KEY_SSUSPEND	Shifted Suspend
KEY_SUNDO	Shifted Undo
KEY_SUSPEND	Suspend
KEY_UNDO	Undo
KEY_MOUSE	Mouse event has occurred
KEY_RESIZE	Terminal resize event
KEY_MAX	Maximum key value

On VT100s and their software emulations, such as X terminal emulators, there are normally at least four function keys (KEY_F1, KEY_F2, KEY_F3, KEY_F4) available, and the arrow keys mapped to KEY_UP, KEY_DOWN, KEY_LEFT and KEY_RIGHT in the obvious way. If your machine has a PC keyboard, it is safe to expect arrow keys and twelve function keys (older PC keyboards may have only ten function keys); also, the following keypad mappings are standard:

Keycap	Constant
Insert	KEY_IC
Delete	KEY_DC
Home	KEY_HOME
End	KEY_END
Page Up	KEY_PPAGE
Page Down	KEY_NPAGE

The following table lists characters from the alternate character set. These are inherited from the VT100 terminal, and will generally be available on software emulations such as X terminals. When there is no graphic available, curses falls back on a crude printable ASCII approximation.

Note: These are available only after *initscr()* has been called.

ACS code	Meaning
ACS_BBSS	alternate name for upper right corner
ACS_BLOCK	solid square block
ACS_BOARD	board of squares
ACS_BSBS	alternate name for horizontal line
ACS_BSSB	alternate name for upper left corner
ACS_BSSS	alternate name for top tee
ACS_BTEE	bottom tee
ACS_BULLET	bullet
ACS_CKBOARD	checker board (stipple)
ACS_DARROW	arrow pointing down
ACS_DEGREE	degree symbol
ACS_DIAMOND	diamond
ACS_GEQUAL	greater-than-or-equal-to
ACS_HLINE	horizontal line
ACS_LANTERN	lantern symbol
ACS_LARROW	left arrow
ACS_LEQUAL	less-than-or-equal-to
ACS_LLCORNER	lower left-hand corner
ACS_LRCORNER	lower right-hand corner
ACS_LTEE	left tee
ACS_NEQUAL	not-equal sign
ACS_PI	letter pi
ACS_PLMINUS	plus-or-minus sign
ACS_PLUS	big plus sign
ACS_RARROW	right arrow
ACS_RTEE	right tee
ACS_S1	scan line 1
ACS_S3	scan line 3
ACS_S7	scan line 7
ACS_S9	scan line 9
ACS_SBBS	alternate name for lower right corner
ACS_SBSB	alternate name for vertical line
ACS_SBSS	alternate name for right tee
ACS_SSBB	alternate name for lower left corner
ACS_SSBS	alternate name for bottom tee
ACS_SSSB	alternate name for left tee
ACS_SSSS	alternate name for crossover or big plus
ACS_STERLING	pound sterling
ACS_TTEE	top tee
ACS_UARROW	up arrow
ACS_ULCORNER	upper left corner
ACS_URCORNER	upper right corner
ACS_VLINE	vertical line

The following table lists the predefined colors:

Constant	Color
COLOR_BLACK	Black
COLOR_BLUE	Blue
COLOR_CYAN	Cyan (light greenish blue)
COLOR_GREEN	Green
COLOR_MAGENTA	Magenta (purplish red)
COLOR_RED	Red
COLOR_WHITE	White
COLOR_YELLOW	Yellow

16.11 curses.textpad — Text input widget for curses programs

The *curses.textpad* module provides a *Textbox* class that handles elementary text editing in a curses window, supporting a set of keybindings resembling those of Emacs (thus, also of Netscape Navigator, BBedit 6.x, FrameMaker, and many other programs). The module also provides a rectangle-drawing function useful for framing text boxes or for other purposes.

The module *curses.textpad* defines the following function:

curses.textpad.rectangle(*win*, *uly*, *ulx*, *lry*, *lrx*)

Draw a rectangle. The first argument must be a window object; the remaining arguments are coordinates relative to that window. The second and third arguments are the y and x coordinates of the upper left hand corner of the rectangle to be drawn; the fourth and fifth arguments are the y and x coordinates of the lower right hand corner. The rectangle will be drawn using VT100/IBM PC forms characters on terminals that make this possible (including xterm and most other software terminal emulators). Otherwise it will be drawn with ASCII dashes, vertical bars, and plus signs.

16.11.1 Textbox objects

You can instantiate a *Textbox* object as follows:

class curses.textpad.Textbox(*win*)

Return a textbox widget object. The *win* argument should be a curses *window* object in which the textbox is to be contained. The edit cursor of the textbox is initially located at the upper left hand corner of the containing window, with coordinates `(0, 0)`. The instance's *stripspaces* flag is initially on.

Textbox objects have the following methods:

edit(*[validator]*)

This is the entry point you will normally use. It accepts editing keystrokes until one of the termination keystrokes is entered. If *validator* is supplied, it must be a function. It will be called for each keystroke entered with the keystroke as a parameter; command dispatch is done on the result. This method returns the window contents as a string; whether blanks in the window are included is affected by the *stripspaces* attribute.

do_command(*ch*)

Process a single command keystroke. Here are the supported special keystrokes:

Keystroke	Action
Control-A	Go to left edge of window.
Control-B	Cursor left, wrapping to previous line if appropriate.
Control-D	Delete character under cursor.
Control-E	Go to right edge (stripspaces off) or end of line (stripspaces on).
Control-F	Cursor right, wrapping to next line when appropriate.
Control-G	Terminate, returning the window contents.
Control-H	Delete character backward.
Control-J	Terminate if the window is 1 line, otherwise insert newline.
Control-K	If line is blank, delete it, otherwise clear to end of line.
Control-L	Refresh screen.
Control-N	Cursor down; move down one line.
Control-O	Insert a blank line at cursor location.
Control-P	Cursor up; move up one line.

Move operations do nothing if the cursor is at an edge where the movement is not possible. The following synonyms are supported where possible:

Constant	Keystroke
KEY_LEFT	Control-B
KEY_RIGHT	Control-F
KEY_UP	Control-P
KEY_DOWN	Control-N
KEY_BACKSPACE	Control-h

All other keystrokes are treated as a command to insert the given character and move right (with line wrapping).

gather()
Return the window contents as a string; whether blanks in the window are included is affected by the *stripspaces* member.

stripspaces
This attribute is a flag which controls the interpretation of blanks in the window. When it is on, trailing blanks on each line are ignored; any cursor motion that would land the cursor on a trailing blank goes to the end of that line instead, and trailing blanks are stripped when the window contents are gathered.

16.12 curses.ascii — Utilities for ASCII characters

The *curses.ascii* module supplies name constants for ASCII characters and functions to test membership in various ASCII character classes. The constants supplied are names for control characters as follows:

Name	Meaning
NUL	
SOH	Start of heading, console interrupt
STX	Start of text
ETX	End of text
EOT	End of transmission

Continued on next page

Table 3 – continued from previous page

Name	Meaning
ENQ	Enquiry, goes with ACK flow control
ACK	Acknowledgement
BEL	Bell
BS	Backspace
TAB	Tab
HT	Alias for TAB: "Horizontal tab"
LF	Line feed
NL	Alias for LF: "New line"
VT	Vertical tab
FF	Form feed
CR	Carriage return
SO	Shift-out, begin alternate character set
SI	Shift-in, resume default character set
DLE	Data-link escape
DC1	XON, for flow control
DC2	Device control 2, block-mode flow control
DC3	XOFF, for flow control
DC4	Device control 4
NAK	Negative acknowledgement
SYN	Synchronous idle
ETB	End transmission block
CAN	Cancel
EM	End of medium
SUB	Substitute
ESC	Escape
FS	File separator
GS	Group separator
RS	Record separator, block-mode terminator
US	Unit separator
SP	Space
DEL	Delete

Note that many of these have little practical significance in modern usage. The mnemonics derive from teleprinter conventions that predate digital computers.

The module supplies the following functions, patterned on those in the standard C library:

curses.ascii.isalnum(*c*)
Checks for an ASCII alphanumeric character; it is equivalent to `isalpha(c) or isdigit(c)`.

curses.ascii.isalpha(*c*)
Checks for an ASCII alphabetic character; it is equivalent to `isupper(c) or islower(c)`.

curses.ascii.isascii(*c*)
Checks for a character value that fits in the 7-bit ASCII set.

curses.ascii.isblank(*c*)
Checks for an ASCII whitespace character; space or horizontal tab.

curses.ascii.iscntrl(*c*)
Checks for an ASCII control character (in the range 0x00 to 0x1f or 0x7f).

curses.ascii.isdigit(*c*)
Checks for an ASCII decimal digit, `'0'` through `'9'`. This is equivalent to `c in string.digits`.

curses.ascii.**isgraph**(*c*)
Checks for ASCII any printable character except space.

curses.ascii.**islower**(*c*)
Checks for an ASCII lower-case character.

curses.ascii.**isprint**(*c*)
Checks for any ASCII printable character including space.

curses.ascii.**ispunct**(*c*)
Checks for any printable ASCII character which is not a space or an alphanumeric character.

curses.ascii.**isspace**(*c*)
Checks for ASCII white-space characters; space, line feed, carriage return, form feed, horizontal tab, vertical tab.

curses.ascii.**isupper**(*c*)
Checks for an ASCII uppercase letter.

curses.ascii.**isxdigit**(*c*)
Checks for an ASCII hexadecimal digit. This is equivalent to `c in string.hexdigits`.

curses.ascii.**isctrl**(*c*)
Checks for an ASCII control character (ordinal values 0 to 31).

curses.ascii.**ismeta**(*c*)
Checks for a non-ASCII character (ordinal values 0x80 and above).

These functions accept either integers or single-character strings; when the argument is a string, it is first converted using the built-in function *ord()*.

Note that all these functions check ordinal bit values derived from the character of the string you pass in; they do not actually know anything about the host machine's character encoding.

The following two functions take either a single-character string or integer byte value; they return a value of the same type.

curses.ascii.**ascii**(*c*)
Return the ASCII value corresponding to the low 7 bits of *c*.

curses.ascii.**ctrl**(*c*)
Return the control character corresponding to the given character (the character bit value is bitwise-anded with 0x1f).

curses.ascii.**alt**(*c*)
Return the 8-bit character corresponding to the given ASCII character (the character bit value is bitwise-ored with 0x80).

The following function takes either a single-character string or integer value; it returns a string.

curses.ascii.**unctrl**(*c*)
Return a string representation of the ASCII character *c*. If *c* is printable, this string is the character itself. If the character is a control character (0x00–0x1f) the string consists of a caret (`'^'`) followed by the corresponding uppercase letter. If the character is an ASCII delete (0x7f) the string is `'^?'`. If the character has its meta bit (0x80) set, the meta bit is stripped, the preceding rules applied, and `'!'` prepended to the result.

curses.ascii.**controlnames**
A 33-element string array that contains the ASCII mnemonics for the thirty-two ASCII control characters from 0 (NUL) to 0x1f (US), in order, plus the mnemonic `SP` for the space character.

16.13 curses.panel — A panel stack extension for curses

Panels are windows with the added feature of depth, so they can be stacked on top of each other, and only the visible portions of each window will be displayed. Panels can be added, moved up or down in the stack, and removed.

16.13.1 Functions

The module *curses.panel* defines the following functions:

curses.panel.bottom_panel()
Returns the bottom panel in the panel stack.

curses.panel.new_panel(*win*)
Returns a panel object, associating it with the given window *win*. Be aware that you need to keep the returned panel object referenced explicitly. If you don't, the panel object is garbage collected and removed from the panel stack.

curses.panel.top_panel()
Returns the top panel in the panel stack.

curses.panel.update_panels()
Updates the virtual screen after changes in the panel stack. This does not call *curses.doupdate()*, so you'll have to do this yourself.

16.13.2 Panel Objects

Panel objects, as returned by *new_panel()* above, are windows with a stacking order. There's always a window associated with a panel which determines the content, while the panel methods are responsible for the window's depth in the panel stack.

Panel objects have the following methods:

Panel.above()
Returns the panel above the current panel.

Panel.below()
Returns the panel below the current panel.

Panel.bottom()
Push the panel to the bottom of the stack.

Panel.hidden()
Returns `True` if the panel is hidden (not visible), `False` otherwise.

Panel.hide()
Hide the panel. This does not delete the object, it just makes the window on screen invisible.

Panel.move(*y*, *x*)
Move the panel to the screen coordinates `(y, x)`.

Panel.replace(*win*)
Change the window associated with the panel to the window *win*.

Panel.set_userptr(*obj*)
Set the panel's user pointer to *obj*. This is used to associate an arbitrary piece of data with the panel, and can be any Python object.

`Panel.show()`
Display the panel (which might have been hidden).

`Panel.top()`
Push panel to the top of the stack.

`Panel.userptr()`
Returns the user pointer for the panel. This might be any Python object.

`Panel.window()`
Returns the window object associated with the panel.

16.14 `platform` — Access to underlying platform's identifying data

Source code: Lib/platform.py

Note: Specific platforms listed alphabetically, with Linux included in the Unix section.

16.14.1 Cross Platform

`platform.architecture(`*executable=sys.executable*, *bits=''*, *linkage=''*`)`
Queries the given executable (defaults to the Python interpreter binary) for various architecture information.

Returns a tuple `(bits, linkage)` which contain information about the bit architecture and the linkage format used for the executable. Both values are returned as strings.

Values that cannot be determined are returned as given by the parameter presets. If bits is given as `''`, the `sizeof(pointer)` (or `sizeof(long)` on Python version < 1.5.2) is used as indicator for the supported pointer size.

The function relies on the system's `file` command to do the actual work. This is available on most if not all Unix platforms and some non-Unix platforms and then only if the executable points to the Python interpreter. Reasonable defaults are used when the above needs are not met.

Note: On Mac OS X (and perhaps other platforms), executable files may be universal files containing multiple architectures.

To get at the "64-bitness" of the current interpreter, it is more reliable to query the *sys.maxsize* attribute:

```
is_64bits = sys.maxsize > 2**32
```

`platform.machine()`
Returns the machine type, e.g. `'i386'`. An empty string is returned if the value cannot be determined.

`platform.node()`
Returns the computer's network name (may not be fully qualified!). An empty string is returned if the value cannot be determined.

`platform.platform(`*aliased=0*, *terse=0*`)`
Returns a single string identifying the underlying platform with as much useful information as possible.

The output is intended to be *human readable* rather than machine parseable. It may look different on different platforms and this is intended.

If *aliased* is true, the function will use aliases for various platforms that report system names which differ from their common names, for example SunOS will be reported as Solaris. The *system_alias()* function is used to implement this.

Setting *terse* to true causes the function to return only the absolute minimum information needed to identify the platform.

platform.processor()
Returns the (real) processor name, e.g. 'amdk6'.

An empty string is returned if the value cannot be determined. Note that many platforms do not provide this information or simply return the same value as for *machine()*. NetBSD does this.

platform.python_build()
Returns a tuple (buildno, builddate) stating the Python build number and date as strings.

platform.python_compiler()
Returns a string identifying the compiler used for compiling Python.

platform.python_branch()
Returns a string identifying the Python implementation SCM branch.

platform.python_implementation()
Returns a string identifying the Python implementation. Possible return values are: 'CPython', 'IronPython', 'Jython', 'PyPy'.

platform.python_revision()
Returns a string identifying the Python implementation SCM revision.

platform.python_version()
Returns the Python version as string 'major.minor.patchlevel'.

Note that unlike the Python sys.version, the returned value will always include the patchlevel (it defaults to 0).

platform.python_version_tuple()
Returns the Python version as tuple (major, minor, patchlevel) of strings.

Note that unlike the Python sys.version, the returned value will always include the patchlevel (it defaults to '0').

platform.release()
Returns the system's release, e.g. '2.2.0' or 'NT' An empty string is returned if the value cannot be determined.

platform.system()
Returns the system/OS name, e.g. 'Linux', 'Windows', or 'Java'. An empty string is returned if the value cannot be determined.

platform.system_alias(*system*, *release*, *version*)
Returns (system, release, version) aliased to common marketing names used for some systems. It also does some reordering of the information in some cases where it would otherwise cause confusion.

platform.version()
Returns the system's release version, e.g. '#3 on degas'. An empty string is returned if the value cannot be determined.

platform.uname()
Fairly portable uname interface. Returns a *namedtuple()* containing six attributes: *system*, *node*, *release*, *version*, *machine*, and *processor*.

Note that this adds a sixth attribute (*processor*) not present in the *os.uname()* result. Also, the attribute names are different for the first two attributes; *os.uname()* names them `sysname` and `nodename`.

Entries which cannot be determined are set to `''`.

Changed in version 3.3: Result changed from a tuple to a namedtuple.

16.14.2 Java Platform

`platform.java_ver`(*release=''*, *vendor=''*, *vminfo=('', '', '')*, *osinfo=('', '', '')*)

Version interface for Jython.

Returns a tuple `(release, vendor, vminfo, osinfo)` with *vminfo* being a tuple `(vm_name, vm_release, vm_vendor)` and *osinfo* being a tuple `(os_name, os_version, os_arch)`. Values which cannot be determined are set to the defaults given as parameters (which all default to `''`).

16.14.3 Windows Platform

`platform.win32_ver`(*release=''*, *version=''*, *csd=''*, *ptype=''*)

Get additional version information from the Windows Registry and return a tuple `(release, version, csd, ptype)` referring to OS release, version number, CSD level (service pack) and OS type (multi/single processor).

As a hint: *ptype* is `'Uniprocessor Free'` on single processor NT machines and `'Multiprocessor Free'` on multi processor machines. The *'Free'* refers to the OS version being free of debugging code. It could also state *'Checked'* which means the OS version uses debugging code, i.e. code that checks arguments, ranges, etc.

Note: This function works best with Mark Hammond's `win32all` package installed, but also on Python 2.3 and later (support for this was added in Python 2.6). It obviously only runs on Win32 compatible platforms.

Win95/98 specific

`platform.popen`(*cmd*, *mode='r'*, *bufsize=-1*)

Portable *popen()* interface. Find a working popen implementation preferring `win32pipe.popen()`. On Windows NT, `win32pipe.popen()` should work; on Windows 9x it hangs due to bugs in the MS C library.

Deprecated since version 3.3: This function is obsolete. Use the *subprocess* module. Check especially the *Replacing Older Functions with the subprocess Module* section.

16.14.4 Mac OS Platform

`platform.mac_ver`(*release=''*, *versioninfo=('', '', '')*, *machine=''*)

Get Mac OS version information and return it as tuple `(release, versioninfo, machine)` with *versioninfo* being a tuple `(version, dev_stage, non_release_version)`.

Entries which cannot be determined are set to `''`. All tuple entries are strings.

16.14.5 Unix Platforms

`platform.dist`(*distname=''*, *version=''*, *id=''*, *supported_dists=('SuSE', 'debian', 'redhat', 'mandrake', ...)*)
This is another name for *linux_distribution()*.

Deprecated since version 3.5, will be removed in version 3.8: See alternative like the distro package.

`platform.linux_distribution`(*distname=''*, *version=''*, *id=''*, *supported_dists=('SuSE', 'debian', 'redhat', 'mandrake', ...)*, *full_distribution_name=1*)
Tries to determine the name of the Linux OS distribution name.

`supported_dists` may be given to define the set of Linux distributions to look for. It defaults to a list of currently supported Linux distributions identified by their release file name.

If `full_distribution_name` is true (default), the full distribution read from the OS is returned. Otherwise the short name taken from `supported_dists` is used.

Returns a tuple `(distname,version,id)` which defaults to the args given as parameters. `id` is the item in parentheses after the version number. It is usually the version codename.

Deprecated since version 3.5, will be removed in version 3.8: See alternative like the distro package.

`platform.libc_ver`(*executable=sys.executable*, *lib=''*, *version=''*, *chunksize=2048*)
Tries to determine the libc version against which the file executable (defaults to the Python interpreter) is linked. Returns a tuple of strings `(lib, version)` which default to the given parameters in case the lookup fails.

Note that this function has intimate knowledge of how different libc versions add symbols to the executable is probably only usable for executables compiled using `gcc`.

The file is read and scanned in chunks of *chunksize* bytes.

16.15 `errno` — Standard errno system symbols

This module makes available standard `errno` system symbols. The value of each symbol is the corresponding integer value. The names and descriptions are borrowed from `linux/include/errno.h`, which should be pretty all-inclusive.

`errno.errorcode`
Dictionary providing a mapping from the errno value to the string name in the underlying system. For instance, `errno.errorcode[errno.EPERM]` maps to `'EPERM'`.

To translate a numeric error code to an error message, use *os.strerror()*.

Of the following list, symbols that are not used on the current platform are not defined by the module. The specific list of defined symbols is available as `errno.errorcode.keys()`. Symbols available can include:

`errno.EPERM`
Operation not permitted

`errno.ENOENT`
No such file or directory

`errno.ESRCH`
No such process

`errno.EINTR`
Interrupted system call.

See also:

This error is mapped to the exception *InterruptedError*.

errno.**EIO**
I/O error

errno.**ENXIO**
No such device or address

errno.**E2BIG**
Arg list too long

errno.**ENOEXEC**
Exec format error

errno.**EBADF**
Bad file number

errno.**ECHILD**
No child processes

errno.**EAGAIN**
Try again

errno.**ENOMEM**
Out of memory

errno.**EACCES**
Permission denied

errno.**EFAULT**
Bad address

errno.**ENOTBLK**
Block device required

errno.**EBUSY**
Device or resource busy

errno.**EEXIST**
File exists

errno.**EXDEV**
Cross-device link

errno.**ENODEV**
No such device

errno.**ENOTDIR**
Not a directory

errno.**EISDIR**
Is a directory

errno.**EINVAL**
Invalid argument

errno.**ENFILE**
File table overflow

errno.**EMFILE**
Too many open files

errno.**ENOTTY**
Not a typewriter

errno.**ETXTBSY**
Text file busy

errno.**EFBIG**
File too large

errno.**ENOSPC**
No space left on device

errno.**ESPIPE**
Illegal seek

errno.**EROFS**
Read-only file system

errno.**EMLINK**
Too many links

errno.**EPIPE**
Broken pipe

errno.**EDOM**
Math argument out of domain of func

errno.**ERANGE**
Math result not representable

errno.**EDEADLK**
Resource deadlock would occur

errno.**ENAMETOOLONG**
File name too long

errno.**ENOLCK**
No record locks available

errno.**ENOSYS**
Function not implemented

errno.**ENOTEMPTY**
Directory not empty

errno.**ELOOP**
Too many symbolic links encountered

errno.**EWOULDBLOCK**
Operation would block

errno.**ENOMSG**
No message of desired type

errno.**EIDRM**
Identifier removed

errno.**ECHRNG**
Channel number out of range

errno.**EL2NSYNC**
Level 2 not synchronized

errno.**EL3HLT**
Level 3 halted

errno.**EL3RST**
Level 3 reset

errno.**ELNRNG**
Link number out of range

errno.**EUNATCH**
Protocol driver not attached

errno.**ENOCSI**
No CSI structure available

errno.**EL2HLT**
Level 2 halted

errno.**EBADE**
Invalid exchange

errno.**EBADR**
Invalid request descriptor

errno.**EXFULL**
Exchange full

errno.**ENOANO**
No anode

errno.**EBADRQC**
Invalid request code

errno.**EBADSLT**
Invalid slot

errno.**EDEADLOCK**
File locking deadlock error

errno.**EBFONT**
Bad font file format

errno.**ENOSTR**
Device not a stream

errno.**ENODATA**
No data available

errno.**ETIME**
Timer expired

errno.**ENOSR**
Out of streams resources

errno.**ENONET**
Machine is not on the network

errno.**ENOPKG**
Package not installed

errno.**EREMOTE**
Object is remote

errno.**ENOLINK**
Link has been severed

errno.**EADV**
Advertise error

errno.**ESRMNT**
Srmount error

errno.**ECOMM**
Communication error on send

errno.**EPROTO**
Protocol error

errno.**EMULTIHOP**
Multihop attempted

errno.**EDOTDOT**
RFS specific error

errno.**EBADMSG**
Not a data message

errno.**EOVERFLOW**
Value too large for defined data type

errno.**ENOTUNIQ**
Name not unique on network

errno.**EBADFD**
File descriptor in bad state

errno.**EREMCHG**
Remote address changed

errno.**ELIBACC**
Can not access a needed shared library

errno.**ELIBBAD**
Accessing a corrupted shared library

errno.**ELIBSCN**
.lib section in a.out corrupted

errno.**ELIBMAX**
Attempting to link in too many shared libraries

errno.**ELIBEXEC**
Cannot exec a shared library directly

errno.**EILSEQ**
Illegal byte sequence

errno.**ERESTART**
Interrupted system call should be restarted

errno.**ESTRPIPE**
Streams pipe error

errno.**EUSERS**
Too many users

errno.**ENOTSOCK**
Socket operation on non-socket

errno.**EDESTADDRREQ**
Destination address required

errno.**EMSGSIZE**
Message too long

errno.**EPROTOTYPE**
Protocol wrong type for socket

errno.**ENOPROTOOPT**
Protocol not available

errno.**EPROTONOSUPPORT**
Protocol not supported

errno.**ESOCKTNOSUPPORT**
Socket type not supported

errno.**EOPNOTSUPP**
Operation not supported on transport endpoint

errno.**EPFNOSUPPORT**
Protocol family not supported

errno.**EAFNOSUPPORT**
Address family not supported by protocol

errno.**EADDRINUSE**
Address already in use

errno.**EADDRNOTAVAIL**
Cannot assign requested address

errno.**ENETDOWN**
Network is down

errno.**ENETUNREACH**
Network is unreachable

errno.**ENETRESET**
Network dropped connection because of reset

errno.**ECONNABORTED**
Software caused connection abort

errno.**ECONNRESET**
Connection reset by peer

errno.**ENOBUFS**
No buffer space available

errno.**EISCONN**
Transport endpoint is already connected

errno.**ENOTCONN**
Transport endpoint is not connected

errno.**ESHUTDOWN**
Cannot send after transport endpoint shutdown

errno.**ETOOMANYREFS**
Too many references: cannot splice

errno.**ETIMEDOUT**
Connection timed out

errno.**ECONNREFUSED**
Connection refused

errno.**EHOSTDOWN**
Host is down

errno.**EHOSTUNREACH**
No route to host

errno.**EALREADY**
Operation already in progress

errno.EINPROGRESS
Operation now in progress

errno.ESTALE
Stale NFS file handle

errno.EUCLEAN
Structure needs cleaning

errno.ENOTNAM
Not a XENIX named type file

errno.ENAVAIL
No XENIX semaphores available

errno.EISNAM
Is a named type file

errno.EREMOTEIO
Remote I/O error

errno.EDQUOT
Quota exceeded

16.16 ctypes — A foreign function library for Python

ctypes is a foreign function library for Python. It provides C compatible data types, and allows calling functions in DLLs or shared libraries. It can be used to wrap these libraries in pure Python.

16.16.1 ctypes tutorial

Note: The code samples in this tutorial use *doctest* to make sure that they actually work. Since some code samples behave differently under Linux, Windows, or Mac OS X, they contain doctest directives in comments.

Note: Some code samples reference the ctypes *c_int* type. On platforms where `sizeof(long) == sizeof(int)` it is an alias to *c_long*. So, you should not be confused if *c_long* is printed if you would expect *c_int* — they are actually the same type.

Loading dynamic link libraries

ctypes exports the *cdll*, and on Windows *windll* and *oledll* objects, for loading dynamic link libraries.

You load libraries by accessing them as attributes of these objects. *cdll* loads libraries which export functions using the standard `cdecl` calling convention, while *windll* libraries call functions using the `stdcall` calling convention. *oledll* also uses the `stdcall` calling convention, and assumes the functions return a Windows `HRESULT` error code. The error code is used to automatically raise an *OSError* exception when the function call fails.

Changed in version 3.3: Windows errors used to raise *WindowsError*, which is now an alias of *OSError*.

Here are some examples for Windows. Note that `msvcrt` is the MS standard C library containing most standard C functions, and uses the cdecl calling convention:

```
>>> from ctypes import *
>>> print(windll.kernel32)
<WinDLL 'kernel32', handle ... at ...>
>>> print(cdll.msvcrt)
<CDLL 'msvcrt', handle ... at ...>
>>> libc = cdll.msvcrt
>>>
```

Windows appends the usual `.dll` file suffix automatically.

Note: Accessing the standard C library through `cdll.msvcrt` will use an outdated version of the library that may be incompatible with the one being used by Python. Where possible, use native Python functionality, or else import and use the `msvcrt` module.

On Linux, it is required to specify the filename *including* the extension to load a library, so attribute access can not be used to load libraries. Either the `LoadLibrary()` method of the dll loaders should be used, or you should load the library by creating an instance of CDLL by calling the constructor:

```
>>> cdll.LoadLibrary("libc.so.6")
<CDLL 'libc.so.6', handle ... at ...>
>>> libc = CDLL("libc.so.6")
>>> libc
<CDLL 'libc.so.6', handle ... at ...>
>>>
```

Accessing functions from loaded dlls

Functions are accessed as attributes of dll objects:

```
>>> from ctypes import *
>>> libc.printf
<_FuncPtr object at 0x...>
>>> print(windll.kernel32.GetModuleHandleA)
<_FuncPtr object at 0x...>
>>> print(windll.kernel32.MyOwnFunction)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "ctypes.py", line 239, in __getattr__
    func = _StdcallFuncPtr(name, self)
AttributeError: function 'MyOwnFunction' not found
>>>
```

Note that win32 system dlls like `kernel32` and `user32` often export ANSI as well as UNICODE versions of a function. The UNICODE version is exported with an `W` appended to the name, while the ANSI version is exported with an `A` appended to the name. The win32 `GetModuleHandle` function, which returns a *module handle* for a given module name, has the following C prototype, and a macro is used to expose one of them as `GetModuleHandle` depending on whether UNICODE is defined or not:

```
/* ANSI version */
HMODULE GetModuleHandleA(LPCSTR lpModuleName);
/* UNICODE version */
HMODULE GetModuleHandleW(LPCWSTR lpModuleName);
```

windll does not try to select one of them by magic, you must access the version you need by specifying `GetModuleHandleA` or `GetModuleHandleW` explicitly, and then call it with bytes or string objects respectively.

Sometimes, dlls export functions with names which aren't valid Python identifiers, like `"??2@YAPAXI@Z"`. In this case you have to use *getattr()* to retrieve the function:

```
>>> getattr(cdll.msvcrt, "??2@YAPAXI@Z")
<_FuncPtr object at 0x...>
>>>
```

On Windows, some dlls export functions not by name but by ordinal. These functions can be accessed by indexing the dll object with the ordinal number:

```
>>> cdll.kernel32[1]
<_FuncPtr object at 0x...>
>>> cdll.kernel32[0]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "ctypes.py", line 310, in __getitem__
    func = _StdcallFuncPtr(name, self)
AttributeError: function ordinal 0 not found
>>>
```

Calling functions

You can call these functions like any other Python callable. This example uses the `time()` function, which returns system time in seconds since the Unix epoch, and the `GetModuleHandleA()` function, which returns a win32 module handle.

This example calls both functions with a NULL pointer (`None` should be used as the NULL pointer):

```
>>> print(libc.time(None))
1150640792
>>> print(hex(windll.kernel32.GetModuleHandleA(None)))
0x1d000000
>>>
```

Note: *ctypes* may raise a *ValueError* after calling the function, if it detects that an invalid number of arguments were passed. This behavior should not be relied upon. It is deprecated in 3.6.2, and will be removed in 3.7.

ValueError is raised when you call an `stdcall` function with the `cdecl` calling convention, or vice versa:

```
>>> cdll.kernel32.GetModuleHandleA(None)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: Procedure probably called with not enough arguments (4 bytes missing)
>>>

>>> windll.msvcrt.printf(b"spam")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: Procedure probably called with too many arguments (4 bytes in excess)
>>>
```

To find out the correct calling convention you have to look into the C header file or the documentation for the function you want to call.

On Windows, *ctypes* uses win32 structured exception handling to prevent crashes from general protection faults when functions are called with invalid argument values:

```
>>> windll.kernel32.GetModuleHandleA(32)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
OSError: exception: access violation reading 0x00000020
>>>
```

There are, however, enough ways to crash Python with *ctypes*, so you should be careful anyway. The *faulthandler* module can be helpful in debugging crashes (e.g. from segmentation faults produced by erroneous C library calls).

`None`, integers, bytes objects and (unicode) strings are the only native Python objects that can directly be used as parameters in these function calls. `None` is passed as a C `NULL` pointer, bytes objects and strings are passed as pointer to the memory block that contains their data (`char *` or `wchar_t *`). Python integers are passed as the platforms default C `int` type, their value is masked to fit into the C type.

Before we move on calling functions with other parameter types, we have to learn more about *ctypes* data types.

Fundamental data types

ctypes defines a number of primitive C compatible data types:

ctypes type	C type	Python type
c_bool	_Bool	bool (1)
c_char	char	1-character bytes object
c_wchar	wchar_t	1-character string
c_byte	char	int
c_ubyte	unsigned char	int
c_short	short	int
c_ushort	unsigned short	int
c_int	int	int
c_uint	unsigned int	int
c_long	long	int
c_ulong	unsigned long	int
c_longlong	__int64 or long long	int
c_ulonglong	unsigned __int64 or unsigned long long	int
c_size_t	size_t	int
c_ssize_t	ssize_t or Py_ssize_t	int
c_float	float	float
c_double	double	float
c_longdouble	long double	float
c_char_p	char * (NUL terminated)	bytes object or None
c_wchar_p	wchar_t * (NUL terminated)	string or None
c_void_p	void *	int or None

1. The constructor accepts any object with a truth value.

All these types can be created by calling them with an optional initializer of the correct type and value:

```
>>> c_int()
c_long(0)
>>> c_wchar_p("Hello, World")
```

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```
c_wchar_p(140018365411392)
>>> c_ushort(-3)
c_ushort(65533)
>>>
```

Since these types are mutable, their value can also be changed afterwards:

```
>>> i = c_int(42)
>>> print(i)
c_long(42)
>>> print(i.value)
42
>>> i.value = -99
>>> print(i.value)
-99
>>>
```

Assigning a new value to instances of the pointer types *c_char_p*, *c_wchar_p*, and *c_void_p* changes the *memory location* they point to, *not the contents* of the memory block (of course not, because Python bytes objects are immutable):

```
>>> s = "Hello, World"
>>> c_s = c_wchar_p(s)
>>> print(c_s)
c_wchar_p(139966785747344)
>>> print(c_s.value)
Hello World
>>> c_s.value = "Hi, there"
>>> print(c_s)              # the memory location has changed
c_wchar_p(139966783348904)
>>> print(c_s.value)
Hi, there
>>> print(s)                # first object is unchanged
Hello, World
>>>
```

You should be careful, however, not to pass them to functions expecting pointers to mutable memory. If you need mutable memory blocks, ctypes has a *create_string_buffer()* function which creates these in various ways. The current memory block contents can be accessed (or changed) with the `raw` property; if you want to access it as NUL terminated string, use the `value` property:

```
>>> from ctypes import *
>>> p = create_string_buffer(3)            # create a 3 byte buffer, initialized to NUL bytes
>>> print(sizeof(p), repr(p.raw))
3 b'\x00\x00\x00'
>>> p = create_string_buffer(b"Hello")     # create a buffer containing a NUL terminated string
>>> print(sizeof(p), repr(p.raw))
6 b'Hello\x00'
>>> print(repr(p.value))
b'Hello'
>>> p = create_string_buffer(b"Hello", 10) # create a 10 byte buffer
>>> print(sizeof(p), repr(p.raw))
10 b'Hello\x00\x00\x00\x00\x00'
>>> p.value = b"Hi"
>>> print(sizeof(p), repr(p.raw))
10 b'Hi\x00lo\x00\x00\x00\x00\x00'
>>>
```

The *create_string_buffer()* function replaces the `c_buffer()` function (which is still available as an alias), as well as the `c_string()` function from earlier ctypes releases. To create a mutable memory block containing unicode characters of the C type `wchar_t` use the *create_unicode_buffer()* function.

Calling functions, continued

Note that printf prints to the real standard output channel, *not* to *sys.stdout*, so these examples will only work at the console prompt, not from within *IDLE* or *PythonWin*:

```
>>> printf = libc.printf
>>> printf(b"Hello, %s\n", b"World!")
Hello, World!
14
>>> printf(b"Hello, %S\n", "World!")
Hello, World!
14
>>> printf(b"%d bottles of beer\n", 42)
42 bottles of beer
19
>>> printf(b"%f bottles of beer\n", 42.5)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ArgumentError: argument 2: exceptions.TypeError: Don't know how to convert parameter 2
>>>
```

As has been mentioned before, all Python types except integers, strings, and bytes objects have to be wrapped in their corresponding *ctypes* type, so that they can be converted to the required C data type:

```
>>> printf(b"An int %d, a double %f\n", 1234, c_double(3.14))
An int 1234, a double 3.140000
31
>>>
```

Calling functions with your own custom data types

You can also customize *ctypes* argument conversion to allow instances of your own classes be used as function arguments. *ctypes* looks for an `_as_parameter_` attribute and uses this as the function argument. Of course, it must be one of integer, string, or bytes:

```
>>> class Bottles:
...     def __init__(self, number):
...         self._as_parameter_ = number
...
>>> bottles = Bottles(42)
>>> printf(b"%d bottles of beer\n", bottles)
42 bottles of beer
19
>>>
```

If you don't want to store the instance's data in the `_as_parameter_` instance variable, you could define a *property* which makes the attribute available on request.

Specifying the required argument types (function prototypes)

It is possible to specify the required argument types of functions exported from DLLs by setting the `argtypes` attribute.

`argtypes` must be a sequence of C data types (the `printf` function is probably not a good example here, because it takes a variable number and different types of parameters depending on the format string, on the other hand this is quite handy to experiment with this feature):

```
>>> printf.argtypes = [c_char_p, c_char_p, c_int, c_double]
>>> printf(b"String '%s', Int %d, Double %f\n", b"Hi", 10, 2.2)
String 'Hi', Int 10, Double 2.200000
37
>>>
```

Specifying a format protects against incompatible argument types (just as a prototype for a C function), and tries to convert the arguments to valid types:

```
>>> printf(b"%d %d %d", 1, 2, 3)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ArgumentError: argument 2: exceptions.TypeError: wrong type
>>> printf(b"%s %d %f\n", b"X", 2, 3)
X 2 3.000000
13
>>>
```

If you have defined your own classes which you pass to function calls, you have to implement a `from_param()` class method for them to be able to use them in the `argtypes` sequence. The `from_param()` class method receives the Python object passed to the function call, it should do a typecheck or whatever is needed to make sure this object is acceptable, and then return the object itself, its `_as_parameter_` attribute, or whatever you want to pass as the C function argument in this case. Again, the result should be an integer, string, bytes, a *ctypes* instance, or an object with an `_as_parameter_` attribute.

Return types

By default functions are assumed to return the C `int` type. Other return types can be specified by setting the `restype` attribute of the function object.

Here is a more advanced example, it uses the `strchr` function, which expects a string pointer and a char, and returns a pointer to a string:

```
>>> strchr = libc.strchr
>>> strchr(b"abcdef", ord("d"))
8059983
>>> strchr.restype = c_char_p    # c_char_p is a pointer to a string
>>> strchr(b"abcdef", ord("d"))
b'def'
>>> print(strchr(b"abcdef", ord("x")))
None
>>>
```

If you want to avoid the `ord("x")` calls above, you can set the `argtypes` attribute, and the second argument will be converted from a single character Python bytes object into a C char:

```
>>> strchr.restype = c_char_p
>>> strchr.argtypes = [c_char_p, c_char]
```

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```
>>> strchr(b"abcdef", b"d")
'def'
>>> strchr(b"abcdef", b"def")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ArgumentError: argument 2: exceptions.TypeError: one character string expected
>>> print(strchr(b"abcdef", b"x"))
None
>>> strchr(b"abcdef", b"d")
'def'
>>>
```

You can also use a callable Python object (a function or a class for example) as the `restype` attribute, if the foreign function returns an integer. The callable will be called with the *integer* the C function returns, and the result of this call will be used as the result of your function call. This is useful to check for error return values and automatically raise an exception:

```
>>> GetModuleHandle = windll.kernel32.GetModuleHandleA
>>> def ValidHandle(value):
...     if value == 0:
...         raise WinError()
...     return value
...
>>>
>>> GetModuleHandle.restype = ValidHandle
>>> GetModuleHandle(None)
486539264
>>> GetModuleHandle("something silly")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 3, in ValidHandle
OSError: [Errno 126] The specified module could not be found.
>>>
```

`WinError` is a function which will call Windows `FormatMessage()` api to get the string representation of an error code, and *returns* an exception. `WinError` takes an optional error code parameter, if no one is used, it calls *`GetLastError()`* to retrieve it.

Please note that a much more powerful error checking mechanism is available through the `errcheck` attribute; see the reference manual for details.

Passing pointers (or: passing parameters by reference)

Sometimes a C api function expects a *pointer* to a data type as parameter, probably to write into the corresponding location, or if the data is too large to be passed by value. This is also known as *passing parameters by reference*.

`ctypes` exports the *`byref()`* function which is used to pass parameters by reference. The same effect can be achieved with the *`pointer()`* function, although *`pointer()`* does a lot more work since it constructs a real pointer object, so it is faster to use *`byref()`* if you don't need the pointer object in Python itself:

```
>>> i = c_int()
>>> f = c_float()
>>> s = create_string_buffer(b'\000' * 32)
>>> print(i.value, f.value, repr(s.value))
0 0.0 b''
```

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```
>>> libc.sscanf(b"1 3.14 Hello", b"%d %f %s",
...             byref(i), byref(f), s)
3
>>> print(i.value, f.value, repr(s.value))
1 3.1400001049 b'Hello'
>>>
```

Structures and unions

Structures and unions must derive from the *Structure* and *Union* base classes which are defined in the *ctypes* module. Each subclass must define a `_fields_` attribute. `_fields_` must be a list of *2-tuples*, containing a *field name* and a *field type*.

The field type must be a *ctypes* type like *c_int*, or any other derived *ctypes* type: structure, union, array, pointer.

Here is a simple example of a POINT structure, which contains two integers named *x* and *y*, and also shows how to initialize a structure in the constructor:

```
>>> from ctypes import *
>>> class POINT(Structure):
...     _fields_ = [("x", c_int),
...                 ("y", c_int)]
...
>>> point = POINT(10, 20)
>>> print(point.x, point.y)
10 20
>>> point = POINT(y=5)
>>> print(point.x, point.y)
0 5
>>> POINT(1, 2, 3)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: too many initializers
>>>
```

You can, however, build much more complicated structures. A structure can itself contain other structures by using a structure as a field type.

Here is a RECT structure which contains two POINTs named *upperleft* and *lowerright*:

```
>>> class RECT(Structure):
...     _fields_ = [("upperleft", POINT),
...                 ("lowerright", POINT)]
...
>>> rc = RECT(point)
>>> print(rc.upperleft.x, rc.upperleft.y)
0 5
>>> print(rc.lowerright.x, rc.lowerright.y)
0 0
>>>
```

Nested structures can also be initialized in the constructor in several ways:

```
>>> r = RECT(POINT(1, 2), POINT(3, 4))
>>> r = RECT((1, 2), (3, 4))
```

Field *descriptor*s can be retrieved from the *class*, they are useful for debugging because they can provide useful information:

```
>>> print(POINT.x)
<Field type=c_long, ofs=0, size=4>
>>> print(POINT.y)
<Field type=c_long, ofs=4, size=4>
>>>
```

Warning: *ctypes* does not support passing unions or structures with bit-fields to functions by value. While this may work on 32-bit x86, it's not guaranteed by the library to work in the general case. Unions and structures with bit-fields should always be passed to functions by pointer.

Structure/union alignment and byte order

By default, Structure and Union fields are aligned in the same way the C compiler does it. It is possible to override this behavior be specifying a `_pack_` class attribute in the subclass definition. This must be set to a positive integer and specifies the maximum alignment for the fields. This is what `#pragma pack(n)` also does in MSVC.

ctypes uses the native byte order for Structures and Unions. To build structures with non-native byte order, you can use one of the *BigEndianStructure*, *LittleEndianStructure*, `BigEndianUnion`, and `LittleEndianUnion` base classes. These classes cannot contain pointer fields.

Bit fields in structures and unions

It is possible to create structures and unions containing bit fields. Bit fields are only possible for integer fields, the bit width is specified as the third item in the `_fields_` tuples:

```
>>> class Int(Structure):
...     _fields_ = [("first_16", c_int, 16),
...                 ("second_16", c_int, 16)]
...
>>> print(Int.first_16)
<Field type=c_long, ofs=0:0, bits=16>
>>> print(Int.second_16)
<Field type=c_long, ofs=0:16, bits=16>
>>>
```

Arrays

Arrays are sequences, containing a fixed number of instances of the same type.

The recommended way to create array types is by multiplying a data type with a positive integer:

```
TenPointsArrayType = POINT * 10
```

Here is an example of a somewhat artificial data type, a structure containing 4 POINTs among other stuff:

```
>>> from ctypes import *
>>> class POINT(Structure):
...     _fields_ = ("x", c_int), ("y", c_int)
...
```

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```
>>> class MyStruct(Structure):
...     _fields_ = [("a", c_int),
...                 ("b", c_float),
...                 ("point_array", POINT * 4)]
>>>
>>> print(len(MyStruct().point_array))
4
>>>
```

Instances are created in the usual way, by calling the class:

```
arr = TenPointsArrayType()
for pt in arr:
    print(pt.x, pt.y)
```

The above code print a series of `0 0` lines, because the array contents is initialized to zeros.

Initializers of the correct type can also be specified:

```
>>> from ctypes import *
>>> TenIntegers = c_int * 10
>>> ii = TenIntegers(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
>>> print(ii)
<c_long_Array_10 object at 0x...>
>>> for i in ii: print(i, end=" ")
...
1 2 3 4 5 6 7 8 9 10
>>>
```

Pointers

Pointer instances are created by calling the *pointer()* function on a *ctypes* type:

```
>>> from ctypes import *
>>> i = c_int(42)
>>> pi = pointer(i)
>>>
```

Pointer instances have a *contents* attribute which returns the object to which the pointer points, the `i` object above:

```
>>> pi.contents
c_long(42)
>>>
```

Note that *ctypes* does not have OOR (original object return), it constructs a new, equivalent object each time you retrieve an attribute:

```
>>> pi.contents is i
False
>>> pi.contents is pi.contents
False
>>>
```

Assigning another *c_int* instance to the pointer's contents attribute would cause the pointer to point to the memory location where this is stored:

```
>>> i = c_int(99)
>>> pi.contents = i
>>> pi.contents
c_long(99)
>>>
```

Pointer instances can also be indexed with integers:

```
>>> pi[0]
99
>>>
```

Assigning to an integer index changes the pointed to value:

```
>>> print(i)
c_long(99)
>>> pi[0] = 22
>>> print(i)
c_long(22)
>>>
```

It is also possible to use indexes different from 0, but you must know what you're doing, just as in C: You can access or change arbitrary memory locations. Generally you only use this feature if you receive a pointer from a C function, and you *know* that the pointer actually points to an array instead of a single item.

Behind the scenes, the *pointer()* function does more than simply create pointer instances, it has to create pointer *types* first. This is done with the *POINTER()* function, which accepts any *ctypes* type, and returns a new type:

```
>>> PI = POINTER(c_int)
>>> PI
<class 'ctypes.LP_c_long'>
>>> PI(42)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: expected c_long instead of int
>>> PI(c_int(42))
<ctypes.LP_c_long object at 0x...>
>>>
```

Calling the pointer type without an argument creates a `NULL` pointer. `NULL` pointers have a `False` boolean value:

```
>>> null_ptr = POINTER(c_int)()
>>> print(bool(null_ptr))
False
>>>
```

ctypes checks for `NULL` when dereferencing pointers (but dereferencing invalid non-`NULL` pointers would crash Python):

```
>>> null_ptr[0]
Traceback (most recent call last):
    ....
ValueError: NULL pointer access
>>>
```

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```
>>> null_ptr[0] = 1234
Traceback (most recent call last):
    ....
ValueError: NULL pointer access
>>>
```

Type conversions

Usually, ctypes does strict type checking. This means, if you have `POINTER(c_int)` in the `argtypes` list of a function or as the type of a member field in a structure definition, only instances of exactly the same type are accepted. There are some exceptions to this rule, where ctypes accepts other objects. For example, you can pass compatible array instances instead of pointer types. So, for `POINTER(c_int)`, ctypes accepts an array of c_int:

```
>>> class Bar(Structure):
...     _fields_ = [("count", c_int), ("values", POINTER(c_int))]
...
>>> bar = Bar()
>>> bar.values = (c_int * 3)(1, 2, 3)
>>> bar.count = 3
>>> for i in range(bar.count):
...     print(bar.values[i])
...
1
2
3
>>>
```

In addition, if a function argument is explicitly declared to be a pointer type (such as `POINTER(c_int)`) in `argtypes`, an object of the pointed type (`c_int` in this case) can be passed to the function. ctypes will apply the required *byref()* conversion in this case automatically.

To set a POINTER type field to `NULL`, you can assign `None`:

```
>>> bar.values = None
>>>
```

Sometimes you have instances of incompatible types. In C, you can cast one type into another type. *ctypes* provides a *cast()* function which can be used in the same way. The `Bar` structure defined above accepts `POINTER(c_int)` pointers or *c_int* arrays for its `values` field, but not instances of other types:

```
>>> bar.values = (c_byte * 4)()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: incompatible types, c_byte_Array_4 instance instead of LP_c_long instance
>>>
```

For these cases, the *cast()* function is handy.

The *cast()* function can be used to cast a ctypes instance into a pointer to a different ctypes data type. *cast()* takes two parameters, a ctypes object that is or can be converted to a pointer of some kind, and a ctypes pointer type. It returns an instance of the second argument, which references the same memory block as the first argument:

```
>>> a = (c_byte * 4)()
>>> cast(a, POINTER(c_int))
<ctypes.LP_c_long object at ...>
>>>
```

So, *cast()* can be used to assign to the `values` field of `Bar` the structure:

```
>>> bar = Bar()
>>> bar.values = cast((c_byte * 4)(), POINTER(c_int))
>>> print(bar.values[0])
0
>>>
```

Incomplete Types

Incomplete Types are structures, unions or arrays whose members are not yet specified. In C, they are specified by forward declarations, which are defined later:

```
struct cell; /* forward declaration */

struct cell {
    char *name;
    struct cell *next;
};
```

The straightforward translation into ctypes code would be this, but it does not work:

```
>>> class cell(Structure):
...     _fields_ = [("name", c_char_p),
...                 ("next", POINTER(cell))]
...
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 2, in cell
NameError: name 'cell' is not defined
>>>
```

because the new `class cell` is not available in the class statement itself. In *ctypes*, we can define the `cell` class and set the `_fields_` attribute later, after the class statement:

```
>>> from ctypes import *
>>> class cell(Structure):
...     pass
...
>>> cell._fields_ = [("name", c_char_p),
...                  ("next", POINTER(cell))]
>>>
```

Lets try it. We create two instances of `cell`, and let them point to each other, and finally follow the pointer chain a few times:

```
>>> c1 = cell()
>>> c1.name = "foo"
>>> c2 = cell()
>>> c2.name = "bar"
>>> c1.next = pointer(c2)
```

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```
>>> c2.next = pointer(c1)
>>> p = c1
>>> for i in range(8):
...     print(p.name, end=" ")
...     p = p.next[0]
...
foo bar foo bar foo bar foo bar
>>>
```

Callback functions

ctypes allows creating C callable function pointers from Python callables. These are sometimes called *callback functions*.

First, you must create a class for the callback function. The class knows the calling convention, the return type, and the number and types of arguments this function will receive.

The *CFUNCTYPE()* factory function creates types for callback functions using the `cdecl` calling convention. On Windows, the *WINFUNCTYPE()* factory function creates types for callback functions using the `stdcall` calling convention.

Both of these factory functions are called with the result type as first argument, and the callback functions expected argument types as the remaining arguments.

I will present an example here which uses the standard C library's `qsort()` function, that is used to sort items with the help of a callback function. `qsort()` will be used to sort an array of integers:

```
>>> IntArray5 = c_int * 5
>>> ia = IntArray5(5, 1, 7, 33, 99)
>>> qsort = libc.qsort
>>> qsort.restype = None
>>>
```

`qsort()` must be called with a pointer to the data to sort, the number of items in the data array, the size of one item, and a pointer to the comparison function, the callback. The callback will then be called with two pointers to items, and it must return a negative integer if the first item is smaller than the second, a zero if they are equal, and a positive integer otherwise.

So our callback function receives pointers to integers, and must return an integer. First we create the `type` for the callback function:

```
>>> CMPFUNC = CFUNCTYPE(c_int, POINTER(c_int), POINTER(c_int))
>>>
```

To get started, here is a simple callback that shows the values it gets passed:

```
>>> def py_cmp_func(a, b):
...     print("py_cmp_func", a[0], b[0])
...     return 0
...
>>> cmp_func = CMPFUNC(py_cmp_func)
>>>
```

The result:

```
>>> qsort(ia, len(ia), sizeof(c_int), cmp_func)
py_cmp_func 5 1
py_cmp_func 33 99
py_cmp_func 7 33
py_cmp_func 5 7
py_cmp_func 1 7
>>>
```

Now we can actually compare the two items and return a useful result:

```
>>> def py_cmp_func(a, b):
...     print("py_cmp_func", a[0], b[0])
...     return a[0] - b[0]
...
>>>
>>> qsort(ia, len(ia), sizeof(c_int), CMPFUNC(py_cmp_func))
py_cmp_func 5 1
py_cmp_func 33 99
py_cmp_func 7 33
py_cmp_func 1 7
py_cmp_func 5 7
>>>
```

As we can easily check, our array is sorted now:

```
>>> for i in ia: print(i, end=" ")
...
1 5 7 33 99
>>>
```

Note: Make sure you keep references to *CFUNCTYPE()* objects as long as they are used from C code. *ctypes* doesn't, and if you don't, they may be garbage collected, crashing your program when a callback is made.

Also, note that if the callback function is called in a thread created outside of Python's control (e.g. by the foreign code that calls the callback), ctypes creates a new dummy Python thread on every invocation. This behavior is correct for most purposes, but it means that values stored with *threading.local* will *not* survive across different callbacks, even when those calls are made from the same C thread.

Accessing values exported from dlls

Some shared libraries not only export functions, they also export variables. An example in the Python library itself is the `Py_OptimizeFlag`, an integer set to 0, 1, or 2, depending on the `-O` or `-OO` flag given on startup.

ctypes can access values like this with the `in_dll()` class methods of the type. *pythonapi* is a predefined symbol giving access to the Python C api:

```
>>> opt_flag = c_int.in_dll(pythonapi, "Py_OptimizeFlag")
>>> print(opt_flag)
c_long(0)
>>>
```

If the interpreter would have been started with `-O`, the sample would have printed `c_long(1)`, or `c_long(2)` if `-OO` would have been specified.

An extended example which also demonstrates the use of pointers accesses the `PyImport_FrozenModules` pointer exported by Python.

Quoting the docs for that value:

> This pointer is initialized to point to an array of `struct _frozen` records, terminated by one whose members are all *NULL* or zero. When a frozen module is imported, it is searched in this table. Third-party code could play tricks with this to provide a dynamically created collection of frozen modules.

So manipulating this pointer could even prove useful. To restrict the example size, we show only how this table can be read with *ctypes*:

```
>>> from ctypes import *
>>>
>>> class struct_frozen(Structure):
...     _fields_ = [("name", c_char_p),
...                 ("code", POINTER(c_ubyte)),
...                 ("size", c_int)]
...
>>>
```

We have defined the `struct _frozen` data type, so we can get the pointer to the table:

```
>>> FrozenTable = POINTER(struct_frozen)
>>> table = FrozenTable.in_dll(pythonapi, "PyImport_FrozenModules")
>>>
```

Since `table` is a `pointer` to the array of `struct_frozen` records, we can iterate over it, but we just have to make sure that our loop terminates, because pointers have no size. Sooner or later it would probably crash with an access violation or whatever, so it's better to break out of the loop when we hit the NULL entry:

```
>>> for item in table:
...     if item.name is None:
...         break
...     print(item.name.decode("ascii"), item.size)
...
_frozen_importlib 31764
_frozen_importlib_external 41499
__hello__ 161
__phello__ -161
__phello__.spam 161
>>>
```

The fact that standard Python has a frozen module and a frozen package (indicated by the negative size member) is not well known, it is only used for testing. Try it out with `import __hello__` for example.

Surprises

There are some edges in *ctypes* where you might expect something other than what actually happens.

Consider the following example:

```
>>> from ctypes import *
>>> class POINT(Structure):
...     _fields_ = ("x", c_int), ("y", c_int)
...
>>> class RECT(Structure):
```

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```
...     _fields_ = ("a", POINT), ("b", POINT)
...
>>> p1 = POINT(1, 2)
>>> p2 = POINT(3, 4)
>>> rc = RECT(p1, p2)
>>> print(rc.a.x, rc.a.y, rc.b.x, rc.b.y)
1 2 3 4
>>> # now swap the two points
>>> rc.a, rc.b = rc.b, rc.a
>>> print(rc.a.x, rc.a.y, rc.b.x, rc.b.y)
3 4 3 4
>>>
```

Hm. We certainly expected the last statement to print `3 4 1 2`. What happened? Here are the steps of the `rc.a, rc.b = rc.b, rc.a` line above:

```
>>> temp0, temp1 = rc.b, rc.a
>>> rc.a = temp0
>>> rc.b = temp1
>>>
```

Note that `temp0` and `temp1` are objects still using the internal buffer of the `rc` object above. So executing `rc.a = temp0` copies the buffer contents of `temp0` into `rc` 's buffer. This, in turn, changes the contents of `temp1`. So, the last assignment `rc.b = temp1`, doesn't have the expected effect.

Keep in mind that retrieving sub-objects from Structure, Unions, and Arrays doesn't *copy* the sub-object, instead it retrieves a wrapper object accessing the root-object's underlying buffer.

Another example that may behave different from what one would expect is this:

```
>>> s = c_char_p()
>>> s.value = "abc def ghi"
>>> s.value
'abc def ghi'
>>> s.value is s.value
False
>>>
```

Why is it printing `False`? ctypes instances are objects containing a memory block plus some *descriptor*s accessing the contents of the memory. Storing a Python object in the memory block does not store the object itself, instead the `contents` of the object is stored. Accessing the contents again constructs a new Python object each time!

Variable-sized data types

ctypes provides some support for variable-sized arrays and structures.

The *resize()* function can be used to resize the memory buffer of an existing ctypes object. The function takes the object as first argument, and the requested size in bytes as the second argument. The memory block cannot be made smaller than the natural memory block specified by the objects type, a *ValueError* is raised if this is tried:

```
>>> short_array = (c_short * 4)()
>>> print(sizeof(short_array))
8
>>> resize(short_array, 4)
```

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```
Traceback (most recent call last):
    ...
ValueError: minimum size is 8
>>> resize(short_array, 32)
>>> sizeof(short_array)
32
>>> sizeof(type(short_array))
8
>>>
```

This is nice and fine, but how would one access the additional elements contained in this array? Since the type still only knows about 4 elements, we get errors accessing other elements:

```
>>> short_array[:]
[0, 0, 0, 0]
>>> short_array[7]
Traceback (most recent call last):
    ...
IndexError: invalid index
>>>
```

Another way to use variable-sized data types with *ctypes* is to use the dynamic nature of Python, and (re-)define the data type after the required size is already known, on a case by case basis.

16.16.2 ctypes reference

Finding shared libraries

When programming in a compiled language, shared libraries are accessed when compiling/linking a program, and when the program is run.

The purpose of the `find_library()` function is to locate a library in a way similar to what the compiler or runtime loader does (on platforms with several versions of a shared library the most recent should be loaded), while the ctypes library loaders act like when a program is run, and call the runtime loader directly.

The `ctypes.util` module provides a function which can help to determine the library to load.

`ctypes.util.find_library(`*name*`)`

Try to find a library and return a pathname. *name* is the library name without any prefix like *lib*, suffix like `.so`, `.dylib` or version number (this is the form used for the posix linker option `-l`). If no library can be found, returns `None`.

The exact functionality is system dependent.

On Linux, `find_library()` tries to run external programs (`/sbin/ldconfig`, `gcc`, `objdump` and `ld`) to find the library file. It returns the filename of the library file.

Changed in version 3.6: On Linux, the value of the environment variable `LD_LIBRARY_PATH` is used when searching for libraries, if a library cannot be found by any other means.

Here are some examples:

```
>>> from ctypes.util import find_library
>>> find_library("m")
'libm.so.6'
>>> find_library("c")
'libc.so.6'
```

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```
>>> find_library("bz2")
'libbz2.so.1.0'
>>>
```

On OS X, `find_library()` tries several predefined naming schemes and paths to locate the library, and returns a full pathname if successful:

```
>>> from ctypes.util import find_library
>>> find_library("c")
'/usr/lib/libc.dylib'
>>> find_library("m")
'/usr/lib/libm.dylib'
>>> find_library("bz2")
'/usr/lib/libbz2.dylib'
>>> find_library("AGL")
'/System/Library/Frameworks/AGL.framework/AGL'
>>>
```

On Windows, `find_library()` searches along the system search path, and returns the full pathname, but since there is no predefined naming scheme a call like `find_library("c")` will fail and return `None`.

If wrapping a shared library with *ctypes*, it *may* be better to determine the shared library name at development time, and hardcode that into the wrapper module instead of using `find_library()` to locate the library at runtime.

Loading shared libraries

There are several ways to load shared libraries into the Python process. One way is to instantiate one of the following classes:

class ctypes.CDLL(*name*, *mode=DEFAULT_MODE*, *handle=None*, *use_errno=False*, *use_last_error=False*)

Instances of this class represent loaded shared libraries. Functions in these libraries use the standard C calling convention, and are assumed to return `int`.

class ctypes.OleDLL(*name*, *mode=DEFAULT_MODE*, *handle=None*, *use_errno=False*, *use_last_error=False*)

Windows only: Instances of this class represent loaded shared libraries, functions in these libraries use the `stdcall` calling convention, and are assumed to return the windows specific *HRESULT* code. *HRESULT* values contain information specifying whether the function call failed or succeeded, together with additional error code. If the return value signals a failure, an *OSError* is automatically raised.

Changed in version 3.3: *WindowsError* used to be raised.

class ctypes.WinDLL(*name*, *mode=DEFAULT_MODE*, *handle=None*, *use_errno=False*, *use_last_error=False*)

Windows only: Instances of this class represent loaded shared libraries, functions in these libraries use the `stdcall` calling convention, and are assumed to return `int` by default.

On Windows CE only the standard calling convention is used, for convenience the *WinDLL* and *OleDLL* use the standard calling convention on this platform.

The Python *global interpreter lock* is released before calling any function exported by these libraries, and reacquired afterwards.

class ctypes.PyDLL(*name*, *mode=DEFAULT_MODE*, *handle=None*)

Instances of this class behave like *CDLL* instances, except that the Python GIL is *not* released during the function call, and after the function execution the Python error flag is checked. If the error flag is set, a Python exception is raised.

Thus, this is only useful to call Python C api functions directly.

All these classes can be instantiated by calling them with at least one argument, the pathname of the shared library. If you have an existing handle to an already loaded shared library, it can be passed as the `handle` named parameter, otherwise the underlying platforms `dlopen` or `LoadLibrary` function is used to load the library into the process, and to get a handle to it.

The *mode* parameter can be used to specify how the library is loaded. For details, consult the *dlopen(3)* manpage. On Windows, *mode* is ignored. On posix systems, RTLD_NOW is always added, and is not configurable.

The *use_errno* parameter, when set to true, enables a ctypes mechanism that allows accessing the system *errno* error number in a safe way. *ctypes* maintains a thread-local copy of the systems *errno* variable; if you call foreign functions created with `use_errno=True` then the *errno* value before the function call is swapped with the ctypes private copy, the same happens immediately after the function call.

The function *ctypes.get_errno()* returns the value of the ctypes private copy, and the function *ctypes.set_errno()* changes the ctypes private copy to a new value and returns the former value.

The *use_last_error* parameter, when set to true, enables the same mechanism for the Windows error code which is managed by the *GetLastError()* and `SetLastError()` Windows API functions; *ctypes.get_last_error()* and *ctypes.set_last_error()* are used to request and change the ctypes private copy of the windows error code.

`ctypes.RTLD_GLOBAL`
: Flag to use as *mode* parameter. On platforms where this flag is not available, it is defined as the integer zero.

`ctypes.RTLD_LOCAL`
: Flag to use as *mode* parameter. On platforms where this is not available, it is the same as *RTLD_GLOBAL*.

`ctypes.DEFAULT_MODE`
: The default mode which is used to load shared libraries. On OSX 10.3, this is *RTLD_GLOBAL*, otherwise it is the same as *RTLD_LOCAL*.

Instances of these classes have no public methods. Functions exported by the shared library can be accessed as attributes or by index. Please note that accessing the function through an attribute caches the result and therefore accessing it repeatedly returns the same object each time. On the other hand, accessing it through an index returns a new object each time:

```
>>> from ctypes import CDLL
>>> libc = CDLL("libc.so.6")  # On Linux
>>> libc.time == libc.time
True
>>> libc['time'] == libc['time']
False
```

The following public attributes are available, their name starts with an underscore to not clash with exported function names:

`PyDLL._handle`
: The system handle used to access the library.

`PyDLL._name`
: The name of the library passed in the constructor.

Shared libraries can also be loaded by using one of the prefabricated objects, which are instances of the *LibraryLoader* class, either by calling the `LoadLibrary()` method, or by retrieving the library as attribute of the loader instance.

class ctypes.LibraryLoader(*dlltype*)
Class which loads shared libraries. *dlltype* should be one of the *CDLL*, *PyDLL*, *WinDLL*, or *OleDLL* types.

__getattr__() has special behavior: It allows loading a shared library by accessing it as attribute of a library loader instance. The result is cached, so repeated attribute accesses return the same library each time.

LoadLibrary(*name*)
Load a shared library into the process and return it. This method always returns a new instance of the library.

These prefabricated library loaders are available:

ctypes.cdll
Creates *CDLL* instances.

ctypes.windll
Windows only: Creates *WinDLL* instances.

ctypes.oledll
Windows only: Creates *OleDLL* instances.

ctypes.pydll
Creates *PyDLL* instances.

For accessing the C Python api directly, a ready-to-use Python shared library object is available:

ctypes.pythonapi
An instance of *PyDLL* that exposes Python C API functions as attributes. Note that all these functions are assumed to return C **int**, which is of course not always the truth, so you have to assign the correct **restype** attribute to use these functions.

Foreign functions

As explained in the previous section, foreign functions can be accessed as attributes of loaded shared libraries. The function objects created in this way by default accept any number of arguments, accept any ctypes data instances as arguments, and return the default result type specified by the library loader. They are instances of a private class:

class ctypes._FuncPtr
Base class for C callable foreign functions.

Instances of foreign functions are also C compatible data types; they represent C function pointers.

This behavior can be customized by assigning to special attributes of the foreign function object.

restype
Assign a ctypes type to specify the result type of the foreign function. Use **None** for **void**, a function not returning anything.

It is possible to assign a callable Python object that is not a ctypes type, in this case the function is assumed to return a C **int**, and the callable will be called with this integer, allowing further processing or error checking. Using this is deprecated, for more flexible post processing or error checking use a ctypes data type as *restype* and assign a callable to the *errcheck* attribute.

argtypes
Assign a tuple of ctypes types to specify the argument types that the function accepts. Functions using the **stdcall** calling convention can only be called with the same number of arguments as the length of this tuple; functions using the C calling convention accept additional, unspecified arguments as well.

When a foreign function is called, each actual argument is passed to the **from_param()** class method of the items in the *argtypes* tuple, this method allows adapting the actual argument to

an object that the foreign function accepts. For example, a *c_char_p* item in the *argtypes* tuple will convert a string passed as argument into a bytes object using ctypes conversion rules.

New: It is now possible to put items in argtypes which are not ctypes types, but each item must have a `from_param()` method which returns a value usable as argument (integer, string, ctypes instance). This allows defining adapters that can adapt custom objects as function parameters.

errcheck
Assign a Python function or another callable to this attribute. The callable will be called with three or more arguments:

callable(*result*, *func*, *arguments*)
result is what the foreign function returns, as specified by the `restype` attribute.

func is the foreign function object itself, this allows reusing the same callable object to check or post process the results of several functions.

arguments is a tuple containing the parameters originally passed to the function call, this allows specializing the behavior on the arguments used.

The object that this function returns will be returned from the foreign function call, but it can also check the result value and raise an exception if the foreign function call failed.

exception ctypes.ArgumentError
This exception is raised when a foreign function call cannot convert one of the passed arguments.

Function prototypes

Foreign functions can also be created by instantiating function prototypes. Function prototypes are similar to function prototypes in C; they describe a function (return type, argument types, calling convention) without defining an implementation. The factory functions must be called with the desired result type and the argument types of the function.

ctypes.CFUNCTYPE(*restype*, **argtypes*, *use_errno=False*, *use_last_error=False*)
The returned function prototype creates functions that use the standard C calling convention. The function will release the GIL during the call. If *use_errno* is set to true, the ctypes private copy of the system *errno* variable is exchanged with the real *errno* value before and after the call; *use_last_error* does the same for the Windows error code.

ctypes.WINFUNCTYPE(*restype*, **argtypes*, *use_errno=False*, *use_last_error=False*)
Windows only: The returned function prototype creates functions that use the `stdcall` calling convention, except on Windows CE where *WINFUNCTYPE()* is the same as *CFUNCTYPE()*. The function will release the GIL during the call. *use_errno* and *use_last_error* have the same meaning as above.

ctypes.PYFUNCTYPE(*restype*, **argtypes*)
The returned function prototype creates functions that use the Python calling convention. The function will *not* release the GIL during the call.

Function prototypes created by these factory functions can be instantiated in different ways, depending on the type and number of the parameters in the call:

prototype(*address*)
Returns a foreign function at the specified address which must be an integer.

prototype(*callable*)
Create a C callable function (a callback function) from a Python *callable*.

prototype(*func_spec*[, *paramflags*])
Returns a foreign function exported by a shared library. *func_spec* must be a 2-tuple `(name_or_ordinal, library)`. The first item is the name of the exported function as

string, or the ordinal of the exported function as small integer. The second item is the shared library instance.

prototype(*vtbl_index*, *name*[, *paramflags*[, *iid*]])
Returns a foreign function that will call a COM method. *vtbl_index* is the index into the virtual function table, a small non-negative integer. *name* is name of the COM method. *iid* is an optional pointer to the interface identifier which is used in extended error reporting.

COM methods use a special calling convention: They require a pointer to the COM interface as first argument, in addition to those parameters that are specified in the `argtypes` tuple.

The optional *paramflags* parameter creates foreign function wrappers with much more functionality than the features described above.

paramflags must be a tuple of the same length as `argtypes`.

Each item in this tuple contains further information about a parameter, it must be a tuple containing one, two, or three items.

The first item is an integer containing a combination of direction flags for the parameter:

1 Specifies an input parameter to the function.

2 Output parameter. The foreign function fills in a value.

4 Input parameter which defaults to the integer zero.

The optional second item is the parameter name as string. If this is specified, the foreign function can be called with named parameters.

The optional third item is the default value for this parameter.

This example demonstrates how to wrap the Windows `MessageBoxW` function so that it supports default parameters and named arguments. The C declaration from the windows header file is this:

```
WINUSERAPI int WINAPI
MessageBoxW(
    HWND hWnd,
    LPCWSTR lpText,
    LPCWSTR lpCaption,
    UINT uType);
```

Here is the wrapping with *ctypes*:

```
>>> from ctypes import c_int, WINFUNCTYPE, windll
>>> from ctypes.wintypes import HWND, LPCWSTR, UINT
>>> prototype = WINFUNCTYPE(c_int, HWND, LPCWSTR, LPCWSTR, UINT)
>>> paramflags = (1, "hwnd", 0), (1, "text", "Hi"), (1, "caption", "Hello from ctypes"), (1, "flags
↪", 0)
>>> MessageBox = prototype(("MessageBoxW", windll.user32), paramflags)
```

The `MessageBox` foreign function can now be called in these ways:

```
>>> MessageBox()
>>> MessageBox(text="Spam, spam, spam")
>>> MessageBox(flags=2, text="foo bar")
```

A second example demonstrates output parameters. The win32 `GetWindowRect` function retrieves the dimensions of a specified window by copying them into `RECT` structure that the caller has to supply. Here is the C declaration:

```
WINUSERAPI BOOL WINAPI
GetWindowRect(
     HWND hWnd,
     LPRECT lpRect);
```

Here is the wrapping with *ctypes*:

```
>>> from ctypes import POINTER, WINFUNCTYPE, windll, WinError
>>> from ctypes.wintypes import BOOL, HWND, RECT
>>> prototype = WINFUNCTYPE(BOOL, HWND, POINTER(RECT))
>>> paramflags = (1, "hwnd"), (2, "lprect")
>>> GetWindowRect = prototype(("GetWindowRect", windll.user32), paramflags)
>>>
```

Functions with output parameters will automatically return the output parameter value if there is a single one, or a tuple containing the output parameter values when there are more than one, so the GetWindowRect function now returns a RECT instance, when called.

Output parameters can be combined with the `errcheck` protocol to do further output processing and error checking. The win32 `GetWindowRect` api function returns a `BOOL` to signal success or failure, so this function could do the error checking, and raises an exception when the api call failed:

```
>>> def errcheck(result, func, args):
...     if not result:
...         raise WinError()
...     return args
...
>>> GetWindowRect.errcheck = errcheck
>>>
```

If the `errcheck` function returns the argument tuple it receives unchanged, *ctypes* continues the normal processing it does on the output parameters. If you want to return a tuple of window coordinates instead of a `RECT` instance, you can retrieve the fields in the function and return them instead, the normal processing will no longer take place:

```
>>> def errcheck(result, func, args):
...     if not result:
...         raise WinError()
...     rc = args[1]
...     return rc.left, rc.top, rc.bottom, rc.right
...
>>> GetWindowRect.errcheck = errcheck
>>>
```

Utility functions

`ctypes.addressof(`*obj*`)`
: Returns the address of the memory buffer as integer. *obj* must be an instance of a ctypes type.

`ctypes.alignment(`*obj_or_type*`)`
: Returns the alignment requirements of a ctypes type. *obj_or_type* must be a ctypes type or instance.

`ctypes.byref(`*obj*[, *offset*]`)`
: Returns a light-weight pointer to *obj*, which must be an instance of a ctypes type. *offset* defaults to zero, and must be an integer that will be added to the internal pointer value.

  `byref(obj, offset)` corresponds to this C code:

```
(((char *)&obj) + offset)
```

The returned object can only be used as a foreign function call parameter. It behaves similar to `pointer(obj)`, but the construction is a lot faster.

`ctypes.cast(`*obj*, *type*`)`
This function is similar to the cast operator in C. It returns a new instance of *type* which points to the same memory block as *obj*. *type* must be a pointer type, and *obj* must be an object that can be interpreted as a pointer.

`ctypes.create_string_buffer(`*init_or_size*, *size=None*`)`
This function creates a mutable character buffer. The returned object is a ctypes array of *c_char*.

init_or_size must be an integer which specifies the size of the array, or a bytes object which will be used to initialize the array items.

If a bytes object is specified as first argument, the buffer is made one item larger than its length so that the last element in the array is a NUL termination character. An integer can be passed as second argument which allows specifying the size of the array if the length of the bytes should not be used.

`ctypes.create_unicode_buffer(`*init_or_size*, *size=None*`)`
This function creates a mutable unicode character buffer. The returned object is a ctypes array of *c_wchar*.

init_or_size must be an integer which specifies the size of the array, or a string which will be used to initialize the array items.

If a string is specified as first argument, the buffer is made one item larger than the length of the string so that the last element in the array is a NUL termination character. An integer can be passed as second argument which allows specifying the size of the array if the length of the string should not be used.

`ctypes.DllCanUnloadNow()`
Windows only: This function is a hook which allows implementing in-process COM servers with ctypes. It is called from the DllCanUnloadNow function that the _ctypes extension dll exports.

`ctypes.DllGetClassObject()`
Windows only: This function is a hook which allows implementing in-process COM servers with ctypes. It is called from the DllGetClassObject function that the `_ctypes` extension dll exports.

`ctypes.util.find_library(`*name*`)`
Try to find a library and return a pathname. *name* is the library name without any prefix like `lib`, suffix like `.so`, `.dylib` or version number (this is the form used for the posix linker option `-l`). If no library can be found, returns `None`.

The exact functionality is system dependent.

`ctypes.util.find_msvcrt()`
Windows only: return the filename of the VC runtime library used by Python, and by the extension modules. If the name of the library cannot be determined, `None` is returned.

If you need to free memory, for example, allocated by an extension module with a call to the `free(void *)`, it is important that you use the function in the same library that allocated the memory.

`ctypes.FormatError(`[*code*]`)`
Windows only: Returns a textual description of the error code *code*. If no error code is specified, the last error code is used by calling the Windows api function GetLastError.

`ctypes.GetLastError()`
Windows only: Returns the last error code set by Windows in the calling thread. This function calls the Windows *GetLastError()* function directly, it does not return the ctypes-private copy of the error code.

ctypes.**get_errno**()
Returns the current value of the ctypes-private copy of the system *errno* variable in the calling thread.

ctypes.**get_last_error**()
Windows only: returns the current value of the ctypes-private copy of the system `LastError` variable in the calling thread.

ctypes.**memmove**(*dst*, *src*, *count*)
Same as the standard C memmove library function: copies *count* bytes from *src* to *dst*. *dst* and *src* must be integers or ctypes instances that can be converted to pointers.

ctypes.**memset**(*dst*, *c*, *count*)
Same as the standard C memset library function: fills the memory block at address *dst* with *count* bytes of value *c*. *dst* must be an integer specifying an address, or a ctypes instance.

ctypes.**POINTER**(*type*)
This factory function creates and returns a new ctypes pointer type. Pointer types are cached and reused internally, so calling this function repeatedly is cheap. *type* must be a ctypes type.

ctypes.**pointer**(*obj*)
This function creates a new pointer instance, pointing to *obj*. The returned object is of the type `POINTER(type(obj))`.

Note: If you just want to pass a pointer to an object to a foreign function call, you should use `byref(obj)` which is much faster.

ctypes.**resize**(*obj*, *size*)
This function resizes the internal memory buffer of *obj*, which must be an instance of a ctypes type. It is not possible to make the buffer smaller than the native size of the objects type, as given by `sizeof(type(obj))`, but it is possible to enlarge the buffer.

ctypes.**set_errno**(*value*)
Set the current value of the ctypes-private copy of the system *errno* variable in the calling thread to *value* and return the previous value.

ctypes.**set_last_error**(*value*)
Windows only: set the current value of the ctypes-private copy of the system `LastError` variable in the calling thread to *value* and return the previous value.

ctypes.**sizeof**(*obj_or_type*)
Returns the size in bytes of a ctypes type or instance memory buffer. Does the same as the C `sizeof` operator.

ctypes.**string_at**(*address*, *size=-1*)
This function returns the C string starting at memory address *address* as a bytes object. If size is specified, it is used as size, otherwise the string is assumed to be zero-terminated.

ctypes.**WinError**(*code=None*, *descr=None*)
Windows only: this function is probably the worst-named thing in ctypes. It creates an instance of OSError. If *code* is not specified, `GetLastError` is called to determine the error code. If *descr* is not specified, *FormatError()* is called to get a textual description of the error.

Changed in version 3.3: An instance of *WindowsError* used to be created.

ctypes.**wstring_at**(*address*, *size=-1*)
This function returns the wide character string starting at memory address *address* as a string. If *size* is specified, it is used as the number of characters of the string, otherwise the string is assumed to be zero-terminated.

Data types

class ctypes._CData

This non-public class is the common base class of all ctypes data types. Among other things, all ctypes type instances contain a memory block that hold C compatible data; the address of the memory block is returned by the *addressof()* helper function. Another instance variable is exposed as *_objects*; this contains other Python objects that need to be kept alive in case the memory block contains pointers.

Common methods of ctypes data types, these are all class methods (to be exact, they are methods of the *metaclass*):

from_buffer(*source*[, *offset*])

This method returns a ctypes instance that shares the buffer of the *source* object. The *source* object must support the writeable buffer interface. The optional *offset* parameter specifies an offset into the source buffer in bytes; the default is zero. If the source buffer is not large enough a *ValueError* is raised.

from_buffer_copy(*source*[, *offset*])

This method creates a ctypes instance, copying the buffer from the *source* object buffer which must be readable. The optional *offset* parameter specifies an offset into the source buffer in bytes; the default is zero. If the source buffer is not large enough a *ValueError* is raised.

from_address(*address*)

This method returns a ctypes type instance using the memory specified by *address* which must be an integer.

from_param(*obj*)

This method adapts *obj* to a ctypes type. It is called with the actual object used in a foreign function call when the type is present in the foreign function's **argtypes** tuple; it must return an object that can be used as a function call parameter.

All ctypes data types have a default implementation of this classmethod that normally returns *obj* if that is an instance of the type. Some types accept other objects as well.

in_dll(*library*, *name*)

This method returns a ctypes type instance exported by a shared library. *name* is the name of the symbol that exports the data, *library* is the loaded shared library.

Common instance variables of ctypes data types:

_b_base_

Sometimes ctypes data instances do not own the memory block they contain, instead they share part of the memory block of a base object. The *_b_base_* read-only member is the root ctypes object that owns the memory block.

_b_needsfree_

This read-only variable is true when the ctypes data instance has allocated the memory block itself, false otherwise.

_objects

This member is either **None** or a dictionary containing Python objects that need to be kept alive so that the memory block contents is kept valid. This object is only exposed for debugging; never modify the contents of this dictionary.

Fundamental data types

class ctypes._SimpleCData

This non-public class is the base class of all fundamental ctypes data types. It is mentioned here because it contains the common attributes of the fundamental ctypes data types. *_SimpleCData* is a

subclass of *_CData*, so it inherits their methods and attributes. ctypes data types that are not and do not contain pointers can now be pickled.

Instances have a single attribute:

value
This attribute contains the actual value of the instance. For integer and pointer types, it is an integer, for character types, it is a single character bytes object or string, for character pointer types it is a Python bytes object or string.

When the `value` attribute is retrieved from a ctypes instance, usually a new object is returned each time. *ctypes* does *not* implement original object return, always a new object is constructed. The same is true for all other ctypes object instances.

Fundamental data types, when returned as foreign function call results, or, for example, by retrieving structure field members or array items, are transparently converted to native Python types. In other words, if a foreign function has a `restype` of *c_char_p*, you will always receive a Python bytes object, *not* a *c_char_p* instance.

Subclasses of fundamental data types do *not* inherit this behavior. So, if a foreign functions `restype` is a subclass of *c_void_p*, you will receive an instance of this subclass from the function call. Of course, you can get the value of the pointer by accessing the `value` attribute.

These are the fundamental ctypes data types:

class ctypes.c_byte
Represents the C `signed char` datatype, and interprets the value as small integer. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_char
Represents the C `char` datatype, and interprets the value as a single character. The constructor accepts an optional string initializer, the length of the string must be exactly one character.

class ctypes.c_char_p
Represents the C `char *` datatype when it points to a zero-terminated string. For a general character pointer that may also point to binary data, `POINTER(c_char)` must be used. The constructor accepts an integer address, or a bytes object.

class ctypes.c_double
Represents the C `double` datatype. The constructor accepts an optional float initializer.

class ctypes.c_longdouble
Represents the C `long double` datatype. The constructor accepts an optional float initializer. On platforms where `sizeof(long double) == sizeof(double)` it is an alias to *c_double*.

class ctypes.c_float
Represents the C `float` datatype. The constructor accepts an optional float initializer.

class ctypes.c_int
Represents the C `signed int` datatype. The constructor accepts an optional integer initializer; no overflow checking is done. On platforms where `sizeof(int) == sizeof(long)` it is an alias to *c_long*.

class ctypes.c_int8
Represents the C 8-bit `signed int` datatype. Usually an alias for *c_byte*.

class ctypes.c_int16
Represents the C 16-bit `signed int` datatype. Usually an alias for *c_short*.

class ctypes.c_int32
Represents the C 32-bit `signed int` datatype. Usually an alias for *c_int*.

class ctypes.c_int64
Represents the C 64-bit `signed int` datatype. Usually an alias for *c_longlong*.

class ctypes.c_long
Represents the C `signed long` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_longlong
Represents the C `signed long long` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_short
Represents the C `signed short` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_size_t
Represents the C `size_t` datatype.

class ctypes.c_ssize_t
Represents the C `ssize_t` datatype.

New in version 3.2.

class ctypes.c_ubyte
Represents the C `unsigned char` datatype, it interprets the value as small integer. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_uint
Represents the C `unsigned int` datatype. The constructor accepts an optional integer initializer; no overflow checking is done. On platforms where `sizeof(int) == sizeof(long)` it is an alias for *c_ulong*.

class ctypes.c_uint8
Represents the C 8-bit `unsigned int` datatype. Usually an alias for *c_ubyte*.

class ctypes.c_uint16
Represents the C 16-bit `unsigned int` datatype. Usually an alias for *c_ushort*.

class ctypes.c_uint32
Represents the C 32-bit `unsigned int` datatype. Usually an alias for *c_uint*.

class ctypes.c_uint64
Represents the C 64-bit `unsigned int` datatype. Usually an alias for *c_ulonglong*.

class ctypes.c_ulong
Represents the C `unsigned long` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_ulonglong
Represents the C `unsigned long long` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_ushort
Represents the C `unsigned short` datatype. The constructor accepts an optional integer initializer; no overflow checking is done.

class ctypes.c_void_p
Represents the C `void *` type. The value is represented as integer. The constructor accepts an optional integer initializer.

class ctypes.c_wchar
Represents the C `wchar_t` datatype, and interprets the value as a single character unicode string. The constructor accepts an optional string initializer, the length of the string must be exactly one character.

class ctypes.c_wchar_p
Represents the C `wchar_t *` datatype, which must be a pointer to a zero-terminated wide character string. The constructor accepts an integer address, or a string.

class ctypes.c_bool
Represent the C `bool` datatype (more accurately, `_Bool` from C99). Its value can be `True` or `False`, and the constructor accepts any object that has a truth value.

class ctypes.HRESULT
Windows only: Represents a `HRESULT` value, which contains success or error information for a function or method call.

class ctypes.py_object
Represents the C `PyObject *` datatype. Calling this without an argument creates a `NULL PyObject *` pointer.

The `ctypes.wintypes` module provides quite some other Windows specific data types, for example `HWND`, `WPARAM`, or `DWORD`. Some useful structures like `MSG` or `RECT` are also defined.

Structured data types

class ctypes.Union(*args, **kw)
Abstract base class for unions in native byte order.

class ctypes.BigEndianStructure(*args, **kw)
Abstract base class for structures in *big endian* byte order.

class ctypes.LittleEndianStructure(*args, **kw)
Abstract base class for structures in *little endian* byte order.

Structures with non-native byte order cannot contain pointer type fields, or any other data types containing pointer type fields.

class ctypes.Structure(*args, **kw)
Abstract base class for structures in *native* byte order.

Concrete structure and union types must be created by subclassing one of these types, and at least define a *_fields_* class variable. *ctypes* will create *descriptor*s which allow reading and writing the fields by direct attribute accesses. These are the

fields
A sequence defining the structure fields. The items must be 2-tuples or 3-tuples. The first item is the name of the field, the second item specifies the type of the field; it can be any ctypes data type.

For integer type fields like *c_int*, a third optional item can be given. It must be a small positive integer defining the bit width of the field.

Field names must be unique within one structure or union. This is not checked, only one field can be accessed when names are repeated.

It is possible to define the *_fields_* class variable *after* the class statement that defines the Structure subclass, this allows creating data types that directly or indirectly reference themselves:

```
class List(Structure):
    pass
List._fields_ = [("pnext", POINTER(List)),
                 ...
                ]
```

The *_fields_* class variable must, however, be defined before the type is first used (an instance is created, *sizeof()* is called on it, and so on). Later assignments to the *_fields_* class variable will raise an AttributeError.

It is possible to defined sub-subclasses of structure types, they inherit the fields of the base class plus the *_fields_* defined in the sub-subclass, if any.

pack
An optional small integer that allows overriding the alignment of structure fields in the instance. *_pack_* must already be defined when *_fields_* is assigned, otherwise it will have no effect.

anonymous
An optional sequence that lists the names of unnamed (anonymous) fields. *_anonymous_* must be already defined when *_fields_* is assigned, otherwise it will have no effect.

The fields listed in this variable must be structure or union type fields. *ctypes* will create descriptors in the structure type that allows accessing the nested fields directly, without the need to create the structure or union field.

Here is an example type (Windows):

```
class _U(Union):
    _fields_ = [("lptdesc", POINTER(TYPEDESC)),
                ("lpadesc", POINTER(ARRAYDESC)),
                ("hreftype", HREFTYPE)]

class TYPEDESC(Structure):
    _anonymous_ = ("u",)
    _fields_ = [("u", _U),
                ("vt", VARTYPE)]
```

The `TYPEDESC` structure describes a COM data type, the `vt` field specifies which one of the union fields is valid. Since the `u` field is defined as anonymous field, it is now possible to access the members directly off the TYPEDESC instance. `td.lptdesc` and `td.u.lptdesc` are equivalent, but the former is faster since it does not need to create a temporary union instance:

```
td = TYPEDESC()
td.vt = VT_PTR
td.lptdesc = POINTER(some_type)
td.u.lptdesc = POINTER(some_type)
```

It is possible to defined sub-subclasses of structures, they inherit the fields of the base class. If the subclass definition has a separate *_fields_* variable, the fields specified in this are appended to the fields of the base class.

Structure and union constructors accept both positional and keyword arguments. Positional arguments are used to initialize member fields in the same order as they are appear in *_fields_*. Keyword arguments in the constructor are interpreted as attribute assignments, so they will initialize *_fields_* with the same name, or create new attributes for names not present in *_fields_*.

Arrays and pointers

class ctypes.Array(args*)**
Abstract base class for arrays.

The recommended way to create concrete array types is by multiplying any *ctypes* data type with a positive integer. Alternatively, you can subclass this type and define *_length_* and *_type_* class variables. Array elements can be read and written using standard subscript and slice accesses; for slice reads, the resulting object is *not* itself an *Array*.

length
A positive integer specifying the number of elements in the array. Out-of-range subscripts result in an *IndexError*. Will be returned by *len()*.

type
Specifies the type of each element in the array.

Array subclass constructors accept positional arguments, used to initialize the elements in order.

class ctypes._Pointer

Private, abstract base class for pointers.

Concrete pointer types are created by calling *POINTER()* with the type that will be pointed to; this is done automatically by *pointer()*.

If a pointer points to an array, its elements can be read and written using standard subscript and slice accesses. Pointer objects have no size, so *len()* will raise *TypeError*. Negative subscripts will read from the memory *before* the pointer (as in C), and out-of-range subscripts will probably crash with an access violation (if you're lucky).

type

Specifies the type pointed to.

contents

Returns the object to which to pointer points. Assigning to this attribute changes the pointer to point to the assigned object.

CHAPTER

SEVENTEEN

CONCURRENT EXECUTION

The modules described in this chapter provide support for concurrent execution of code. The appropriate choice of tool will depend on the task to be executed (CPU bound vs IO bound) and preferred style of development (event driven cooperative multitasking vs preemptive multitasking). Here's an overview:

17.1 `threading` — Thread-based parallelism

Source code: Lib/threading.py

This module constructs higher-level threading interfaces on top of the lower level *`_thread`* module. See also the *`queue`* module.

Changed in version 3.7: This module used to be optional, it is now always available.

Note: While they are not listed below, the `camelCase` names used for some methods and functions in this module in the Python 2.x series are still supported by this module.

This module defines the following functions:

`threading.active_count()`
: Return the number of *`Thread`* objects currently alive. The returned count is equal to the length of the list returned by *`enumerate()`*.

`threading.current_thread()`
: Return the current *`Thread`* object, corresponding to the caller's thread of control. If the caller's thread of control was not created through the *`threading`* module, a dummy thread object with limited functionality is returned.

`threading.get_ident()`
: Return the 'thread identifier' of the current thread. This is a nonzero integer. Its value has no direct meaning; it is intended as a magic cookie to be used e.g. to index a dictionary of thread-specific data. Thread identifiers may be recycled when a thread exits and another thread is created.

  New in version 3.3.

`threading.enumerate()`
: Return a list of all *`Thread`* objects currently alive. The list includes daemonic threads, dummy thread objects created by *`current_thread()`*, and the main thread. It excludes terminated threads and threads that have not yet been started.

`threading.main_thread()`
: Return the main *`Thread`* object. In normal conditions, the main thread is the thread from which the Python interpreter was started.

New in version 3.4.

threading.settrace(*func*)
Set a trace function for all threads started from the *threading* module. The *func* will be passed to *sys.settrace()* for each thread, before its *run()* method is called.

threading.setprofile(*func*)
Set a profile function for all threads started from the *threading* module. The *func* will be passed to *sys.setprofile()* for each thread, before its *run()* method is called.

threading.stack_size([*size*])
Return the thread stack size used when creating new threads. The optional *size* argument specifies the stack size to be used for subsequently created threads, and must be 0 (use platform or configured default) or a positive integer value of at least 32,768 (32 KiB). If *size* is not specified, 0 is used. If changing the thread stack size is unsupported, a *RuntimeError* is raised. If the specified stack size is invalid, a *ValueError* is raised and the stack size is unmodified. 32 KiB is currently the minimum supported stack size value to guarantee sufficient stack space for the interpreter itself. Note that some platforms may have particular restrictions on values for the stack size, such as requiring a minimum stack size > 32 KiB or requiring allocation in multiples of the system memory page size - platform documentation should be referred to for more information (4 KiB pages are common; using multiples of 4096 for the stack size is the suggested approach in the absence of more specific information). Availability: Windows, systems with POSIX threads.

This module also defines the following constant:

threading.TIMEOUT_MAX
The maximum value allowed for the *timeout* parameter of blocking functions (*Lock.acquire()*, *RLock.acquire()*, *Condition.wait()*, etc.). Specifying a timeout greater than this value will raise an *OverflowError*.

New in version 3.2.

This module defines a number of classes, which are detailed in the sections below.

The design of this module is loosely based on Java's threading model. However, where Java makes locks and condition variables basic behavior of every object, they are separate objects in Python. Python's *Thread* class supports a subset of the behavior of Java's Thread class; currently, there are no priorities, no thread groups, and threads cannot be destroyed, stopped, suspended, resumed, or interrupted. The static methods of Java's Thread class, when implemented, are mapped to module-level functions.

All of the methods described below are executed atomically.

17.1.1 Thread-Local Data

Thread-local data is data whose values are thread specific. To manage thread-local data, just create an instance of *local* (or a subclass) and store attributes on it:

```
mydata = threading.local()
mydata.x = 1
```

The instance's values will be different for separate threads.

class threading.local
A class that represents thread-local data.

For more details and extensive examples, see the documentation string of the `_threading_local` module.

17.1.2 Thread Objects

The *Thread* class represents an activity that is run in a separate thread of control. There are two ways to specify the activity: by passing a callable object to the constructor, or by overriding the *run()* method in a subclass. No other methods (except for the constructor) should be overridden in a subclass. In other words, *only* override the `__init__()` and *run()* methods of this class.

Once a thread object is created, its activity must be started by calling the thread's *start()* method. This invokes the *run()* method in a separate thread of control.

Once the thread's activity is started, the thread is considered 'alive'. It stops being alive when its *run()* method terminates – either normally, or by raising an unhandled exception. The *is_alive()* method tests whether the thread is alive.

Other threads can call a thread's *join()* method. This blocks the calling thread until the thread whose *join()* method is called is terminated.

A thread has a name. The name can be passed to the constructor, and read or changed through the *name* attribute.

A thread can be flagged as a "daemon thread". The significance of this flag is that the entire Python program exits when only daemon threads are left. The initial value is inherited from the creating thread. The flag can be set through the *daemon* property or the *daemon* constructor argument.

Note: Daemon threads are abruptly stopped at shutdown. Their resources (such as open files, database transactions, etc.) may not be released properly. If you want your threads to stop gracefully, make them non-daemonic and use a suitable signalling mechanism such as an *Event*.

There is a "main thread" object; this corresponds to the initial thread of control in the Python program. It is not a daemon thread.

There is the possibility that "dummy thread objects" are created. These are thread objects corresponding to "alien threads", which are threads of control started outside the threading module, such as directly from C code. Dummy thread objects have limited functionality; they are always considered alive and daemonic, and cannot be *join()*ed. They are never deleted, since it is impossible to detect the termination of alien threads.

class threading.Thread(*group=None*, *target=None*, *name=None*, *args=()*, *kwargs={}*, ***, *daemon=None*)

This constructor should always be called with keyword arguments. Arguments are:

group should be `None`; reserved for future extension when a `ThreadGroup` class is implemented.

target is the callable object to be invoked by the *run()* method. Defaults to `None`, meaning nothing is called.

name is the thread name. By default, a unique name is constructed of the form "Thread-*N*" where *N* is a small decimal number.

args is the argument tuple for the target invocation. Defaults to `()`.

kwargs is a dictionary of keyword arguments for the target invocation. Defaults to `{}`.

If not `None`, *daemon* explicitly sets whether the thread is daemonic. If `None` (the default), the daemonic property is inherited from the current thread.

If the subclass overrides the constructor, it must make sure to invoke the base class constructor (`Thread.__init__()`) before doing anything else to the thread.

Changed in version 3.3: Added the *daemon* argument.

start()

Start the thread's activity.

It must be called at most once per thread object. It arranges for the object's *run()* method to be invoked in a separate thread of control.

This method will raise a *RuntimeError* if called more than once on the same thread object.

run()
Method representing the thread's activity.

You may override this method in a subclass. The standard *run()* method invokes the callable object passed to the object's constructor as the *target* argument, if any, with sequential and keyword arguments taken from the *args* and *kwargs* arguments, respectively.

join(*timeout=None*)
Wait until the thread terminates. This blocks the calling thread until the thread whose *join()* method is called terminates – either normally or through an unhandled exception – or until the optional timeout occurs.

When the *timeout* argument is present and not `None`, it should be a floating point number specifying a timeout for the operation in seconds (or fractions thereof). As *join()* always returns `None`, you must call *is_alive()* after *join()* to decide whether a timeout happened – if the thread is still alive, the *join()* call timed out.

When the *timeout* argument is not present or `None`, the operation will block until the thread terminates.

A thread can be *join()*ed many times.

join() raises a *RuntimeError* if an attempt is made to join the current thread as that would cause a deadlock. It is also an error to *join()* a thread before it has been started and attempts to do so raise the same exception.

name
A string used for identification purposes only. It has no semantics. Multiple threads may be given the same name. The initial name is set by the constructor.

getName()
setName()
Old getter/setter API for *name*; use it directly as a property instead.

ident
The 'thread identifier' of this thread or `None` if the thread has not been started. This is a nonzero integer. See the *get_ident()* function. Thread identifiers may be recycled when a thread exits and another thread is created. The identifier is available even after the thread has exited.

is_alive()
Return whether the thread is alive.

This method returns `True` just before the *run()* method starts until just after the *run()* method terminates. The module function *enumerate()* returns a list of all alive threads.

daemon
A boolean value indicating whether this thread is a daemon thread (True) or not (False). This must be set before *start()* is called, otherwise *RuntimeError* is raised. Its initial value is inherited from the creating thread; the main thread is not a daemon thread and therefore all threads created in the main thread default to *daemon* = `False`.

The entire Python program exits when no alive non-daemon threads are left.

isDaemon()
setDaemon()
Old getter/setter API for *daemon*; use it directly as a property instead.

CPython implementation detail: In CPython, due to the *Global Interpreter Lock*, only one thread can execute Python code at once (even though certain performance-oriented libraries might overcome this

limitation). If you want your application to make better use of the computational resources of multi-core machines, you are advised to use *multiprocessing* or *concurrent.futures.ProcessPoolExecutor*. However, threading is still an appropriate model if you want to run multiple I/O-bound tasks simultaneously.

17.1.3 Lock Objects

A primitive lock is a synchronization primitive that is not owned by a particular thread when locked. In Python, it is currently the lowest level synchronization primitive available, implemented directly by the *_thread* extension module.

A primitive lock is in one of two states, "locked" or "unlocked". It is created in the unlocked state. It has two basic methods, *acquire()* and *release()*. When the state is unlocked, *acquire()* changes the state to locked and returns immediately. When the state is locked, *acquire()* blocks until a call to *release()* in another thread changes it to unlocked, then the *acquire()* call resets it to locked and returns. The *release()* method should only be called in the locked state; it changes the state to unlocked and returns immediately. If an attempt is made to release an unlocked lock, a *RuntimeError* will be raised.

Locks also support the *context management protocol*.

When more than one thread is blocked in *acquire()* waiting for the state to turn to unlocked, only one thread proceeds when a *release()* call resets the state to unlocked; which one of the waiting threads proceeds is not defined, and may vary across implementations.

All methods are executed atomically.

class threading.Lock

The class implementing primitive lock objects. Once a thread has acquired a lock, subsequent attempts to acquire it block, until it is released; any thread may release it.

Note that `Lock` is actually a factory function which returns an instance of the most efficient version of the concrete Lock class that is supported by the platform.

acquire(*blocking=True*, *timeout=-1*)

Acquire a lock, blocking or non-blocking.

When invoked with the *blocking* argument set to `True` (the default), block until the lock is unlocked, then set it to locked and return `True`.

When invoked with the *blocking* argument set to `False`, do not block. If a call with *blocking* set to `True` would block, return `False` immediately; otherwise, set the lock to locked and return `True`.

When invoked with the floating-point *timeout* argument set to a positive value, block for at most the number of seconds specified by *timeout* and as long as the lock cannot be acquired. A *timeout* argument of `-1` specifies an unbounded wait. It is forbidden to specify a *timeout* when *blocking* is false.

The return value is `True` if the lock is acquired successfully, `False` if not (for example if the *timeout* expired).

Changed in version 3.2: The *timeout* parameter is new.

Changed in version 3.2: Lock acquires can now be interrupted by signals on POSIX.

release()

Release a lock. This can be called from any thread, not only the thread which has acquired the lock.

When the lock is locked, reset it to unlocked, and return. If any other threads are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed.

When invoked on an unlocked lock, a *RuntimeError* is raised.

There is no return value.

17.1.4 RLock Objects

A reentrant lock is a synchronization primitive that may be acquired multiple times by the same thread. Internally, it uses the concepts of "owning thread" and "recursion level" in addition to the locked/unlocked state used by primitive locks. In the locked state, some thread owns the lock; in the unlocked state, no thread owns it.

To lock the lock, a thread calls its *acquire()* method; this returns once the thread owns the lock. To unlock the lock, a thread calls its *release()* method. *acquire()*/*release()* call pairs may be nested; only the final *release()* (the *release()* of the outermost pair) resets the lock to unlocked and allows another thread blocked in *acquire()* to proceed.

Reentrant locks also support the *context management protocol*.

class threading.RLock

This class implements reentrant lock objects. A reentrant lock must be released by the thread that acquired it. Once a thread has acquired a reentrant lock, the same thread may acquire it again without blocking; the thread must release it once for each time it has acquired it.

Note that `RLock` is actually a factory function which returns an instance of the most efficient version of the concrete RLock class that is supported by the platform.

acquire(*blocking=True*, *timeout=-1*)

Acquire a lock, blocking or non-blocking.

When invoked without arguments: if this thread already owns the lock, increment the recursion level by one, and return immediately. Otherwise, if another thread owns the lock, block until the lock is unlocked. Once the lock is unlocked (not owned by any thread), then grab ownership, set the recursion level to one, and return. If more than one thread is blocked waiting until the lock is unlocked, only one at a time will be able to grab ownership of the lock. There is no return value in this case.

When invoked with the *blocking* argument set to true, do the same thing as when called without arguments, and return true.

When invoked with the *blocking* argument set to false, do not block. If a call without an argument would block, return false immediately; otherwise, do the same thing as when called without arguments, and return true.

When invoked with the floating-point *timeout* argument set to a positive value, block for at most the number of seconds specified by *timeout* and as long as the lock cannot be acquired. Return true if the lock has been acquired, false if the timeout has elapsed.

Changed in version 3.2: The *timeout* parameter is new.

release()

Release a lock, decrementing the recursion level. If after the decrement it is zero, reset the lock to unlocked (not owned by any thread), and if any other threads are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed. If after the decrement the recursion level is still nonzero, the lock remains locked and owned by the calling thread.

Only call this method when the calling thread owns the lock. A *RuntimeError* is raised if this method is called when the lock is unlocked.

There is no return value.

17.1.5 Condition Objects

A condition variable is always associated with some kind of lock; this can be passed in or one will be created by default. Passing one in is useful when several condition variables must share the same lock. The lock is part of the condition object: you don't have to track it separately.

A condition variable obeys the *context management protocol*: using the `with` statement acquires the associated lock for the duration of the enclosed block. The *acquire()* and *release()* methods also call the corresponding methods of the associated lock.

Other methods must be called with the associated lock held. The *wait()* method releases the lock, and then blocks until another thread awakens it by calling *notify()* or *notify_all()*. Once awakened, *wait()* re-acquires the lock and returns. It is also possible to specify a timeout.

The *notify()* method wakes up one of the threads waiting for the condition variable, if any are waiting. The *notify_all()* method wakes up all threads waiting for the condition variable.

Note: the *notify()* and *notify_all()* methods don't release the lock; this means that the thread or threads awakened will not return from their *wait()* call immediately, but only when the thread that called *notify()* or *notify_all()* finally relinquishes ownership of the lock.

The typical programming style using condition variables uses the lock to synchronize access to some shared state; threads that are interested in a particular change of state call *wait()* repeatedly until they see the desired state, while threads that modify the state call *notify()* or *notify_all()* when they change the state in such a way that it could possibly be a desired state for one of the waiters. For example, the following code is a generic producer-consumer situation with unlimited buffer capacity:

```
# Consume one item
with cv:
    while not an_item_is_available():
        cv.wait()
    get_an_available_item()

# Produce one item
with cv:
    make_an_item_available()
    cv.notify()
```

The `while` loop checking for the application's condition is necessary because *wait()* can return after an arbitrary long time, and the condition which prompted the *notify()* call may no longer hold true. This is inherent to multi-threaded programming. The *wait_for()* method can be used to automate the condition checking, and eases the computation of timeouts:

```
# Consume an item
with cv:
    cv.wait_for(an_item_is_available)
    get_an_available_item()
```

To choose between *notify()* and *notify_all()*, consider whether one state change can be interesting for only one or several waiting threads. E.g. in a typical producer-consumer situation, adding one item to the buffer only needs to wake up one consumer thread.

class threading.Condition(*lock=None*)

This class implements condition variable objects. A condition variable allows one or more threads to wait until they are notified by another thread.

If the *lock* argument is given and not `None`, it must be a *Lock* or *RLock* object, and it is used as the underlying lock. Otherwise, a new *RLock* object is created and used as the underlying lock.

Changed in version 3.3: changed from a factory function to a class.

acquire(**args*)

Acquire the underlying lock. This method calls the corresponding method on the underlying lock; the return value is whatever that method returns.

release()

Release the underlying lock. This method calls the corresponding method on the underlying lock;

there is no return value.

wait(*timeout=None*)
Wait until notified or until a timeout occurs. If the calling thread has not acquired the lock when this method is called, a *RuntimeError* is raised.

This method releases the underlying lock, and then blocks until it is awakened by a *notify()* or *notify_all()* call for the same condition variable in another thread, or until the optional timeout occurs. Once awakened or timed out, it re-acquires the lock and returns.

When the *timeout* argument is present and not `None`, it should be a floating point number specifying a timeout for the operation in seconds (or fractions thereof).

When the underlying lock is an *RLock*, it is not released using its *release()* method, since this may not actually unlock the lock when it was acquired multiple times recursively. Instead, an internal interface of the *RLock* class is used, which really unlocks it even when it has been recursively acquired several times. Another internal interface is then used to restore the recursion level when the lock is reacquired.

The return value is `True` unless a given *timeout* expired, in which case it is `False`.

Changed in version 3.2: Previously, the method always returned `None`.

wait_for(*predicate*, *timeout=None*)
Wait until a condition evaluates to true. *predicate* should be a callable which result will be interpreted as a boolean value. A *timeout* may be provided giving the maximum time to wait.

This utility method may call *wait()* repeatedly until the predicate is satisfied, or until a timeout occurs. The return value is the last return value of the predicate and will evaluate to `False` if the method timed out.

Ignoring the timeout feature, calling this method is roughly equivalent to writing:

```
while not predicate():
    cv.wait()
```

Therefore, the same rules apply as with *wait()*: The lock must be held when called and is re-acquired on return. The predicate is evaluated with the lock held.

New in version 3.2.

notify(*n=1*)
By default, wake up one thread waiting on this condition, if any. If the calling thread has not acquired the lock when this method is called, a *RuntimeError* is raised.

This method wakes up at most *n* of the threads waiting for the condition variable; it is a no-op if no threads are waiting.

The current implementation wakes up exactly *n* threads, if at least *n* threads are waiting. However, it's not safe to rely on this behavior. A future, optimized implementation may occasionally wake up more than *n* threads.

Note: an awakened thread does not actually return from its *wait()* call until it can reacquire the lock. Since *notify()* does not release the lock, its caller should.

notify_all()
Wake up all threads waiting on this condition. This method acts like *notify()*, but wakes up all waiting threads instead of one. If the calling thread has not acquired the lock when this method is called, a *RuntimeError* is raised.

17.1.6 Semaphore Objects

This is one of the oldest synchronization primitives in the history of computer science, invented by the early Dutch computer scientist Edsger W. Dijkstra (he used the names `P()` and `V()` instead of *acquire()* and *release()*).

A semaphore manages an internal counter which is decremented by each *acquire()* call and incremented by each *release()* call. The counter can never go below zero; when *acquire()* finds that it is zero, it blocks, waiting until some other thread calls *release()*.

Semaphores also support the *context management protocol*.

class threading.Semaphore(*value=1*)

This class implements semaphore objects. A semaphore manages an atomic counter representing the number of *release()* calls minus the number of *acquire()* calls, plus an initial value. The *acquire()* method blocks if necessary until it can return without making the counter negative. If not given, *value* defaults to 1.

The optional argument gives the initial *value* for the internal counter; it defaults to `1`. If the *value* given is less than 0, *ValueError* is raised.

Changed in version 3.3: changed from a factory function to a class.

acquire(*blocking=True*, *timeout=None*)

Acquire a semaphore.

When invoked without arguments:

- If the internal counter is larger than zero on entry, decrement it by one and return true immediately.
- If the internal counter is zero on entry, block until awoken by a call to *release()*. Once awoken (and the counter is greater than 0), decrement the counter by 1 and return true. Exactly one thread will be awoken by each call to *release()*. The order in which threads are awoken should not be relied on.

When invoked with *blocking* set to false, do not block. If a call without an argument would block, return false immediately; otherwise, do the same thing as when called without arguments, and return true.

When invoked with a *timeout* other than `None`, it will block for at most *timeout* seconds. If acquire does not complete successfully in that interval, return false. Return true otherwise.

Changed in version 3.2: The *timeout* parameter is new.

release()

Release a semaphore, incrementing the internal counter by one. When it was zero on entry and another thread is waiting for it to become larger than zero again, wake up that thread.

class threading.BoundedSemaphore(*value=1*)

Class implementing bounded semaphore objects. A bounded semaphore checks to make sure its current value doesn't exceed its initial value. If it does, *ValueError* is raised. In most situations semaphores are used to guard resources with limited capacity. If the semaphore is released too many times it's a sign of a bug. If not given, *value* defaults to 1.

Changed in version 3.3: changed from a factory function to a class.

`Semaphore` Example

Semaphores are often used to guard resources with limited capacity, for example, a database server. In any situation where the size of the resource is fixed, you should use a bounded semaphore. Before spawning any worker threads, your main thread would initialize the semaphore:

```
maxconnections = 5
# ...
pool_sema = BoundedSemaphore(value=maxconnections)
```

Once spawned, worker threads call the semaphore's acquire and release methods when they need to connect to the server:

```
with pool_sema:
    conn = connectdb()
    try:
        # ... use connection ...
    finally:
        conn.close()
```

The use of a bounded semaphore reduces the chance that a programming error which causes the semaphore to be released more than it's acquired will go undetected.

17.1.7 Event Objects

This is one of the simplest mechanisms for communication between threads: one thread signals an event and other threads wait for it.

An event object manages an internal flag that can be set to true with the *set()* method and reset to false with the *clear()* method. The *wait()* method blocks until the flag is true.

class threading.Event

Class implementing event objects. An event manages a flag that can be set to true with the *set()* method and reset to false with the *clear()* method. The *wait()* method blocks until the flag is true. The flag is initially false.

Changed in version 3.3: changed from a factory function to a class.

is_set()

Return true if and only if the internal flag is true.

set()

Set the internal flag to true. All threads waiting for it to become true are awakened. Threads that call *wait()* once the flag is true will not block at all.

clear()

Reset the internal flag to false. Subsequently, threads calling *wait()* will block until *set()* is called to set the internal flag to true again.

wait(*timeout=None*)

Block until the internal flag is true. If the internal flag is true on entry, return immediately. Otherwise, block until another thread calls *set()* to set the flag to true, or until the optional timeout occurs.

When the timeout argument is present and not `None`, it should be a floating point number specifying a timeout for the operation in seconds (or fractions thereof).

This method returns true if and only if the internal flag has been set to true, either before the wait call or after the wait starts, so it will always return `True` except if a timeout is given and the operation times out.

Changed in version 3.1: Previously, the method always returned `None`.

17.1.8 Timer Objects

This class represents an action that should be run only after a certain amount of time has passed — a timer. *Timer* is a subclass of *Thread* and as such also functions as an example of creating custom threads.

Timers are started, as with threads, by calling their `start()` method. The timer can be stopped (before its action has begun) by calling the *cancel()* method. The interval the timer will wait before executing its action may not be exactly the same as the interval specified by the user.

For example:

```
def hello():
    print("hello, world")

t = Timer(30.0, hello)
t.start()  # after 30 seconds, "hello, world" will be printed
```

class threading.Timer(*interval*, *function*, *args=None*, *kwargs=None*)

Create a timer that will run *function* with arguments *args* and keyword arguments *kwargs*, after *interval* seconds have passed. If *args* is `None` (the default) then an empty list will be used. If *kwargs* is `None` (the default) then an empty dict will be used.

Changed in version 3.3: changed from a factory function to a class.

cancel()

Stop the timer, and cancel the execution of the timer's action. This will only work if the timer is still in its waiting stage.

17.1.9 Barrier Objects

New in version 3.2.

This class provides a simple synchronization primitive for use by a fixed number of threads that need to wait for each other. Each of the threads tries to pass the barrier by calling the *wait()* method and will block until all of the threads have made their *wait()* calls. At this point, the threads are released simultaneously.

The barrier can be reused any number of times for the same number of threads.

As an example, here is a simple way to synchronize a client and server thread:

```
b = Barrier(2, timeout=5)

def server():
    start_server()
    b.wait()
    while True:
        connection = accept_connection()
        process_server_connection(connection)

def client():
    b.wait()
    while True:
        connection = make_connection()
        process_client_connection(connection)
```

class threading.Barrier(*parties*, *action=None*, *timeout=None*)

Create a barrier object for *parties* number of threads. An *action*, when provided, is a callable to be called by one of the threads when they are released. *timeout* is the default timeout value if none is specified for the *wait()* method.

wait(*timeout=None*)
Pass the barrier. When all the threads party to the barrier have called this function, they are all released simultaneously. If a *timeout* is provided, it is used in preference to any that was supplied to the class constructor.

The return value is an integer in the range 0 to *parties* – 1, different for each thread. This can be used to select a thread to do some special housekeeping, e.g.:

```
i = barrier.wait()
if i == 0:
    # Only one thread needs to print this
    print("passed the barrier")
```

If an *action* was provided to the constructor, one of the threads will have called it prior to being released. Should this call raise an error, the barrier is put into the broken state.

If the call times out, the barrier is put into the broken state.

This method may raise a *BrokenBarrierError* exception if the barrier is broken or reset while a thread is waiting.

reset()
Return the barrier to the default, empty state. Any threads waiting on it will receive the *BrokenBarrierError* exception.

Note that using this function may can require some external synchronization if there are other threads whose state is unknown. If a barrier is broken it may be better to just leave it and create a new one.

abort()
Put the barrier into a broken state. This causes any active or future calls to *wait()* to fail with the *BrokenBarrierError*. Use this for example if one of the needs to abort, to avoid deadlocking the application.

It may be preferable to simply create the barrier with a sensible *timeout* value to automatically guard against one of the threads going awry.

parties
The number of threads required to pass the barrier.

n_waiting
The number of threads currently waiting in the barrier.

broken
A boolean that is `True` if the barrier is in the broken state.

exception threading.BrokenBarrierError
This exception, a subclass of *RuntimeError*, is raised when the *Barrier* object is reset or broken.

17.1.10 Using locks, conditions, and semaphores in the `with` statement

All of the objects provided by this module that have `acquire()` and `release()` methods can be used as context managers for a `with` statement. The `acquire()` method will be called when the block is entered, and `release()` will be called when the block is exited. Hence, the following snippet:

```
with some_lock:
    # do something...
```

is equivalent to:

```
some_lock.acquire()
try:
    # do something...
finally:
    some_lock.release()
```

Currently, *Lock*, *RLock*, *Condition*, *Semaphore*, and *BoundedSemaphore* objects may be used as `with` statement context managers.

17.2 `multiprocessing` — Process-based parallelism

Source code: Lib/multiprocessing/

17.2.1 Introduction

multiprocessing is a package that supports spawning processes using an API similar to the *threading* module. The *multiprocessing* package offers both local and remote concurrency, effectively side-stepping the *Global Interpreter Lock* by using subprocesses instead of threads. Due to this, the *multiprocessing* module allows the programmer to fully leverage multiple processors on a given machine. It runs on both Unix and Windows.

The *multiprocessing* module also introduces APIs which do not have analogs in the *threading* module. A prime example of this is the *Pool* object which offers a convenient means of parallelizing the execution of a function across multiple input values, distributing the input data across processes (data parallelism). The following example demonstrates the common practice of defining such functions in a module so that child processes can successfully import that module. This basic example of data parallelism using *Pool*,

```
from multiprocessing import Pool

def f(x):
    return x*x

if __name__ == '__main__':
    with Pool(5) as p:
        print(p.map(f, [1, 2, 3]))
```

will print to standard output

```
[1, 4, 9]
```

The `Process` class

In *multiprocessing*, processes are spawned by creating a *Process* object and then calling its *start()* method. *Process* follows the API of *threading.Thread*. A trivial example of a multiprocess program is

```
from multiprocessing import Process

def f(name):
    print('hello', name)
```

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```
if __name__ == '__main__':
    p = Process(target=f, args=('bob',))
    p.start()
    p.join()
```

To show the individual process IDs involved, here is an expanded example:

```
from multiprocessing import Process
import os

def info(title):
    print(title)
    print('module name:', __name__)
    print('parent process:', os.getppid())
    print('process id:', os.getpid())

def f(name):
    info('function f')
    print('hello', name)

if __name__ == '__main__':
    info('main line')
    p = Process(target=f, args=('bob',))
    p.start()
    p.join()
```

For an explanation of why the `if __name__ == '__main__'` part is necessary, see *Programming guidelines*.

Contexts and start methods

Depending on the platform, *multiprocessing* supports three ways to start a process. These *start methods* are

spawn The parent process starts a fresh python interpreter process. The child process will only inherit those resources necessary to run the process objects *run()* method. In particular, unnecessary file descriptors and handles from the parent process will not be inherited. Starting a process using this method is rather slow compared to using *fork* or *forkserver*.

Available on Unix and Windows. The default on Windows.

fork The parent process uses *os.fork()* to fork the Python interpreter. The child process, when it begins, is effectively identical to the parent process. All resources of the parent are inherited by the child process. Note that safely forking a multithreaded process is problematic.

Available on Unix only. The default on Unix.

forkserver When the program starts and selects the *forkserver* start method, a server process is started. From then on, whenever a new process is needed, the parent process connects to the server and requests that it fork a new process. The fork server process is single threaded so it is safe for it to use *os.fork()*. No unnecessary resources are inherited.

Available on Unix platforms which support passing file descriptors over Unix pipes.

Changed in version 3.4: *spawn* added on all unix platforms, and *forkserver* added for some unix platforms. Child processes no longer inherit all of the parents inheritable handles on Windows.

On Unix using the *spawn* or *forkserver* start methods will also start a *semaphore tracker* process which tracks the unlinked named semaphores created by processes of the program. When all processes have exited the

semaphore tracker unlinks any remaining semaphores. Usually there should be none, but if a process was killed by a signal there may be some "leaked" semaphores. (Unlinking the named semaphores is a serious matter since the system allows only a limited number, and they will not be automatically unlinked until the next reboot.)

To select a start method you use the *set_start_method()* in the `if __name__ == '__main__'` clause of the main module. For example:

```
import multiprocessing as mp

def foo(q):
    q.put('hello')

if __name__ == '__main__':
    mp.set_start_method('spawn')
    q = mp.Queue()
    p = mp.Process(target=foo, args=(q,))
    p.start()
    print(q.get())
    p.join()
```

set_start_method() should not be used more than once in the program.

Alternatively, you can use *get_context()* to obtain a context object. Context objects have the same API as the multiprocessing module, and allow one to use multiple start methods in the same program.

```
import multiprocessing as mp

def foo(q):
    q.put('hello')

if __name__ == '__main__':
    ctx = mp.get_context('spawn')
    q = ctx.Queue()
    p = ctx.Process(target=foo, args=(q,))
    p.start()
    print(q.get())
    p.join()
```

Note that objects related to one context may not be compatible with processes for a different context. In particular, locks created using the *fork* context cannot be passed to processes started using the *spawn* or *forkserver* start methods.

A library which wants to use a particular start method should probably use *get_context()* to avoid interfering with the choice of the library user.

Exchanging objects between processes

multiprocessing supports two types of communication channel between processes:

Queues

The *Queue* class is a near clone of *queue.Queue*. For example:

```
from multiprocessing import Process, Queue

def f(q):
    q.put([42, None, 'hello'])
```

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```
if __name__ == '__main__':
    q = Queue()
    p = Process(target=f, args=(q,))
    p.start()
    print(q.get())    # prints "[42, None, 'hello']"
    p.join()
```

Queues are thread and process safe.

Pipes

The *Pipe()* function returns a pair of connection objects connected by a pipe which by default is duplex (two-way). For example:

```
from multiprocessing import Process, Pipe

def f(conn):
    conn.send([42, None, 'hello'])
    conn.close()

if __name__ == '__main__':
    parent_conn, child_conn = Pipe()
    p = Process(target=f, args=(child_conn,))
    p.start()
    print(parent_conn.recv())   # prints "[42, None, 'hello']"
    p.join()
```

The two connection objects returned by *Pipe()* represent the two ends of the pipe. Each connection object has `send()` and `recv()` methods (among others). Note that data in a pipe may become corrupted if two processes (or threads) try to read from or write to the *same* end of the pipe at the same time. Of course there is no risk of corruption from processes using different ends of the pipe at the same time.

Synchronization between processes

multiprocessing contains equivalents of all the synchronization primitives from *threading*. For instance one can use a lock to ensure that only one process prints to standard output at a time:

```
from multiprocessing import Process, Lock

def f(l, i):
    l.acquire()
    try:
        print('hello world', i)
    finally:
        l.release()

if __name__ == '__main__':
    lock = Lock()

    for num in range(10):
        Process(target=f, args=(lock, num)).start()
```

Without using the lock output from the different processes is liable to get all mixed up.

Sharing state between processes

As mentioned above, when doing concurrent programming it is usually best to avoid using shared state as far as possible. This is particularly true when using multiple processes.

However, if you really do need to use some shared data then *multiprocessing* provides a couple of ways of doing so.

Shared memory

Data can be stored in a shared memory map using *Value* or *Array*. For example, the following code

```
from multiprocessing import Process, Value, Array

def f(n, a):
    n.value = 3.1415927
    for i in range(len(a)):
        a[i] = -a[i]

if __name__ == '__main__':
    num = Value('d', 0.0)
    arr = Array('i', range(10))

    p = Process(target=f, args=(num, arr))
    p.start()
    p.join()

    print(num.value)
    print(arr[:])
```

will print

```
3.1415927
[0, -1, -2, -3, -4, -5, -6, -7, -8, -9]
```

The `'d'` and `'i'` arguments used when creating `num` and `arr` are typecodes of the kind used by the *array* module: `'d'` indicates a double precision float and `'i'` indicates a signed integer. These shared objects will be process and thread-safe.

For more flexibility in using shared memory one can use the *multiprocessing.sharedctypes* module which supports the creation of arbitrary ctypes objects allocated from shared memory.

Server process

A manager object returned by `Manager()` controls a server process which holds Python objects and allows other processes to manipulate them using proxies.

A manager returned by `Manager()` will support types *list*, *dict*, *Namespace*, *Lock*, *RLock*, *Semaphore*, *BoundedSemaphore*, *Condition*, *Event*, *Barrier*, *Queue*, *Value* and *Array*. For example,

```
from multiprocessing import Process, Manager

def f(d, l):
    d[1] = '1'
    d['2'] = 2
    d[0.25] = None
    l.reverse()
```

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```
if __name__ == '__main__':
    with Manager() as manager:
        d = manager.dict()
        l = manager.list(range(10))

        p = Process(target=f, args=(d, l))
        p.start()
        p.join()

        print(d)
        print(l)
```

will print

```
{0.25: None, 1: '1', '2': 2}
[9, 8, 7, 6, 5, 4, 3, 2, 1, 0]
```

Server process managers are more flexible than using shared memory objects because they can be made to support arbitrary object types. Also, a single manager can be shared by processes on different computers over a network. They are, however, slower than using shared memory.

Using a pool of workers

The *Pool* class represents a pool of worker processes. It has methods which allows tasks to be offloaded to the worker processes in a few different ways.

For example:

```
from multiprocessing import Pool, TimeoutError
import time
import os

def f(x):
    return x*x

if __name__ == '__main__':
    # start 4 worker processes
    with Pool(processes=4) as pool:

        # print "[0, 1, 4,..., 81]"
        print(pool.map(f, range(10)))

        # print same numbers in arbitrary order
        for i in pool.imap_unordered(f, range(10)):
            print(i)

        # evaluate "f(20)" asynchronously
        res = pool.apply_async(f, (20,))      # runs in *only* one process
        print(res.get(timeout=1))             # prints "400"

        # evaluate "os.getpid()" asynchronously
        res = pool.apply_async(os.getpid, ()) # runs in *only* one process
        print(res.get(timeout=1))             # prints the PID of that process

        # launching multiple evaluations asynchronously *may* use more processes
        multiple_results = [pool.apply_async(os.getpid, ()) for i in range(4)]
```

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```
        print([res.get(timeout=1) for res in multiple_results])

        # make a single worker sleep for 10 secs
        res = pool.apply_async(time.sleep, (10,))
        try:
            print(res.get(timeout=1))
        except TimeoutError:
            print("We lacked patience and got a multiprocessing.TimeoutError")

        print("For the moment, the pool remains available for more work")

    # exiting the 'with'-block has stopped the pool
    print("Now the pool is closed and no longer available")
```

Note that the methods of a pool should only ever be used by the process which created it.

Note: Functionality within this package requires that the `__main__` module be importable by the children. This is covered in *Programming guidelines* however it is worth pointing out here. This means that some examples, such as the *multiprocessing.pool.Pool* examples will not work in the interactive interpreter. For example:

```
>>> from multiprocessing import Pool
>>> p = Pool(5)
>>> def f(x):
...     return x*x
...
>>> p.map(f, [1,2,3])
Process PoolWorker-1:
Process PoolWorker-2:
Process PoolWorker-3:
Traceback (most recent call last):
AttributeError: 'module' object has no attribute 'f'
AttributeError: 'module' object has no attribute 'f'
AttributeError: 'module' object has no attribute 'f'
```

(If you try this it will actually output three full tracebacks interleaved in a semi-random fashion, and then you may have to stop the master process somehow.)

17.2.2 Reference

The *multiprocessing* package mostly replicates the API of the *threading* module.

Process and exceptions

class multiprocessing.Process(*group=None*, *target=None*, *name=None*, *args=()*, *kwargs={}*, ***, *daemon=None*)

Process objects represent activity that is run in a separate process. The *Process* class has equivalents of all the methods of *threading.Thread*.

The constructor should always be called with keyword arguments. *group* should always be `None`; it exists solely for compatibility with *threading.Thread*. *target* is the callable object to be invoked by the *run()* method. It defaults to `None`, meaning nothing is called. *name* is the process name (see *name* for more details). *args* is the argument tuple for the target invocation. *kwargs* is a dictionary

of keyword arguments for the target invocation. If provided, the keyword-only *daemon* argument sets the process *daemon* flag to `True` or `False`. If `None` (the default), this flag will be inherited from the creating process.

By default, no arguments are passed to *target*.

If a subclass overrides the constructor, it must make sure it invokes the base class constructor (`Process.__init__()`) before doing anything else to the process.

Changed in version 3.3: Added the *daemon* argument.

run()
Method representing the process's activity.

You may override this method in a subclass. The standard *run()* method invokes the callable object passed to the object's constructor as the target argument, if any, with sequential and keyword arguments taken from the *args* and *kwargs* arguments, respectively.

start()
Start the process's activity.

This must be called at most once per process object. It arranges for the object's *run()* method to be invoked in a separate process.

join([*timeout*]**)**
If the optional argument *timeout* is `None` (the default), the method blocks until the process whose *join()* method is called terminates. If *timeout* is a positive number, it blocks at most *timeout* seconds. Note that the method returns `None` if its process terminates or if the method times out. Check the process's *exitcode* to determine if it terminated.

A process can be joined many times.

A process cannot join itself because this would cause a deadlock. It is an error to attempt to join a process before it has been started.

name
The process's name. The name is a string used for identification purposes only. It has no semantics. Multiple processes may be given the same name.

The initial name is set by the constructor. If no explicit name is provided to the constructor, a name of the form 'Process-N_1:N_2:...:N_k' is constructed, where each N_k is the N-th child of its parent.

is_alive()
Return whether the process is alive.

Roughly, a process object is alive from the moment the *start()* method returns until the child process terminates.

daemon
The process's daemon flag, a Boolean value. This must be set before *start()* is called.

The initial value is inherited from the creating process.

When a process exits, it attempts to terminate all of its daemonic child processes.

Note that a daemonic process is not allowed to create child processes. Otherwise a daemonic process would leave its children orphaned if it gets terminated when its parent process exits. Additionally, these are **not** Unix daemons or services, they are normal processes that will be terminated (and not joined) if non-daemonic processes have exited.

In addition to the *threading.Thread* API, *Process* objects also support the following attributes and methods:

pid
Return the process ID. Before the process is spawned, this will be `None`.

exitcode
The child's exit code. This will be `None` if the process has not yet terminated. A negative value *-N* indicates that the child was terminated by signal *N*.

authkey
The process's authentication key (a byte string).

When *multiprocessing* is initialized the main process is assigned a random string using *os.urandom()*.

When a *Process* object is created, it will inherit the authentication key of its parent process, although this may be changed by setting *authkey* to another byte string.

See *Authentication keys*.

sentinel
A numeric handle of a system object which will become "ready" when the process ends.

You can use this value if you want to wait on several events at once using *multiprocessing.connection.wait()*. Otherwise calling *join()* is simpler.

On Windows, this is an OS handle usable with the `WaitForSingleObject` and `WaitForMultipleObjects` family of API calls. On Unix, this is a file descriptor usable with primitives from the *select* module.

New in version 3.3.

terminate()
Terminate the process. On Unix this is done using the `SIGTERM` signal; on Windows `TerminateProcess()` is used. Note that exit handlers and finally clauses, etc., will not be executed.

Note that descendant processes of the process will *not* be terminated – they will simply become orphaned.

> **Warning:** If this method is used when the associated process is using a pipe or queue then the pipe or queue is liable to become corrupted and may become unusable by other process. Similarly, if the process has acquired a lock or semaphore etc. then terminating it is liable to cause other processes to deadlock.

kill()
Same as *terminate()* but using the `SIGKILL` signal on Unix.

New in version 3.7.

close()
Close the *Process* object, releasing all resources associated with it. *ValueError* is raised if the underlying process is still running. Once *close()* returns successfully, most other methods and attributes of the *Process* object will raise *ValueError*.

New in version 3.7.

Note that the *start()*, *join()*, *is_alive()*, *terminate()* and *exitcode* methods should only be called by the process that created the process object.

Example usage of some of the methods of *Process*:

```
>>> import multiprocessing, time, signal
>>> p = multiprocessing.Process(target=time.sleep, args=(1000,))
>>> print(p, p.is_alive())
<Process(Process-1, initial)> False
>>> p.start()
>>> print(p, p.is_alive())
<Process(Process-1, started)> True
>>> p.terminate()
>>> time.sleep(0.1)
>>> print(p, p.is_alive())
<Process(Process-1, stopped[SIGTERM])> False
>>> p.exitcode == -signal.SIGTERM
True
```

exception multiprocessing.ProcessError
The base class of all *multiprocessing* exceptions.

exception multiprocessing.BufferTooShort
Exception raised by `Connection.recv_bytes_into()` when the supplied buffer object is too small for the message read.

If `e` is an instance of *BufferTooShort* then `e.args[0]` will give the message as a byte string.

exception multiprocessing.AuthenticationError
Raised when there is an authentication error.

exception multiprocessing.TimeoutError
Raised by methods with a timeout when the timeout expires.

Pipes and Queues

When using multiple processes, one generally uses message passing for communication between processes and avoids having to use any synchronization primitives like locks.

For passing messages one can use *Pipe()* (for a connection between two processes) or a queue (which allows multiple producers and consumers).

The *Queue*, *SimpleQueue* and *JoinableQueue* types are multi-producer, multi-consumer FIFO queues modelled on the *queue.Queue* class in the standard library. They differ in that *Queue* lacks the *task_done()* and *join()* methods introduced into Python 2.5's *queue.Queue* class.

If you use *JoinableQueue* then you **must** call *JoinableQueue.task_done()* for each task removed from the queue or else the semaphore used to count the number of unfinished tasks may eventually overflow, raising an exception.

Note that one can also create a shared queue by using a manager object – see *Managers*.

Note: *multiprocessing* uses the usual *queue.Empty* and *queue.Full* exceptions to signal a timeout. They are not available in the *multiprocessing* namespace so you need to import them from *queue*.

Note: When an object is put on a queue, the object is pickled and a background thread later flushes the pickled data to an underlying pipe. This has some consequences which are a little surprising, but should not cause any practical difficulties – if they really bother you then you can instead use a queue created with a *manager*.

1. After putting an object on an empty queue there may be an infinitesimal delay before the queue's *empty()* method returns *False* and *get_nowait()* can return without raising *queue.Empty*.

2. If multiple processes are enqueuing objects, it is possible for the objects to be received at the other end out-of-order. However, objects enqueued by the same process will always be in the expected order with respect to each other.

Warning: If a process is killed using *Process.terminate()* or *os.kill()* while it is trying to use a *Queue*, then the data in the queue is likely to become corrupted. This may cause any other process to get an exception when it tries to use the queue later on.

Warning: As mentioned above, if a child process has put items on a queue (and it has not used *JoinableQueue.cancel_join_thread*), then that process will not terminate until all buffered items have been flushed to the pipe.

This means that if you try joining that process you may get a deadlock unless you are sure that all items which have been put on the queue have been consumed. Similarly, if the child process is non-daemonic then the parent process may hang on exit when it tries to join all its non-daemonic children.

Note that a queue created using a manager does not have this issue. See *Programming guidelines*.

For an example of the usage of queues for interprocess communication see *Examples*.

`multiprocessing.Pipe`([*duplex*])
: Returns a pair `(conn1, conn2)` of *Connection* objects representing the ends of a pipe.

  If *duplex* is `True` (the default) then the pipe is bidirectional. If *duplex* is `False` then the pipe is unidirectional: `conn1` can only be used for receiving messages and `conn2` can only be used for sending messages.

`class multiprocessing.Queue`([*maxsize*])
: Returns a process shared queue implemented using a pipe and a few locks/semaphores. When a process first puts an item on the queue a feeder thread is started which transfers objects from a buffer into the pipe.

  The usual *queue.Empty* and *queue.Full* exceptions from the standard library's *queue* module are raised to signal timeouts.

  Queue implements all the methods of *queue.Queue* except for *task_done()* and *join()*.

  `qsize()`
  : Return the approximate size of the queue. Because of multithreading/multiprocessing semantics, this number is not reliable.

    Note that this may raise *NotImplementedError* on Unix platforms like Mac OS X where `sem_getvalue()` is not implemented.

  `empty()`
  : Return `True` if the queue is empty, `False` otherwise. Because of multithreading/multiprocessing semantics, this is not reliable.

  `full()`
  : Return `True` if the queue is full, `False` otherwise. Because of multithreading/multiprocessing semantics, this is not reliable.

  `put`(*obj*[, *block*[, *timeout*]])
  : Put obj into the queue. If the optional argument *block* is `True` (the default) and *timeout* is `None` (the default), block if necessary until a free slot is available. If *timeout* is a positive number, it blocks at most *timeout* seconds and raises the *queue.Full* exception if no free slot was available

within that time. Otherwise (*block* is `False`), put an item on the queue if a free slot is immediately available, else raise the *queue.Full* exception (*timeout* is ignored in that case).

`put_nowait(`*obj*`)`
Equivalent to `put(obj, False)`.

`get(`[*block*[, *timeout*]]`)`
Remove and return an item from the queue. If optional args *block* is `True` (the default) and *timeout* is `None` (the default), block if necessary until an item is available. If *timeout* is a positive number, it blocks at most *timeout* seconds and raises the *queue.Empty* exception if no item was available within that time. Otherwise (block is `False`), return an item if one is immediately available, else raise the *queue.Empty* exception (*timeout* is ignored in that case).

`get_nowait()`
Equivalent to `get(False)`.

multiprocessing.Queue has a few additional methods not found in *queue.Queue*. These methods are usually unnecessary for most code:

`close()`
Indicate that no more data will be put on this queue by the current process. The background thread will quit once it has flushed all buffered data to the pipe. This is called automatically when the queue is garbage collected.

`join_thread()`
Join the background thread. This can only be used after *close()* has been called. It blocks until the background thread exits, ensuring that all data in the buffer has been flushed to the pipe.

By default if a process is not the creator of the queue then on exit it will attempt to join the queue's background thread. The process can call *cancel_join_thread()* to make *join_thread()* do nothing.

`cancel_join_thread()`
Prevent *join_thread()* from blocking. In particular, this prevents the background thread from being joined automatically when the process exits – see *join_thread()*.

A better name for this method might be `allow_exit_without_flush()`. It is likely to cause enqueued data to lost, and you almost certainly will not need to use it. It is really only there if you need the current process to exit immediately without waiting to flush enqueued data to the underlying pipe, and you don't care about lost data.

Note: This class's functionality requires a functioning shared semaphore implementation on the host operating system. Without one, the functionality in this class will be disabled, and attempts to instantiate a *Queue* will result in an *ImportError*. See bpo-3770 for additional information. The same holds true for any of the specialized queue types listed below.

`class multiprocessing.SimpleQueue`
It is a simplified *Queue* type, very close to a locked *Pipe*.

`empty()`
Return `True` if the queue is empty, `False` otherwise.

`get()`
Remove and return an item from the queue.

`put(`*item*`)`
Put *item* into the queue.

`class multiprocessing.JoinableQueue(`[*maxsize*]`)`
JoinableQueue, a *Queue* subclass, is a queue which additionally has *task_done()* and *join()* methods.

task_done()
Indicate that a formerly enqueued task is complete. Used by queue consumers. For each *get()* used to fetch a task, a subsequent call to *task_done()* tells the queue that the processing on the task is complete.

If a *join()* is currently blocking, it will resume when all items have been processed (meaning that a *task_done()* call was received for every item that had been *put()* into the queue).

Raises a *ValueError* if called more times than there were items placed in the queue.

join()
Block until all items in the queue have been gotten and processed.

The count of unfinished tasks goes up whenever an item is added to the queue. The count goes down whenever a consumer calls *task_done()* to indicate that the item was retrieved and all work on it is complete. When the count of unfinished tasks drops to zero, *join()* unblocks.

Miscellaneous

multiprocessing.active_children()
Return list of all live children of the current process.

Calling this has the side effect of "joining" any processes which have already finished.

multiprocessing.cpu_count()
Return the number of CPUs in the system.

This number is not equivalent to the number of CPUs the current process can use. The number of usable CPUs can be obtained with `len(os.sched_getaffinity(0))`

May raise *NotImplementedError*.

See also:

os.cpu_count()

multiprocessing.current_process()
Return the *Process* object corresponding to the current process.

An analogue of *threading.current_thread()*.

multiprocessing.freeze_support()
Add support for when a program which uses *multiprocessing* has been frozen to produce a Windows executable. (Has been tested with **py2exe**, **PyInstaller** and **cx_Freeze**.)

One needs to call this function straight after the `if __name__ == '__main__'` line of the main module. For example:

```
from multiprocessing import Process, freeze_support

def f():
    print('hello world!')

if __name__ == '__main__':
    freeze_support()
    Process(target=f).start()
```

If the `freeze_support()` line is omitted then trying to run the frozen executable will raise *RuntimeError*.

Calling `freeze_support()` has no effect when invoked on any operating system other than Windows. In addition, if the module is being run normally by the Python interpreter on Windows (the program has not been frozen), then `freeze_support()` has no effect.

`multiprocessing.get_all_start_methods()`
Returns a list of the supported start methods, the first of which is the default. The possible start methods are `'fork'`, `'spawn'` and `'forkserver'`. On Windows only `'spawn'` is available. On Unix `'fork'` and `'spawn'` are always supported, with `'fork'` being the default.

New in version 3.4.

`multiprocessing.get_context(`*method=None*`)`
Return a context object which has the same attributes as the *multiprocessing* module.

If *method* is `None` then the default context is returned. Otherwise *method* should be `'fork'`, `'spawn'`, `'forkserver'`. *ValueError* is raised if the specified start method is not available.

New in version 3.4.

`multiprocessing.get_start_method(`*allow_none=False*`)`
Return the name of start method used for starting processes.

If the start method has not been fixed and *allow_none* is false, then the start method is fixed to the default and the name is returned. If the start method has not been fixed and *allow_none* is true then `None` is returned.

The return value can be `'fork'`, `'spawn'`, `'forkserver'` or `None`. `'fork'` is the default on Unix, while `'spawn'` is the default on Windows.

New in version 3.4.

`multiprocessing.set_executable()`
Sets the path of the Python interpreter to use when starting a child process. (By default *sys.executable* is used). Embedders will probably need to do some thing like

```
set_executable(os.path.join(sys.exec_prefix, 'pythonw.exe'))
```

before they can create child processes.

Changed in version 3.4: Now supported on Unix when the `'spawn'` start method is used.

`multiprocessing.set_start_method(`*method*`)`
Set the method which should be used to start child processes. *method* can be `'fork'`, `'spawn'` or `'forkserver'`.

Note that this should be called at most once, and it should be protected inside the `if __name__ == '__main__'` clause of the main module.

New in version 3.4.

Note: *multiprocessing* contains no analogues of *threading.active_count()*, *threading.enumerate()*, *threading.settrace()*, *threading.setprofile()*, *threading.Timer*, or *threading.local*.

Connection Objects

Connection objects allow the sending and receiving of picklable objects or strings. They can be thought of as message oriented connected sockets.

Connection objects are usually created using *Pipe* – see also *Listeners and Clients*.

`class multiprocessing.connection.Connection`

send(*obj*)
Send an object to the other end of the connection which should be read using *recv()*.

The object must be picklable. Very large pickles (approximately 32 MiB+, though it depends on the OS) may raise a *ValueError* exception.

recv()
Return an object sent from the other end of the connection using *send()*. Blocks until there is something to receive. Raises *EOFError* if there is nothing left to receive and the other end was closed.

fileno()
Return the file descriptor or handle used by the connection.

close()
Close the connection.

This is called automatically when the connection is garbage collected.

poll([*timeout*])
Return whether there is any data available to be read.

If *timeout* is not specified then it will return immediately. If *timeout* is a number then this specifies the maximum time in seconds to block. If *timeout* is `None` then an infinite timeout is used.

Note that multiple connection objects may be polled at once by using *multiprocessing.connection.wait()*.

send_bytes(*buffer*[, *offset*[, *size*]])
Send byte data from a *bytes-like object* as a complete message.

If *offset* is given then data is read from that position in *buffer*. If *size* is given then that many bytes will be read from buffer. Very large buffers (approximately 32 MiB+, though it depends on the OS) may raise a *ValueError* exception

recv_bytes([*maxlength*])
Return a complete message of byte data sent from the other end of the connection as a string. Blocks until there is something to receive. Raises *EOFError* if there is nothing left to receive and the other end has closed.

If *maxlength* is specified and the message is longer than *maxlength* then *OSError* is raised and the connection will no longer be readable.

Changed in version 3.3: This function used to raise *IOError*, which is now an alias of *OSError*.

recv_bytes_into(*buffer*[, *offset*])
Read into *buffer* a complete message of byte data sent from the other end of the connection and return the number of bytes in the message. Blocks until there is something to receive. Raises *EOFError* if there is nothing left to receive and the other end was closed.

buffer must be a writable *bytes-like object*. If *offset* is given then the message will be written into the buffer from that position. Offset must be a non-negative integer less than the length of *buffer* (in bytes).

If the buffer is too short then a `BufferTooShort` exception is raised and the complete message is available as `e.args[0]` where `e` is the exception instance.

Changed in version 3.3: Connection objects themselves can now be transferred between processes using *Connection.send()* and *Connection.recv()*.

New in version 3.3: Connection objects now support the context management protocol – see *Context Manager Types*. *__enter__()* returns the connection object, and *__exit__()* calls *close()*.

For example:

```
>>> from multiprocessing import Pipe
>>> a, b = Pipe()
>>> a.send([1, 'hello', None])
>>> b.recv()
[1, 'hello', None]
>>> b.send_bytes(b'thank you')
>>> a.recv_bytes()
b'thank you'
>>> import array
>>> arr1 = array.array('i', range(5))
>>> arr2 = array.array('i', [0] * 10)
>>> a.send_bytes(arr1)
>>> count = b.recv_bytes_into(arr2)
>>> assert count == len(arr1) * arr1.itemsize
>>> arr2
array('i', [0, 1, 2, 3, 4, 0, 0, 0, 0, 0])
```

Warning: The *Connection.recv()* method automatically unpickles the data it receives, which can be a security risk unless you can trust the process which sent the message.

Therefore, unless the connection object was produced using `Pipe()` you should only use the *recv()* and *send()* methods after performing some sort of authentication. See *Authentication keys*.

Warning: If a process is killed while it is trying to read or write to a pipe then the data in the pipe is likely to become corrupted, because it may become impossible to be sure where the message boundaries lie.

Synchronization primitives

Generally synchronization primitives are not as necessary in a multiprocess program as they are in a multi-threaded program. See the documentation for *threading* module.

Note that one can also create synchronization primitives by using a manager object – see *Managers*.

class multiprocessing.**Barrier**(*parties*[, *action*[, *timeout*]])
A barrier object: a clone of *threading.Barrier*.

New in version 3.3.

class multiprocessing.**BoundedSemaphore**([*value*])
A bounded semaphore object: a close analog of *threading.BoundedSemaphore*.

A solitary difference from its close analog exists: its `acquire` method's first argument is named *block*, as is consistent with *Lock.acquire()*.

Note: On Mac OS X, this is indistinguishable from *Semaphore* because `sem_getvalue()` is not implemented on that platform.

class multiprocessing.**Condition**([*lock*])
A condition variable: an alias for *threading.Condition*.

If *lock* is specified then it should be a *Lock* or *RLock* object from *multiprocessing*.

Changed in version 3.3: The *wait_for()* method was added.

class multiprocessing.Event
A clone of *threading.Event*.

class multiprocessing.Lock
A non-recursive lock object: a close analog of *threading.Lock*. Once a process or thread has acquired a lock, subsequent attempts to acquire it from any process or thread will block until it is released; any process or thread may release it. The concepts and behaviors of *threading.Lock* as it applies to threads are replicated here in *multiprocessing.Lock* as it applies to either processes or threads, except as noted.

Note that *Lock* is actually a factory function which returns an instance of `multiprocessing.synchronize.Lock` initialized with a default context.

Lock supports the *context manager* protocol and thus may be used in `with` statements.

acquire(*block=True*, *timeout=None*)
Acquire a lock, blocking or non-blocking.

With the *block* argument set to `True` (the default), the method call will block until the lock is in an unlocked state, then set it to locked and return `True`. Note that the name of this first argument differs from that in *threading.Lock.acquire()*.

With the *block* argument set to `False`, the method call does not block. If the lock is currently in a locked state, return `False`; otherwise set the lock to a locked state and return `True`.

When invoked with a positive, floating-point value for *timeout*, block for at most the number of seconds specified by *timeout* as long as the lock can not be acquired. Invocations with a negative value for *timeout* are equivalent to a *timeout* of zero. Invocations with a *timeout* value of `None` (the default) set the timeout period to infinite. Note that the treatment of negative or `None` values for *timeout* differs from the implemented behavior in *threading.Lock.acquire()*. The *timeout* argument has no practical implications if the *block* argument is set to `False` and is thus ignored. Returns `True` if the lock has been acquired or `False` if the timeout period has elapsed.

release()
Release a lock. This can be called from any process or thread, not only the process or thread which originally acquired the lock.

Behavior is the same as in *threading.Lock.release()* except that when invoked on an unlocked lock, a *ValueError* is raised.

class multiprocessing.RLock
A recursive lock object: a close analog of *threading.RLock*. A recursive lock must be released by the process or thread that acquired it. Once a process or thread has acquired a recursive lock, the same process or thread may acquire it again without blocking; that process or thread must release it once for each time it has been acquired.

Note that *RLock* is actually a factory function which returns an instance of `multiprocessing.synchronize.RLock` initialized with a default context.

RLock supports the *context manager* protocol and thus may be used in `with` statements.

acquire(*block=True*, *timeout=None*)
Acquire a lock, blocking or non-blocking.

When invoked with the *block* argument set to `True`, block until the lock is in an unlocked state (not owned by any process or thread) unless the lock is already owned by the current process or thread. The current process or thread then takes ownership of the lock (if it does not already have ownership) and the recursion level inside the lock increments by one, resulting in a return value of `True`. Note that there are several differences in this first argument's behavior compared to the implementation of *threading.RLock.acquire()*, starting with the name of the argument itself.

When invoked with the *block* argument set to `False`, do not block. If the lock has already been acquired (and thus is owned) by another process or thread, the current process or thread does not take ownership and the recursion level within the lock is not changed, resulting in a return value of `False`. If the lock is in an unlocked state, the current process or thread takes ownership and the recursion level is incremented, resulting in a return value of `True`.

Use and behaviors of the *timeout* argument are the same as in *Lock.acquire()*. Note that some of these behaviors of *timeout* differ from the implemented behaviors in *threading.RLock.acquire()*.

`release()`
Release a lock, decrementing the recursion level. If after the decrement the recursion level is zero, reset the lock to unlocked (not owned by any process or thread) and if any other processes or threads are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed. If after the decrement the recursion level is still nonzero, the lock remains locked and owned by the calling process or thread.

Only call this method when the calling process or thread owns the lock. An *AssertionError* is raised if this method is called by a process or thread other than the owner or if the lock is in an unlocked (unowned) state. Note that the type of exception raised in this situation differs from the implemented behavior in *threading.RLock.release()*.

`class multiprocessing.Semaphore(`[*value*]`)`
A semaphore object: a close analog of *threading.Semaphore*.

A solitary difference from its close analog exists: its `acquire` method's first argument is named *block*, as is consistent with *Lock.acquire()*.

Note: On Mac OS X, `sem_timedwait` is unsupported, so calling `acquire()` with a timeout will emulate that function's behavior using a sleeping loop.

Note: If the SIGINT signal generated by `Ctrl-C` arrives while the main thread is blocked by a call to `BoundedSemaphore.acquire()`, *Lock.acquire()*, *RLock.acquire()*, `Semaphore.acquire()`, `Condition.acquire()` or `Condition.wait()` then the call will be immediately interrupted and *KeyboardInterrupt* will be raised.

This differs from the behaviour of *threading* where SIGINT will be ignored while the equivalent blocking calls are in progress.

Note: Some of this package's functionality requires a functioning shared semaphore implementation on the host operating system. Without one, the `multiprocessing.synchronize` module will be disabled, and attempts to import it will result in an *ImportError*. See bpo-3770 for additional information.

Shared `ctypes` Objects

It is possible to create shared objects using shared memory which can be inherited by child processes.

`multiprocessing.Value(`*typecode_or_type*, **args*, *lock=True*`)`
Return a *ctypes* object allocated from shared memory. By default the return value is actually a synchronized wrapper for the object. The object itself can be accessed via the *value* attribute of a *Value*.

typecode_or_type determines the type of the returned object: it is either a ctypes type or a one character typecode of the kind used by the *array* module. **args* is passed on to the constructor for the type.

If *lock* is `True` (the default) then a new recursive lock object is created to synchronize access to the value. If *lock* is a *Lock* or *RLock* object then that will be used to synchronize access to the value. If *lock* is `False` then access to the returned object will not be automatically protected by a lock, so it will not necessarily be "process-safe".

Operations like `+=` which involve a read and write are not atomic. So if, for instance, you want to atomically increment a shared value it is insufficient to just do

```
counter.value += 1
```

Assuming the associated lock is recursive (which it is by default) you can instead do

```
with counter.get_lock():
    counter.value += 1
```

Note that *lock* is a keyword-only argument.

`multiprocessing.Array`(*typecode_or_type*, *size_or_initializer*, *, *lock=True*)
Return a ctypes array allocated from shared memory. By default the return value is actually a synchronized wrapper for the array.

typecode_or_type determines the type of the elements of the returned array: it is either a ctypes type or a one character typecode of the kind used by the *array* module. If *size_or_initializer* is an integer, then it determines the length of the array, and the array will be initially zeroed. Otherwise, *size_or_initializer* is a sequence which is used to initialize the array and whose length determines the length of the array.

If *lock* is `True` (the default) then a new lock object is created to synchronize access to the value. If *lock* is a *Lock* or *RLock* object then that will be used to synchronize access to the value. If *lock* is `False` then access to the returned object will not be automatically protected by a lock, so it will not necessarily be "process-safe".

Note that *lock* is a keyword only argument.

Note that an array of *ctypes.c_char* has *value* and *raw* attributes which allow one to use it to store and retrieve strings.

The `multiprocessing.sharedctypes` module

The *multiprocessing.sharedctypes* module provides functions for allocating *ctypes* objects from shared memory which can be inherited by child processes.

Note: Although it is possible to store a pointer in shared memory remember that this will refer to a location in the address space of a specific process. However, the pointer is quite likely to be invalid in the context of a second process and trying to dereference the pointer from the second process may cause a crash.

`multiprocessing.sharedctypes.RawArray`(*typecode_or_type*, *size_or_initializer*)
Return a ctypes array allocated from shared memory.

typecode_or_type determines the type of the elements of the returned array: it is either a ctypes type or a one character typecode of the kind used by the *array* module. If *size_or_initializer* is an integer then it determines the length of the array, and the array will be initially zeroed. Otherwise *size_or_initializer* is a sequence which is used to initialize the array and whose length determines the length of the array.

Note that setting and getting an element is potentially non-atomic – use *Array()* instead to make sure that access is automatically synchronized using a lock.

multiprocessing.sharedctypes.**RawValue**(*typecode_or_type*, **args*)
Return a ctypes object allocated from shared memory.

typecode_or_type determines the type of the returned object: it is either a ctypes type or a one character typecode of the kind used by the *array* module. **args* is passed on to the constructor for the type.

Note that setting and getting the value is potentially non-atomic – use *Value()* instead to make sure that access is automatically synchronized using a lock.

Note that an array of *ctypes.c_char* has `value` and `raw` attributes which allow one to use it to store and retrieve strings – see documentation for *ctypes*.

multiprocessing.sharedctypes.**Array**(*typecode_or_type*, *size_or_initializer*, *, *lock=True*)
The same as *RawArray()* except that depending on the value of *lock* a process-safe synchronization wrapper may be returned instead of a raw ctypes array.

If *lock* is `True` (the default) then a new lock object is created to synchronize access to the value. If *lock* is a *Lock* or *RLock* object then that will be used to synchronize access to the value. If *lock* is `False` then access to the returned object will not be automatically protected by a lock, so it will not necessarily be "process-safe".

Note that *lock* is a keyword-only argument.

multiprocessing.sharedctypes.**Value**(*typecode_or_type*, **args*, *lock=True*)
The same as *RawValue()* except that depending on the value of *lock* a process-safe synchronization wrapper may be returned instead of a raw ctypes object.

If *lock* is `True` (the default) then a new lock object is created to synchronize access to the value. If *lock* is a *Lock* or *RLock* object then that will be used to synchronize access to the value. If *lock* is `False` then access to the returned object will not be automatically protected by a lock, so it will not necessarily be "process-safe".

Note that *lock* is a keyword-only argument.

multiprocessing.sharedctypes.**copy**(*obj*)
Return a ctypes object allocated from shared memory which is a copy of the ctypes object *obj*.

multiprocessing.sharedctypes.**synchronized**(*obj*[, *lock*])
Return a process-safe wrapper object for a ctypes object which uses *lock* to synchronize access. If *lock* is `None` (the default) then a *multiprocessing.RLock* object is created automatically.

A synchronized wrapper will have two methods in addition to those of the object it wraps: `get_obj()` returns the wrapped object and `get_lock()` returns the lock object used for synchronization.

Note that accessing the ctypes object through the wrapper can be a lot slower than accessing the raw ctypes object.

Changed in version 3.5: Synchronized objects support the *context manager* protocol.

The table below compares the syntax for creating shared ctypes objects from shared memory with the normal ctypes syntax. (In the table `MyStruct` is some subclass of *ctypes.Structure*.)

ctypes	sharedctypes using type	sharedctypes using typecode
c_double(2.4)	RawValue(c_double, 2.4)	RawValue('d', 2.4)
MyStruct(4, 6)	RawValue(MyStruct, 4, 6)	
(c_short * 7)()	RawArray(c_short, 7)	RawArray('h', 7)
(c_int * 3)(9, 2, 8)	RawArray(c_int, (9, 2, 8))	RawArray('i', (9, 2, 8))

Below is an example where a number of ctypes objects are modified by a child process:

```
from multiprocessing import Process, Lock
from multiprocessing.sharedctypes import Value, Array
from ctypes import Structure, c_double

class Point(Structure):
    _fields_ = [('x', c_double), ('y', c_double)]

def modify(n, x, s, A):
    n.value **= 2
    x.value **= 2
    s.value = s.value.upper()
    for a in A:
        a.x **= 2
        a.y **= 2

if __name__ == '__main__':
    lock = Lock()

    n = Value('i', 7)
    x = Value(c_double, 1.0/3.0, lock=False)
    s = Array('c', b'hello world', lock=lock)
    A = Array(Point, [(1.875,-6.25), (-5.75,2.0), (2.375,9.5)], lock=lock)

    p = Process(target=modify, args=(n, x, s, A))
    p.start()
    p.join()

    print(n.value)
    print(x.value)
    print(s.value)
    print([(a.x, a.y) for a in A])
```

The results printed are

```
49
0.1111111111111111
HELLO WORLD
[(3.515625, 39.0625), (33.0625, 4.0), (5.640625, 90.25)]
```

Managers

Managers provide a way to create data which can be shared between different processes, including sharing over a network between processes running on different machines. A manager object controls a server process which manages *shared objects*. Other processes can access the shared objects by using proxies.

`multiprocessing.Manager()`
: Returns a started *SyncManager* object which can be used for sharing objects between processes. The returned manager object corresponds to a spawned child process and has methods which will create shared objects and return corresponding proxies.

Manager processes will be shutdown as soon as they are garbage collected or their parent process exits. The manager classes are defined in the *multiprocessing.managers* module:

class `multiprocessing.managers.BaseManager`(*[address[, authkey]]*)
: Create a BaseManager object.

  Once created one should call *start()* or `get_server().serve_forever()` to ensure that the manager object refers to a started manager process.

address is the address on which the manager process listens for new connections. If *address* is `None` then an arbitrary one is chosen.

authkey is the authentication key which will be used to check the validity of incoming connections to the server process. If *authkey* is `None` then `current_process().authkey` is used. Otherwise *authkey* is used and it must be a byte string.

`start`(*[initializer[, initargs]]*)
Start a subprocess to start the manager. If *initializer* is not `None` then the subprocess will call `initializer(*initargs)` when it starts.

`get_server`()
Returns a `Server` object which represents the actual server under the control of the Manager. The `Server` object supports the `serve_forever()` method:

```
>>> from multiprocessing.managers import BaseManager
>>> manager = BaseManager(address=('', 50000), authkey=b'abc')
>>> server = manager.get_server()
>>> server.serve_forever()
```

`Server` additionally has an *address* attribute.

`connect`()
Connect a local manager object to a remote manager process:

```
>>> from multiprocessing.managers import BaseManager
>>> m = BaseManager(address=('127.0.0.1', 5000), authkey=b'abc')
>>> m.connect()
```

`shutdown`()
Stop the process used by the manager. This is only available if *start()* has been used to start the server process.

This can be called multiple times.

`register`(*typeid[, callable[, proxytype[, exposed[, method_to_typeid[, create_method]]]]]*)
A classmethod which can be used for registering a type or callable with the manager class.

typeid is a "type identifier" which is used to identify a particular type of shared object. This must be a string.

callable is a callable used for creating objects for this type identifier. If a manager instance will be connected to the server using the *connect()* method, or if the *create_method* argument is `False` then this can be left as `None`.

proxytype is a subclass of *BaseProxy* which is used to create proxies for shared objects with this *typeid*. If `None` then a proxy class is created automatically.

exposed is used to specify a sequence of method names which proxies for this typeid should be allowed to access using *BaseProxy._callmethod()*. (If *exposed* is `None` then `proxytype._exposed_` is used instead if it exists.) In the case where no exposed list is specified, all "public methods" of the shared object will be accessible. (Here a "public method" means any attribute which has a `__call__()` method and whose name does not begin with `'_'`.)

method_to_typeid is a mapping used to specify the return type of those exposed methods which should return a proxy. It maps method names to typeid strings. (If *method_to_typeid* is `None` then `proxytype._method_to_typeid_` is used instead if it exists.) If a method's name is not a key of this mapping or if the mapping is `None` then the object returned by the method will be copied by value.

create_method determines whether a method should be created with name *typeid* which can be used to tell the server process to create a new shared object and return a proxy for it. By default it is `True`.

BaseManager instances also have one read-only property:

address
The address used by the manager.

Changed in version 3.3: Manager objects support the context management protocol – see *Context Manager Types*. *__enter__()* starts the server process (if it has not already started) and then returns the manager object. *__exit__()* calls *shutdown()*.

In previous versions *__enter__()* did not start the manager's server process if it was not already started.

class multiprocessing.managers.SyncManager
A subclass of *BaseManager* which can be used for the synchronization of processes. Objects of this type are returned by `multiprocessing.Manager()`.

Its methods create and return *Proxy Objects* for a number of commonly used data types to be synchronized across processes. This notably includes shared lists and dictionaries.

Barrier(*parties*[, *action*[, *timeout*]])
Create a shared *threading.Barrier* object and return a proxy for it.

New in version 3.3.

BoundedSemaphore([*value*])
Create a shared *threading.BoundedSemaphore* object and return a proxy for it.

Condition([*lock*])
Create a shared *threading.Condition* object and return a proxy for it.

If *lock* is supplied then it should be a proxy for a *threading.Lock* or *threading.RLock* object.

Changed in version 3.3: The *wait_for()* method was added.

Event()
Create a shared *threading.Event* object and return a proxy for it.

Lock()
Create a shared *threading.Lock* object and return a proxy for it.

Namespace()
Create a shared *Namespace* object and return a proxy for it.

Queue([*maxsize*])
Create a shared *queue.Queue* object and return a proxy for it.

RLock()
Create a shared *threading.RLock* object and return a proxy for it.

Semaphore([*value*])
Create a shared *threading.Semaphore* object and return a proxy for it.

Array(*typecode*, *sequence*)
Create an array and return a proxy for it.

Value(*typecode*, *value*)
Create an object with a writable `value` attribute and return a proxy for it.

dict()
dict(*mapping*)

dict(*sequence*)
Create a shared *dict* object and return a proxy for it.

list()
list(*sequence*)
Create a shared *list* object and return a proxy for it.

Changed in version 3.6: Shared objects are capable of being nested. For example, a shared container object such as a shared list can contain other shared objects which will all be managed and synchronized by the *SyncManager*.

class multiprocessing.managers.Namespace
A type that can register with *SyncManager*.

A namespace object has no public methods, but does have writable attributes. Its representation shows the values of its attributes.

However, when using a proxy for a namespace object, an attribute beginning with '_' will be an attribute of the proxy and not an attribute of the referent:

```
>>> manager = multiprocessing.Manager()
>>> Global = manager.Namespace()
>>> Global.x = 10
>>> Global.y = 'hello'
>>> Global._z = 12.3    # this is an attribute of the proxy
>>> print(Global)
Namespace(x=10, y='hello')
```

Customized managers

To create one's own manager, one creates a subclass of *BaseManager* and uses the *register()* classmethod to register new types or callables with the manager class. For example:

```
from multiprocessing.managers import BaseManager

class MathsClass:
    def add(self, x, y):
        return x + y
    def mul(self, x, y):
        return x * y

class MyManager(BaseManager):
    pass

MyManager.register('Maths', MathsClass)

if __name__ == '__main__':
    with MyManager() as manager:
        maths = manager.Maths()
        print(maths.add(4, 3))         # prints 7
        print(maths.mul(7, 8))         # prints 56
```

Using a remote manager

It is possible to run a manager server on one machine and have clients use it from other machines (assuming that the firewalls involved allow it).

Running the following commands creates a server for a single shared queue which remote clients can access:

```
>>> from multiprocessing.managers import BaseManager
>>> from queue import Queue
>>> queue = Queue()
>>> class QueueManager(BaseManager): pass
>>> QueueManager.register('get_queue', callable=lambda:queue)
>>> m = QueueManager(address=('', 50000), authkey=b'abracadabra')
>>> s = m.get_server()
>>> s.serve_forever()
```

One client can access the server as follows:

```
>>> from multiprocessing.managers import BaseManager
>>> class QueueManager(BaseManager): pass
>>> QueueManager.register('get_queue')
>>> m = QueueManager(address=('foo.bar.org', 50000), authkey=b'abracadabra')
>>> m.connect()
>>> queue = m.get_queue()
>>> queue.put('hello')
```

Another client can also use it:

```
>>> from multiprocessing.managers import BaseManager
>>> class QueueManager(BaseManager): pass
>>> QueueManager.register('get_queue')
>>> m = QueueManager(address=('foo.bar.org', 50000), authkey=b'abracadabra')
>>> m.connect()
>>> queue = m.get_queue()
>>> queue.get()
'hello'
```

Local processes can also access that queue, using the code from above on the client to access it remotely:

```
>>> from multiprocessing import Process, Queue
>>> from multiprocessing.managers import BaseManager
>>> class Worker(Process):
...     def __init__(self, q):
...         self.q = q
...         super(Worker, self).__init__()
...     def run(self):
...         self.q.put('local hello')
...
>>> queue = Queue()
>>> w = Worker(queue)
>>> w.start()
>>> class QueueManager(BaseManager): pass
...
>>> QueueManager.register('get_queue', callable=lambda: queue)
>>> m = QueueManager(address=('', 50000), authkey=b'abracadabra')
>>> s = m.get_server()
>>> s.serve_forever()
```

Proxy Objects

A proxy is an object which *refers* to a shared object which lives (presumably) in a different process. The shared object is said to be the *referent* of the proxy. Multiple proxy objects may have the same referent.

A proxy object has methods which invoke corresponding methods of its referent (although not every method of the referent will necessarily be available through the proxy). In this way, a proxy can be used just like its referent can:

```
>>> from multiprocessing import Manager
>>> manager = Manager()
>>> l = manager.list([i*i for i in range(10)])
>>> print(l)
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
>>> print(repr(l))
<ListProxy object, typeid 'list' at 0x...>
>>> l[4]
16
>>> l[2:5]
[4, 9, 16]
```

Notice that applying *str()* to a proxy will return the representation of the referent, whereas applying *repr()* will return the representation of the proxy.

An important feature of proxy objects is that they are picklable so they can be passed between processes. As such, a referent can contain *Proxy Objects*. This permits nesting of these managed lists, dicts, and other *Proxy Objects*:

```
>>> a = manager.list()
>>> b = manager.list()
>>> a.append(b)         # referent of a now contains referent of b
>>> print(a, b)
[<ListProxy object, typeid 'list' at ...>] []
>>> b.append('hello')
>>> print(a[0], b)
['hello'] ['hello']
```

Similarly, dict and list proxies may be nested inside one another:

```
>>> l_outer = manager.list([ manager.dict() for i in range(2) ])
>>> d_first_inner = l_outer[0]
>>> d_first_inner['a'] = 1
>>> d_first_inner['b'] = 2
>>> l_outer[1]['c'] = 3
>>> l_outer[1]['z'] = 26
>>> print(l_outer[0])
{'a': 1, 'b': 2}
>>> print(l_outer[1])
{'c': 3, 'z': 26}
```

If standard (non-proxy) *list* or *dict* objects are contained in a referent, modifications to those mutable values will not be propagated through the manager because the proxy has no way of knowing when the values contained within are modified. However, storing a value in a container proxy (which triggers a `__setitem__` on the proxy object) does propagate through the manager and so to effectively modify such an item, one could re-assign the modified value to the container proxy:

```
# create a list proxy and append a mutable object (a dictionary)
lproxy = manager.list()
lproxy.append({})
# now mutate the dictionary
d = lproxy[0]
d['a'] = 1
d['b'] = 2
```

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```
# at this point, the changes to d are not yet synced, but by
# updating the dictionary, the proxy is notified of the change
lproxy[0] = d
```

This approach is perhaps less convenient than employing nested *Proxy Objects* for most use cases but also demonstrates a level of control over the synchronization.

Note: The proxy types in *multiprocessing* do nothing to support comparisons by value. So, for instance, we have:

```
>>> manager.list([1,2,3]) == [1,2,3]
False
```

One should just use a copy of the referent instead when making comparisons.

---

class multiprocessing.managers.BaseProxy

Proxy objects are instances of subclasses of *BaseProxy*.

_callmethod(*methodname*[, *args*[, *kwds*]])

Call and return the result of a method of the proxy's referent.

If `proxy` is a proxy whose referent is `obj` then the expression

```
proxy._callmethod(methodname, args, kwds)
```

will evaluate the expression

```
getattr(obj, methodname)(*args, **kwds)
```

in the manager's process.

The returned value will be a copy of the result of the call or a proxy to a new shared object – see documentation for the *method_to_typeid* argument of *BaseManager.register()*.

If an exception is raised by the call, then is re-raised by *_callmethod()*. If some other exception is raised in the manager's process then this is converted into a `RemoteError` exception and is raised by *_callmethod()*.

Note in particular that an exception will be raised if *methodname* has not been *exposed*.

An example of the usage of *_callmethod()*:

```
>>> l = manager.list(range(10))
>>> l._callmethod('__len__')
10
>>> l._callmethod('__getitem__', (slice(2, 7),)) # equivalent to l[2:7]
[2, 3, 4, 5, 6]
>>> l._callmethod('__getitem__', (20,))          # equivalent to l[20]
Traceback (most recent call last):
...
IndexError: list index out of range
```

_getvalue()

Return a copy of the referent.

If the referent is unpicklable then this will raise an exception.

__repr__()

Return a representation of the proxy object.

`__str__()`
Return the representation of the referent.

Cleanup

A proxy object uses a weakref callback so that when it gets garbage collected it deregisters itself from the manager which owns its referent.

A shared object gets deleted from the manager process when there are no longer any proxies referring to it.

Process Pools

One can create a pool of processes which will carry out tasks submitted to it with the *Pool* class.

`class multiprocessing.pool.Pool(`[*processes*[, *initializer*[, *initargs*[, *maxtasksperchild*[, *context*]]]]]`)`

A process pool object which controls a pool of worker processes to which jobs can be submitted. It supports asynchronous results with timeouts and callbacks and has a parallel map implementation.

processes is the number of worker processes to use. If *processes* is `None` then the number returned by *os.cpu_count()* is used.

If *initializer* is not `None` then each worker process will call `initializer(*initargs)` when it starts.

maxtasksperchild is the number of tasks a worker process can complete before it will exit and be replaced with a fresh worker process, to enable unused resources to be freed. The default *maxtasksperchild* is `None`, which means worker processes will live as long as the pool.

context can be used to specify the context used for starting the worker processes. Usually a pool is created using the function `multiprocessing.Pool()` or the *Pool()* method of a context object. In both cases *context* is set appropriately.

Note that the methods of the pool object should only be called by the process which created the pool.

New in version 3.2: *maxtasksperchild*

New in version 3.4: *context*

Note: Worker processes within a *Pool* typically live for the complete duration of the Pool's work queue. A frequent pattern found in other systems (such as Apache, mod_wsgi, etc) to free resources held by workers is to allow a worker within a pool to complete only a set amount of work before being exiting, being cleaned up and a new process spawned to replace the old one. The *maxtasksperchild* argument to the *Pool* exposes this ability to the end user.

`apply(`*func*[, *args*[, *kwds*]]`)`
Call *func* with arguments *args* and keyword arguments *kwds*. It blocks until the result is ready. Given this blocks, *apply_async()* is better suited for performing work in parallel. Additionally, *func* is only executed in one of the workers of the pool.

`apply_async(`*func*[, *args*[, *kwds*[, *callback*[, *error_callback*]]]]`)`
A variant of the *apply()* method which returns a result object.

If *callback* is specified then it should be a callable which accepts a single argument. When the result becomes ready *callback* is applied to it, that is unless the call failed, in which case the *error_callback* is applied instead.

If *error_callback* is specified then it should be a callable which accepts a single argument. If the target function fails, then the *error_callback* is called with the exception instance.

Callbacks should complete immediately since otherwise the thread which handles the results will get blocked.

map(*func*, *iterable*[, *chunksize*])
A parallel equivalent of the *map()* built-in function (it supports only one *iterable* argument though). It blocks until the result is ready.

This method chops the iterable into a number of chunks which it submits to the process pool as separate tasks. The (approximate) size of these chunks can be specified by setting *chunksize* to a positive integer.

map_async(*func*, *iterable*[, *chunksize*[, *callback*[, *error_callback*]]])
A variant of the *map()* method which returns a result object.

If *callback* is specified then it should be a callable which accepts a single argument. When the result becomes ready *callback* is applied to it, that is unless the call failed, in which case the *error_callback* is applied instead.

If *error_callback* is specified then it should be a callable which accepts a single argument. If the target function fails, then the *error_callback* is called with the exception instance.

Callbacks should complete immediately since otherwise the thread which handles the results will get blocked.

imap(*func*, *iterable*[, *chunksize*])
A lazier version of *map()*.

The *chunksize* argument is the same as the one used by the *map()* method. For very long iterables using a large value for *chunksize* can make the job complete **much** faster than using the default value of `1`.

Also if *chunksize* is `1` then the `next()` method of the iterator returned by the *imap()* method has an optional *timeout* parameter: `next(timeout)` will raise *multiprocessing.TimeoutError* if the result cannot be returned within *timeout* seconds.

imap_unordered(*func*, *iterable*[, *chunksize*])
The same as *imap()* except that the ordering of the results from the returned iterator should be considered arbitrary. (Only when there is only one worker process is the order guaranteed to be "correct".)

starmap(*func*, *iterable*[, *chunksize*])
Like *map()* except that the elements of the *iterable* are expected to be iterables that are unpacked as arguments.

Hence an *iterable* of `[(1,2), (3, 4)]` results in `[func(1,2), func(3,4)]`.

New in version 3.3.

starmap_async(*func*, *iterable*[, *chunksize*[, *callback*[, *error_callback*]]])
A combination of *starmap()* and *map_async()* that iterates over *iterable* of iterables and calls *func* with the iterables unpacked. Returns a result object.

New in version 3.3.

close()
Prevents any more tasks from being submitted to the pool. Once all the tasks have been completed the worker processes will exit.

terminate()
Stops the worker processes immediately without completing outstanding work. When the pool object is garbage collected *terminate()* will be called immediately.

join()
Wait for the worker processes to exit. One must call *close()* or *terminate()* before using *join()*.

New in version 3.3: Pool objects now support the context management protocol – see *Context Manager Types*. *__enter__()* returns the pool object, and *__exit__()* calls *terminate()*.

class multiprocessing.pool.AsyncResult

The class of the result returned by *Pool.apply_async()* and *Pool.map_async()*.

get([*timeout*])

Return the result when it arrives. If *timeout* is not `None` and the result does not arrive within *timeout* seconds then *multiprocessing.TimeoutError* is raised. If the remote call raised an exception then that exception will be reraised by *get()*.

wait([*timeout*])

Wait until the result is available or until *timeout* seconds pass.

ready()

Return whether the call has completed.

successful()

Return whether the call completed without raising an exception. Will raise *AssertionError* if the result is not ready.

The following example demonstrates the use of a pool:

```
from multiprocessing import Pool
import time

def f(x):
    return x*x

if __name__ == '__main__':
    with Pool(processes=4) as pool:          # start 4 worker processes
        result = pool.apply_async(f, (10,)) # evaluate "f(10)" asynchronously in a single process
        print(result.get(timeout=1))        # prints "100" unless your computer is *very* slow

        print(pool.map(f, range(10)))       # prints "[0, 1, 4,..., 81]"

        it = pool.imap(f, range(10))
        print(next(it))                     # prints "0"
        print(next(it))                     # prints "1"
        print(it.next(timeout=1))           # prints "4" unless your computer is *very* slow

        result = pool.apply_async(time.sleep, (10,))
        print(result.get(timeout=1))        # raises multiprocessing.TimeoutError
```

Listeners and Clients

Usually message passing between processes is done using queues or by using *Connection* objects returned by *Pipe()*.

However, the *multiprocessing.connection* module allows some extra flexibility. It basically gives a high level message oriented API for dealing with sockets or Windows named pipes. It also has support for *digest authentication* using the *hmac* module, and for polling multiple connections at the same time.

multiprocessing.connection.deliver_challenge(*connection*, *authkey*)

Send a randomly generated message to the other end of the connection and wait for a reply.

If the reply matches the digest of the message using *authkey* as the key then a welcome message is sent to the other end of the connection. Otherwise *AuthenticationError* is raised.

multiprocessing.connection.**answer_challenge**(*connection*, *authkey*)
Receive a message, calculate the digest of the message using *authkey* as the key, and then send the digest back.

If a welcome message is not received, then *AuthenticationError* is raised.

multiprocessing.connection.**Client**(*address*[, *family*[, *authkey*]])
Attempt to set up a connection to the listener which is using address *address*, returning a *Connection*.

The type of the connection is determined by *family* argument, but this can generally be omitted since it can usually be inferred from the format of *address*. (See *Address Formats*)

If *authkey* is given and not None, it should be a byte string and will be used as the secret key for an HMAC-based authentication challenge. No authentication is done if *authkey* is None. *AuthenticationError* is raised if authentication fails. See *Authentication keys*.

class multiprocessing.connection.**Listener**([*address*[, *family*[, *backlog*[, *authkey*]]]])
A wrapper for a bound socket or Windows named pipe which is 'listening' for connections.

address is the address to be used by the bound socket or named pipe of the listener object.

Note: If an address of '0.0.0.0' is used, the address will not be a connectable end point on Windows. If you require a connectable end-point, you should use '127.0.0.1'.

---

family is the type of socket (or named pipe) to use. This can be one of the strings `'AF_INET'` (for a TCP socket), `'AF_UNIX'` (for a Unix domain socket) or `'AF_PIPE'` (for a Windows named pipe). Of these only the first is guaranteed to be available. If *family* is `None` then the family is inferred from the format of *address*. If *address* is also `None` then a default is chosen. This default is the family which is assumed to be the fastest available. See *Address Formats*. Note that if *family* is `'AF_UNIX'` and address is `None` then the socket will be created in a private temporary directory created using *tempfile.mkstemp()*.

If the listener object uses a socket then *backlog* (1 by default) is passed to the *listen()* method of the socket once it has been bound.

If *authkey* is given and not None, it should be a byte string and will be used as the secret key for an HMAC-based authentication challenge. No authentication is done if *authkey* is None. *AuthenticationError* is raised if authentication fails. See *Authentication keys*.

accept()
Accept a connection on the bound socket or named pipe of the listener object and return a *Connection* object. If authentication is attempted and fails, then *AuthenticationError* is raised.

close()
Close the bound socket or named pipe of the listener object. This is called automatically when the listener is garbage collected. However it is advisable to call it explicitly.

Listener objects have the following read-only properties:

address
The address which is being used by the Listener object.

last_accepted
The address from which the last accepted connection came. If this is unavailable then it is `None`.

New in version 3.3: Listener objects now support the context management protocol – see *Context Manager Types*. *__enter__()* returns the listener object, and *__exit__()* calls *close()*.

multiprocessing.connection.**wait**(*object_list*, *timeout=None*)
Wait till an object in *object_list* is ready. Returns the list of those objects in *object_list* which are

ready. If *timeout* is a float then the call blocks for at most that many seconds. If *timeout* is `None` then it will block for an unlimited period. A negative timeout is equivalent to a zero timeout.

For both Unix and Windows, an object can appear in *object_list* if it is

- a readable *Connection* object;
- a connected and readable *socket.socket* object; or
- the *sentinel* attribute of a *Process* object.

A connection or socket object is ready when there is data available to be read from it, or the other end has been closed.

Unix: `wait(object_list, timeout)` almost equivalent `select.select(object_list, [], [], timeout)`. The difference is that, if *select.select()* is interrupted by a signal, it can raise *OSError* with an error number of `EINTR`, whereas *wait()* will not.

Windows: An item in *object_list* must either be an integer handle which is waitable (according to the definition used by the documentation of the Win32 function `WaitForMultipleObjects()`) or it can be an object with a `fileno()` method which returns a socket handle or pipe handle. (Note that pipe handles and socket handles are **not** waitable handles.)

New in version 3.3.

Examples

The following server code creates a listener which uses `'secret password'` as an authentication key. It then waits for a connection and sends some data to the client:

```
from multiprocessing.connection import Listener
from array import array

address = ('localhost', 6000)     # family is deduced to be 'AF_INET'

with Listener(address, authkey=b'secret password') as listener:
    with listener.accept() as conn:
        print('connection accepted from', listener.last_accepted)

        conn.send([2.25, None, 'junk', float])

        conn.send_bytes(b'hello')

        conn.send_bytes(array('i', [42, 1729]))
```

The following code connects to the server and receives some data from the server:

```
from multiprocessing.connection import Client
from array import array

address = ('localhost', 6000)

with Client(address, authkey=b'secret password') as conn:
    print(conn.recv())                  # => [2.25, None, 'junk', float]

    print(conn.recv_bytes())            # => 'hello'

    arr = array('i', [0, 0, 0, 0, 0])
    print(conn.recv_bytes_into(arr))    # => 8
    print(arr)                          # => array('i', [42, 1729, 0, 0, 0])
```

The following code uses *wait()* to wait for messages from multiple processes at once:

```
import time, random
from multiprocessing import Process, Pipe, current_process
from multiprocessing.connection import wait

def foo(w):
    for i in range(10):
        w.send((i, current_process().name))
    w.close()

if __name__ == '__main__':
    readers = []

    for i in range(4):
        r, w = Pipe(duplex=False)
        readers.append(r)
        p = Process(target=foo, args=(w,))
        p.start()
        # We close the writable end of the pipe now to be sure that
        # p is the only process which owns a handle for it.  This
        # ensures that when p closes its handle for the writable end,
        # wait() will promptly report the readable end as being ready.
        w.close()

    while readers:
        for r in wait(readers):
            try:
                msg = r.recv()
            except EOFError:
                readers.remove(r)
            else:
                print(msg)
```

Address Formats

- An `'AF_INET'` address is a tuple of the form `(hostname, port)` where *hostname* is a string and *port* is an integer.
- An `'AF_UNIX'` address is a string representing a filename on the filesystem.
- **An `'AF_PIPE'` address is a string of the form `r'\\.\pipe\`*PipeName*`'`.** To use *`Client()`* to connect to a named pipe on a remote computer called *ServerName* one should use an address of the form `r'\\`*ServerName*`\pipe\`*PipeName*`'` instead.

Note that any string beginning with two backslashes is assumed by default to be an `'AF_PIPE'` address rather than an `'AF_UNIX'` address.

Authentication keys

When one uses *`Connection.recv`*, the data received is automatically unpickled. Unfortunately unpickling data from an untrusted source is a security risk. Therefore *`Listener`* and *`Client()`* use the *`hmac`* module to provide digest authentication.

An authentication key is a byte string which can be thought of as a password: once a connection is established both ends will demand proof that the other knows the authentication key. (Demonstrating that both ends are using the same key does **not** involve sending the key over the connection.)

If authentication is requested but no authentication key is specified then the return value of `current_process().authkey` is used (see *Process*). This value will be automatically inherited by any *Process* object that the current process creates. This means that (by default) all processes of a multi-process program will share a single authentication key which can be used when setting up connections between themselves.

Suitable authentication keys can also be generated by using *os.urandom()*.

Logging

Some support for logging is available. Note, however, that the *logging* package does not use process shared locks so it is possible (depending on the handler type) for messages from different processes to get mixed up.

`multiprocessing.get_logger()`
Returns the logger used by *multiprocessing*. If necessary, a new one will be created.

When first created the logger has level `logging.NOTSET` and no default handler. Messages sent to this logger will not by default propagate to the root logger.

Note that on Windows child processes will only inherit the level of the parent process's logger – any other customization of the logger will not be inherited.

`multiprocessing.log_to_stderr()`
This function performs a call to *get_logger()* but in addition to returning the logger created by get_logger, it adds a handler which sends output to *sys.stderr* using format `'[%(levelname)s/%(processName)s] %(message)s'`.

Below is an example session with logging turned on:

```
>>> import multiprocessing, logging
>>> logger = multiprocessing.log_to_stderr()
>>> logger.setLevel(logging.INFO)
>>> logger.warning('doomed')
[WARNING/MainProcess] doomed
>>> m = multiprocessing.Manager()
[INFO/SyncManager-...] child process calling self.run()
[INFO/SyncManager-...] created temp directory /.../pymp-...
[INFO/SyncManager-...] manager serving at '/.../listener-...'
>>> del m
[INFO/MainProcess] sending shutdown message to manager
[INFO/SyncManager-...] manager exiting with exitcode 0
```

For a full table of logging levels, see the *logging* module.

The `multiprocessing.dummy` module

multiprocessing.dummy replicates the API of *multiprocessing* but is no more than a wrapper around the *threading* module.

17.2.3 Programming guidelines

There are certain guidelines and idioms which should be adhered to when using *multiprocessing*.

All start methods

The following applies to all start methods.

Avoid shared state

As far as possible one should try to avoid shifting large amounts of data between processes.

It is probably best to stick to using queues or pipes for communication between processes rather than using the lower level synchronization primitives.

Picklability

Ensure that the arguments to the methods of proxies are picklable.

Thread safety of proxies

Do not use a proxy object from more than one thread unless you protect it with a lock.

(There is never a problem with different processes using the *same* proxy.)

Joining zombie processes

On Unix when a process finishes but has not been joined it becomes a zombie. There should never be very many because each time a new process starts (or *active_children()* is called) all completed processes which have not yet been joined will be joined. Also calling a finished process's *Process.is_alive* will join the process. Even so it is probably good practice to explicitly join all the processes that you start.

Better to inherit than pickle/unpickle

When using the *spawn* or *forkserver* start methods many types from *multiprocessing* need to be picklable so that child processes can use them. However, one should generally avoid sending shared objects to other processes using pipes or queues. Instead you should arrange the program so that a process which needs access to a shared resource created elsewhere can inherit it from an ancestor process.

Avoid terminating processes

Using the *Process.terminate* method to stop a process is liable to cause any shared resources (such as locks, semaphores, pipes and queues) currently being used by the process to become broken or unavailable to other processes.

Therefore it is probably best to only consider using *Process.terminate* on processes which never use any shared resources.

Joining processes that use queues

Bear in mind that a process that has put items in a queue will wait before terminating until all the buffered items are fed by the "feeder" thread to the underlying pipe. (The child process can call the *Queue.cancel_join_thread* method of the queue to avoid this behaviour.)

This means that whenever you use a queue you need to make sure that all items which have been put on the queue will eventually be removed before the process is joined. Otherwise you cannot be sure that processes which have put items on the queue will terminate. Remember also that non-daemonic processes will be joined automatically.

An example which will deadlock is the following:

```
from multiprocessing import Process, Queue

def f(q):
    q.put('X' * 1000000)

if __name__ == '__main__':
```

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```
    queue = Queue()
    p = Process(target=f, args=(queue,))
    p.start()
    p.join()                    # this deadlocks
    obj = queue.get()
```

A fix here would be to swap the last two lines (or simply remove the `p.join()` line).

Explicitly pass resources to child processes

On Unix using the *fork* start method, a child process can make use of a shared resource created in a parent process using a global resource. However, it is better to pass the object as an argument to the constructor for the child process.

Apart from making the code (potentially) compatible with Windows and the other start methods this also ensures that as long as the child process is still alive the object will not be garbage collected in the parent process. This might be important if some resource is freed when the object is garbage collected in the parent process.

So for instance

```
from multiprocessing import Process, Lock

def f():
    ... do something using "lock" ...

if __name__ == '__main__':
    lock = Lock()
    for i in range(10):
        Process(target=f).start()
```

should be rewritten as

```
from multiprocessing import Process, Lock

def f(l):
    ... do something using "l" ...

if __name__ == '__main__':
    lock = Lock()
    for i in range(10):
        Process(target=f, args=(lock,)).start()
```

Beware of replacing *sys.stdin* with a "file like object"

multiprocessing originally unconditionally called:

```
os.close(sys.stdin.fileno())
```

in the `multiprocessing.Process._bootstrap()` method — this resulted in issues with processes-in-processes. This has been changed to:

```
sys.stdin.close()
sys.stdin = open(os.open(os.devnull, os.O_RDONLY), closefd=False)
```

Which solves the fundamental issue of processes colliding with each other resulting in a bad file descriptor error, but introduces a potential danger to applications which replace *sys.stdin()* with a "file-like object" with output buffering. This danger is that if multiple processes call

close() on this file-like object, it could result in the same data being flushed to the object multiple times, resulting in corruption.

If you write a file-like object and implement your own caching, you can make it fork-safe by storing the pid whenever you append to the cache, and discarding the cache when the pid changes. For example:

```
@property
def cache(self):
    pid = os.getpid()
    if pid != self._pid:
        self._pid = pid
        self._cache = []
    return self._cache
```

For more information, see bpo-5155, bpo-5313 and bpo-5331

The *spawn* and *forkserver* start methods

There are a few extra restriction which don't apply to the *fork* start method.

More picklability

Ensure that all arguments to `Process.__init__()` are picklable. Also, if you subclass *Process* then make sure that instances will be picklable when the *Process.start* method is called.

Global variables

Bear in mind that if code run in a child process tries to access a global variable, then the value it sees (if any) may not be the same as the value in the parent process at the time that *Process.start* was called.

However, global variables which are just module level constants cause no problems.

Safe importing of main module

Make sure that the main module can be safely imported by a new Python interpreter without causing unintended side effects (such a starting a new process).

For example, using the *spawn* or *forkserver* start method running the following module would fail with a *RuntimeError*:

```
from multiprocessing import Process

def foo():
    print('hello')

p = Process(target=foo)
p.start()
```

Instead one should protect the "entry point" of the program by using `if __name__ == '__main__':` as follows:

```
from multiprocessing import Process, freeze_support, set_start_method

def foo():
    print('hello')

if __name__ == '__main__':
    freeze_support()
```

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```
    set_start_method('spawn')
    p = Process(target=foo)
    p.start()
```

(The `freeze_support()` line can be omitted if the program will be run normally instead of frozen.)

This allows the newly spawned Python interpreter to safely import the module and then run the module's `foo()` function.

Similar restrictions apply if a pool or manager is created in the main module.

17.2.4 Examples

Demonstration of how to create and use customized managers and proxies:

```
from multiprocessing import freeze_support
from multiprocessing.managers import BaseManager, BaseProxy
import operator

##

class Foo:
    def f(self):
        print('you called Foo.f()')
    def g(self):
        print('you called Foo.g()')
    def _h(self):
        print('you called Foo._h()')

# A simple generator function
def baz():
    for i in range(10):
        yield i*i

# Proxy type for generator objects
class GeneratorProxy(BaseProxy):
    _exposed_ = ['__next__']
    def __iter__(self):
        return self
    def __next__(self):
        return self._callmethod('__next__')

# Function to return the operator module
def get_operator_module():
    return operator

##

class MyManager(BaseManager):
    pass

# register the Foo class; make `f()` and `g()` accessible via proxy
MyManager.register('Foo1', Foo)

# register the Foo class; make `g()` and `_h()` accessible via proxy
```

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```
MyManager.register('Foo2', Foo, exposed=('g', '_h'))

# register the generator function baz; use `GeneratorProxy` to make proxies
MyManager.register('baz', baz, proxytype=GeneratorProxy)

# register get_operator_module(); make public functions accessible via proxy
MyManager.register('operator', get_operator_module)

##

def test():
    manager = MyManager()
    manager.start()

    print('-' * 20)

    f1 = manager.Foo1()
    f1.f()
    f1.g()
    assert not hasattr(f1, '_h')
    assert sorted(f1._exposed_) == sorted(['f', 'g'])

    print('-' * 20)

    f2 = manager.Foo2()
    f2.g()
    f2._h()
    assert not hasattr(f2, 'f')
    assert sorted(f2._exposed_) == sorted(['g', '_h'])

    print('-' * 20)

    it = manager.baz()
    for i in it:
        print('<%d>' % i, end=' ')
    print()

    print('-' * 20)

    op = manager.operator()
    print('op.add(23, 45) =', op.add(23, 45))
    print('op.pow(2, 94) =', op.pow(2, 94))
    print('op._exposed_ =', op._exposed_)

##

if __name__ == '__main__':
    freeze_support()
    test()
```

Using *Pool*:

```
import multiprocessing
import time
import random
import sys
```

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```
#
# Functions used by test code
#

def calculate(func, args):
    result = func(*args)
    return '%s says that %s%s = %s' % (
        multiprocessing.current_process().name,
        func.__name__, args, result
        )

def calculatestar(args):
    return calculate(*args)

def mul(a, b):
    time.sleep(0.5 * random.random())
    return a * b

def plus(a, b):
    time.sleep(0.5 * random.random())
    return a + b

def f(x):
    return 1.0 / (x - 5.0)

def pow3(x):
    return x ** 3

def noop(x):
    pass

#
# Test code
#

def test():
    PROCESSES = 4
    print('Creating pool with %d processes\n' % PROCESSES)

    with multiprocessing.Pool(PROCESSES) as pool:
        #
        # Tests
        #

        TASKS = [(mul, (i, 7)) for i in range(10)] + \
                [(plus, (i, 8)) for i in range(10)]

        results = [pool.apply_async(calculate, t) for t in TASKS]
        imap_it = pool.imap(calculatestar, TASKS)
        imap_unordered_it = pool.imap_unordered(calculatestar, TASKS)

        print('Ordered results using pool.apply_async():')
        for r in results:
            print('\t', r.get())
        print()
```

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```
    print('Ordered results using pool.imap():')
    for x in imap_it:
        print('\t', x)
    print()

    print('Unordered results using pool.imap_unordered():')
    for x in imap_unordered_it:
        print('\t', x)
    print()

    print('Ordered results using pool.map() --- will block till complete:')
    for x in pool.map(calculatestar, TASKS):
        print('\t', x)
    print()

    #
    # Test error handling
    #

    print('Testing error handling:')

    try:
        print(pool.apply(f, (5,)))
    except ZeroDivisionError:
        print('\tGot ZeroDivisionError as expected from pool.apply()')
    else:
        raise AssertionError('expected ZeroDivisionError')

    try:
        print(pool.map(f, list(range(10))))
    except ZeroDivisionError:
        print('\tGot ZeroDivisionError as expected from pool.map()')
    else:
        raise AssertionError('expected ZeroDivisionError')

    try:
        print(list(pool.imap(f, list(range(10)))))
    except ZeroDivisionError:
        print('\tGot ZeroDivisionError as expected from list(pool.imap())')
    else:
        raise AssertionError('expected ZeroDivisionError')

    it = pool.imap(f, list(range(10)))
    for i in range(10):
        try:
            x = next(it)
        except ZeroDivisionError:
            if i == 5:
                pass
        except StopIteration:
            break
        else:
            if i == 5:
                raise AssertionError('expected ZeroDivisionError')
```

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```
        assert i == 9
        print('\tGot ZeroDivisionError as expected from IMapIterator.next()')
        print()

        #
        # Testing timeouts
        #

        print('Testing ApplyResult.get() with timeout:', end=' ')
        res = pool.apply_async(calculate, TASKS[0])
        while 1:
            sys.stdout.flush()
            try:
                sys.stdout.write('\n\t%s' % res.get(0.02))
                break
            except multiprocessing.TimeoutError:
                sys.stdout.write('.')
        print()
        print()

        print('Testing IMapIterator.next() with timeout:', end=' ')
        it = pool.imap(calculatestar, TASKS)
        while 1:
            sys.stdout.flush()
            try:
                sys.stdout.write('\n\t%s' % it.next(0.02))
            except StopIteration:
                break
            except multiprocessing.TimeoutError:
                sys.stdout.write('.')
        print()
        print()


if __name__ == '__main__':
    multiprocessing.freeze_support()
    test()
```

An example showing how to use queues to feed tasks to a collection of worker processes and collect the results:

```
import time
import random

from multiprocessing import Process, Queue, current_process, freeze_support

#
# Function run by worker processes
#

def worker(input, output):
    for func, args in iter(input.get, 'STOP'):
        result = calculate(func, args)
        output.put(result)

#
```

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```
# Function used to calculate result
#

def calculate(func, args):
    result = func(*args)
    return '%s says that %s%s = %s' % \
        (current_process().name, func.__name__, args, result)

#
# Functions referenced by tasks
#

def mul(a, b):
    time.sleep(0.5*random.random())
    return a * b

def plus(a, b):
    time.sleep(0.5*random.random())
    return a + b

#
#
#

def test():
    NUMBER_OF_PROCESSES = 4
    TASKS1 = [(mul, (i, 7)) for i in range(20)]
    TASKS2 = [(plus, (i, 8)) for i in range(10)]

    # Create queues
    task_queue = Queue()
    done_queue = Queue()

    # Submit tasks
    for task in TASKS1:
        task_queue.put(task)

    # Start worker processes
    for i in range(NUMBER_OF_PROCESSES):
        Process(target=worker, args=(task_queue, done_queue)).start()

    # Get and print results
    print('Unordered results:')
    for i in range(len(TASKS1)):
        print('\t', done_queue.get())

    # Add more tasks using `put()`
    for task in TASKS2:
        task_queue.put(task)

    # Get and print some more results
    for i in range(len(TASKS2)):
        print('\t', done_queue.get())

    # Tell child processes to stop
    for i in range(NUMBER_OF_PROCESSES):
```

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```
        task_queue.put('STOP')


if __name__ == '__main__':
    freeze_support()
    test()
```

17.3 The concurrent package

Currently, there is only one module in this package:

- *concurrent.futures* – Launching parallel tasks

17.4 concurrent.futures — Launching parallel tasks

New in version 3.2.

Source code: Lib/concurrent/futures/thread.py and Lib/concurrent/futures/process.py

---

The *concurrent.futures* module provides a high-level interface for asynchronously executing callables.

The asynchronous execution can be performed with threads, using *ThreadPoolExecutor*, or separate processes, using *ProcessPoolExecutor*. Both implement the same interface, which is defined by the abstract *Executor* class.

17.4.1 Executor Objects

class concurrent.futures.Executor

An abstract class that provides methods to execute calls asynchronously. It should not be used directly, but through its concrete subclasses.

submit(*fn*, **args*, ***kwargs*)

Schedules the callable, *fn*, to be executed as `fn(*args **kwargs)` and returns a *Future* object representing the execution of the callable.

```
with ThreadPoolExecutor(max_workers=1) as executor:
    future = executor.submit(pow, 323, 1235)
    print(future.result())
```

map(*func*, **iterables*, *timeout=None*, *chunksize=1*)

Similar to *map(func, *iterables)* except:

- the *iterables* are collected immediately rather than lazily;
- *func* is executed asynchronously and several calls to *func* may be made concurrently.

The returned iterator raises a *concurrent.futures.TimeoutError* if *__next__()* is called and the result isn't available after *timeout* seconds from the original call to *Executor.map()*. *timeout* can be an int or a float. If *timeout* is not specified or `None`, there is no limit to the wait time.

If a *func* call raises an exception, then that exception will be raised when its value is retrieved from the iterator.

When using *ProcessPoolExecutor*, this method chops *iterables* into a number of chunks which it submits to the pool as separate tasks. The (approximate) size of these chunks can be specified by setting *chunksize* to a positive integer. For very long iterables, using a large value for *chunksize* can significantly improve performance compared to the default size of 1. With *ThreadPoolExecutor*, *chunksize* has no effect.

Changed in version 3.5: Added the *chunksize* argument.

shutdown(*wait=True*)

Signal the executor that it should free any resources that it is using when the currently pending futures are done executing. Calls to *Executor.submit()* and *Executor.map()* made after shutdown will raise *RuntimeError*.

If *wait* is `True` then this method will not return until all the pending futures are done executing and the resources associated with the executor have been freed. If *wait* is `False` then this method will return immediately and the resources associated with the executor will be freed when all pending futures are done executing. Regardless of the value of *wait*, the entire Python program will not exit until all pending futures are done executing.

You can avoid having to call this method explicitly if you use the `with` statement, which will shutdown the *Executor* (waiting as if *Executor.shutdown()* were called with *wait* set to `True`):

```
import shutil
with ThreadPoolExecutor(max_workers=4) as e:
    e.submit(shutil.copy, 'src1.txt', 'dest1.txt')
    e.submit(shutil.copy, 'src2.txt', 'dest2.txt')
    e.submit(shutil.copy, 'src3.txt', 'dest3.txt')
    e.submit(shutil.copy, 'src4.txt', 'dest4.txt')
```

17.4.2 ThreadPoolExecutor

ThreadPoolExecutor is an *Executor* subclass that uses a pool of threads to execute calls asynchronously.

Deadlocks can occur when the callable associated with a *Future* waits on the results of another *Future*. For example:

```
import time
def wait_on_b():
    time.sleep(5)
    print(b.result())  # b will never complete because it is waiting on a.
    return 5

def wait_on_a():
    time.sleep(5)
    print(a.result())  # a will never complete because it is waiting on b.
    return 6


executor = ThreadPoolExecutor(max_workers=2)
a = executor.submit(wait_on_b)
b = executor.submit(wait_on_a)
```

And:

```
def wait_on_future():
    f = executor.submit(pow, 5, 2)
    # This will never complete because there is only one worker thread and
    # it is executing this function.
    print(f.result())

executor = ThreadPoolExecutor(max_workers=1)
executor.submit(wait_on_future)
```

class concurrent.futures.**ThreadPoolExecutor**(*max_workers=None*, *thread_name_prefix=''*, *initializer=None*, *initargs=()*)

An *Executor* subclass that uses a pool of at most *max_workers* threads to execute calls asynchronously.

initializer is an optional callable that is called at the start of each worker thread; *initargs* is a tuple of arguments passed to the initializer. Should *initializer* raise an exception, all currently pending jobs will raise a *BrokenThreadPool*, as well any attempt to submit more jobs to the pool.

Changed in version 3.5: If *max_workers* is `None` or not given, it will default to the number of processors on the machine, multiplied by `5`, assuming that *ThreadPoolExecutor* is often used to overlap I/O instead of CPU work and the number of workers should be higher than the number of workers for *ProcessPoolExecutor*.

New in version 3.6: The *thread_name_prefix* argument was added to allow users to control the threading.Thread names for worker threads created by the pool for easier debugging.

Changed in version 3.7: Added the *initializer* and *initargs* arguments.

ThreadPoolExecutor Example

```
import concurrent.futures
import urllib.request

URLS = ['http://www.foxnews.com/',
        'http://www.cnn.com/',
        'http://europe.wsj.com/',
        'http://www.bbc.co.uk/',
        'http://some-made-up-domain.com/']

# Retrieve a single page and report the URL and contents
def load_url(url, timeout):
    with urllib.request.urlopen(url, timeout=timeout) as conn:
        return conn.read()

# We can use a with statement to ensure threads are cleaned up promptly
with concurrent.futures.ThreadPoolExecutor(max_workers=5) as executor:
    # Start the load operations and mark each future with its URL
    future_to_url = {executor.submit(load_url, url, 60): url for url in URLS}
    for future in concurrent.futures.as_completed(future_to_url):
        url = future_to_url[future]
        try:
            data = future.result()
        except Exception as exc:
            print('%r generated an exception: %s' % (url, exc))
        else:
            print('%r page is %d bytes' % (url, len(data)))
```

17.4.3 ProcessPoolExecutor

The *ProcessPoolExecutor* class is an *Executor* subclass that uses a pool of processes to execute calls asynchronously. *ProcessPoolExecutor* uses the *multiprocessing* module, which allows it to side-step the *Global Interpreter Lock* but also means that only picklable objects can be executed and returned.

The `__main__` module must be importable by worker subprocesses. This means that *ProcessPoolExecutor* will not work in the interactive interpreter.

Calling *Executor* or *Future* methods from a callable submitted to a *ProcessPoolExecutor* will result in deadlock.

class concurrent.futures.**ProcessPoolExecutor**(*max_workers=None*, *mp_context=None*, *initializer=None*, *initargs=()*)

An *Executor* subclass that executes calls asynchronously using a pool of at most *max_workers* processes. If *max_workers* is `None` or not given, it will default to the number of processors on the machine. If *max_workers* is lower or equal to `0`, then a *ValueError* will be raised. *mp_context* can be a multiprocessing context or None. It will be used to launch the workers. If *mp_context* is `None` or not given, the default multiprocessing context is used.

initializer is an optional callable that is called at the start of each worker process; *initargs* is a tuple of arguments passed to the initializer. Should *initializer* raise an exception, all currently pending jobs will raise a *BrokenThreadPool*, as well any attempt to submit more jobs to the pool.

Changed in version 3.3: When one of the worker processes terminates abruptly, a `BrokenProcessPool` error is now raised. Previously, behaviour was undefined but operations on the executor or its futures would often freeze or deadlock.

Changed in version 3.7: The *mp_context* argument was added to allow users to control the start_method for worker processes created by the pool.

Added the *initializer* and *initargs* arguments.

ProcessPoolExecutor Example

```
import concurrent.futures
import math

PRIMES = [
    112272535095293,
    112582705942171,
    112272535095293,
    115280095190773,
    115797848077099,
    1099726899285419]

def is_prime(n):
    if n % 2 == 0:
        return False

    sqrt_n = int(math.floor(math.sqrt(n)))
    for i in range(3, sqrt_n + 1, 2):
        if n % i == 0:
            return False
    return True

def main():
    with concurrent.futures.ProcessPoolExecutor() as executor:
```

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```
        for number, prime in zip(PRIMES, executor.map(is_prime, PRIMES)):
            print('%d is prime: %s' % (number, prime))

if __name__ == '__main__':
    main()
```

17.4.4 Future Objects

The *Future* class encapsulates the asynchronous execution of a callable. *Future* instances are created by *Executor.submit()*.

class concurrent.futures.Future

Encapsulates the asynchronous execution of a callable. *Future* instances are created by *Executor.submit()* and should not be created directly except for testing.

cancel()

Attempt to cancel the call. If the call is currently being executed and cannot be cancelled then the method will return `False`, otherwise the call will be cancelled and the method will return `True`.

cancelled()

Return `True` if the call was successfully cancelled.

running()

Return `True` if the call is currently being executed and cannot be cancelled.

done()

Return `True` if the call was successfully cancelled or finished running.

result(*timeout=None*)

Return the value returned by the call. If the call hasn't yet completed then this method will wait up to *timeout* seconds. If the call hasn't completed in *timeout* seconds, then a *concurrent.futures.TimeoutError* will be raised. *timeout* can be an int or float. If *timeout* is not specified or `None`, there is no limit to the wait time.

If the future is cancelled before completing then *CancelledError* will be raised.

If the call raised, this method will raise the same exception.

exception(*timeout=None*)

Return the exception raised by the call. If the call hasn't yet completed then this method will wait up to *timeout* seconds. If the call hasn't completed in *timeout* seconds, then a *concurrent.futures.TimeoutError* will be raised. *timeout* can be an int or float. If *timeout* is not specified or `None`, there is no limit to the wait time.

If the future is cancelled before completing then *CancelledError* will be raised.

If the call completed without raising, `None` is returned.

add_done_callback(*fn*)

Attaches the callable *fn* to the future. *fn* will be called, with the future as its only argument, when the future is cancelled or finishes running.

Added callables are called in the order that they were added and are always called in a thread belonging to the process that added them. If the callable raises an *Exception* subclass, it will be logged and ignored. If the callable raises a *BaseException* subclass, the behavior is undefined.

If the future has already completed or been cancelled, *fn* will be called immediately.

The following *Future* methods are meant for use in unit tests and *Executor* implementations.

set_running_or_notify_cancel()
This method should only be called by *Executor* implementations before executing the work associated with the *Future* and by unit tests.

If the method returns `False` then the *Future* was cancelled, i.e. *Future.cancel()* was called and returned *True*. Any threads waiting on the *Future* completing (i.e. through *as_completed()* or *wait()*) will be woken up.

If the method returns `True` then the *Future* was not cancelled and has been put in the running state, i.e. calls to *Future.running()* will return *True*.

This method can only be called once and cannot be called after *Future.set_result()* or *Future.set_exception()* have been called.

set_result(*result*)
Sets the result of the work associated with the *Future* to *result*.

This method should only be used by *Executor* implementations and unit tests.

set_exception(*exception*)
Sets the result of the work associated with the *Future* to the *Exception* *exception*.

This method should only be used by *Executor* implementations and unit tests.

17.4.5 Module Functions

concurrent.futures.**wait**(*fs*, *timeout=None*, *return_when=ALL_COMPLETED*)
Wait for the *Future* instances (possibly created by different *Executor* instances) given by *fs* to complete. Returns a named 2-tuple of sets. The first set, named `done`, contains the futures that completed (finished or were cancelled) before the wait completed. The second set, named `not_done`, contains uncompleted futures.

timeout can be used to control the maximum number of seconds to wait before returning. *timeout* can be an int or float. If *timeout* is not specified or `None`, there is no limit to the wait time.

return_when indicates when this function should return. It must be one of the following constants:

Constant	Description
`FIRST_COMPLETED`	The function will return when any future finishes or is cancelled.
`FIRST_EXCEPTION`	The function will return when any future finishes by raising an exception. If no future raises an exception then it is equivalent to `ALL_COMPLETED`.
`ALL_COMPLETED`	The function will return when all futures finish or are cancelled.

concurrent.futures.**as_completed**(*fs*, *timeout=None*)
Returns an iterator over the *Future* instances (possibly created by different *Executor* instances) given by *fs* that yields futures as they complete (finished or were cancelled). Any futures given by *fs* that are duplicated will be returned once. Any futures that completed before *as_completed()* is called will be yielded first. The returned iterator raises a *concurrent.futures.TimeoutError* if *__next__()* is called and the result isn't available after *timeout* seconds from the original call to *as_completed()*. *timeout* can be an int or float. If *timeout* is not specified or `None`, there is no limit to the wait time.

See also:

PEP 3148 – **futures - execute computations asynchronously** The proposal which described this feature for inclusion in the Python standard library.

17.4.6 Exception classes

exception concurrent.futures.**CancelledError**
Raised when a future is cancelled.

exception concurrent.futures.**TimeoutError**
Raised when a future operation exceeds the given timeout.

exception concurrent.futures.**BrokenExecutor**
Derived from *RuntimeError*, this exception class is raised when an executor is broken for some reason, and cannot be used to submit or execute new tasks.

New in version 3.7.

exception concurrent.futures.thread.**BrokenThreadPool**
Derived from *BrokenExecutor*, this exception class is raised when one of the workers of a ThreadPoolExecutor has failed initializing.

New in version 3.7.

exception concurrent.futures.process.**BrokenProcessPool**
Derived from *BrokenExecutor* (formerly *RuntimeError*), this exception class is raised when one of the workers of a ProcessPoolExecutor has terminated in a non-clean fashion (for example, if it was killed from the outside).

New in version 3.3.

17.5 subprocess — Subprocess management

Source code: Lib/subprocess.py

The *subprocess* module allows you to spawn new processes, connect to their input/output/error pipes, and obtain their return codes. This module intends to replace several older modules and functions:

```
os.system
os.spawn*
```

Information about how the *subprocess* module can be used to replace these modules and functions can be found in the following sections.

See also:

PEP 324 – PEP proposing the subprocess module

17.5.1 Using the subprocess Module

The recommended approach to invoking subprocesses is to use the *run()* function for all use cases it can handle. For more advanced use cases, the underlying *Popen* interface can be used directly.

The *run()* function was added in Python 3.5; if you need to retain compatibility with older versions, see the *Older high-level API* section.

subprocess.**run**(*args*, ***, *stdin=None*, *input=None*, *stdout=None*, *stderr=None*, *shell=False*, *cwd=None*, *timeout=None*, *check=False*, *encoding=None*, *errors=None*, *text=None*, *env=None*)
Run the command described by *args*. Wait for command to complete, then return a *CompletedProcess* instance.

The arguments shown above are merely the most common ones, described below in *Frequently Used Arguments* (hence the use of keyword-only notation in the abbreviated signature). The full function signature is largely the same as that of the *Popen* constructor - most of the arguments to this function are passed through to that interface. (*timeout*, *input*, *check*, and *capture_output* are not.)

If *capture_output* is true, stdout and stderr will be captured. When used, the internal *Popen* object is automatically created with `stdout=PIPE` and `stderr=PIPE`. The *stdout* and *stderr* arguments may not be used as well.

The *timeout* argument is passed to *Popen.communicate()*. If the timeout expires, the child process will be killed and waited for. The *TimeoutExpired* exception will be re-raised after the child process has terminated.

The *input* argument is passed to *Popen.communicate()* and thus to the subprocess's stdin. If used it must be a byte sequence, or a string if *encoding* or *errors* is specified or *text* is true. When used, the internal *Popen* object is automatically created with `stdin=PIPE`, and the *stdin* argument may not be used as well.

If *check* is true, and the process exits with a non-zero exit code, a *CalledProcessError* exception will be raised. Attributes of that exception hold the arguments, the exit code, and stdout and stderr if they were captured.

If *encoding* or *errors* are specified, or *text* is true, file objects for stdin, stdout and stderr are opened in text mode using the specified *encoding* and *errors* or the *io.TextIOWrapper* default. The *universal_newlines* argument is equivalent to *text* and is provided for backwards compatibility. By default, file objects are opened in binary mode.

If *env* is not `None`, it must be a mapping that defines the environment variables for the new process; these are used instead of the default behavior of inheriting the current process' environment. It is passed directly to *Popen*.

Examples:

```
>>> subprocess.run(["ls", "-l"])  # doesn't capture output
CompletedProcess(args=['ls', '-l'], returncode=0)

>>> subprocess.run("exit 1", shell=True, check=True)
Traceback (most recent call last):
  ...
subprocess.CalledProcessError: Command 'exit 1' returned non-zero exit status 1

>>> subprocess.run(["ls", "-l", "/dev/null"], capture_output=True)
CompletedProcess(args=['ls', '-l', '/dev/null'], returncode=0,
stdout=b'crw-rw-rw- 1 root root 1, 3 Jan 23 16:23 /dev/null\n', stderr=b'')
```

New in version 3.5.

Changed in version 3.6: Added *encoding* and *errors* parameters

Changed in version 3.7: Added the *text* parameter, as a more understandable alias of *universal_newlines*. Added the *capture_output* parameter.

class subprocess.CompletedProcess

The return value from *run()*, representing a process that has finished.

args

The arguments used to launch the process. This may be a list or a string.

returncode

Exit status of the child process. Typically, an exit status of 0 indicates that it ran successfully.

A negative value `-N` indicates that the child was terminated by signal `N` (POSIX only).

stdout
Captured stdout from the child process. A bytes sequence, or a string if *run()* was called with an encoding, errors, or text=True. `None` if stdout was not captured.

If you ran the process with `stderr=subprocess.STDOUT`, stdout and stderr will be combined in this attribute, and *stderr* will be `None`.

stderr
Captured stderr from the child process. A bytes sequence, or a string if *run()* was called with an encoding, errors, or text=True. `None` if stderr was not captured.

check_returncode()
If *returncode* is non-zero, raise a *CalledProcessError*.

New in version 3.5.

subprocess.DEVNULL
Special value that can be used as the *stdin*, *stdout* or *stderr* argument to *Popen* and indicates that the special file *os.devnull* will be used.

New in version 3.3.

subprocess.PIPE
Special value that can be used as the *stdin*, *stdout* or *stderr* argument to *Popen* and indicates that a pipe to the standard stream should be opened. Most useful with *Popen.communicate()*.

subprocess.STDOUT
Special value that can be used as the *stderr* argument to *Popen* and indicates that standard error should go into the same handle as standard output.

exception subprocess.SubprocessError
Base class for all other exceptions from this module.

New in version 3.3.

exception subprocess.TimeoutExpired
Subclass of *SubprocessError*, raised when a timeout expires while waiting for a child process.

cmd
Command that was used to spawn the child process.

timeout
Timeout in seconds.

output
Output of the child process if it was captured by *run()* or *check_output()*. Otherwise, `None`.

stdout
Alias for output, for symmetry with *stderr*.

stderr
Stderr output of the child process if it was captured by *run()*. Otherwise, `None`.

New in version 3.3.

Changed in version 3.5: *stdout* and *stderr* attributes added

exception subprocess.CalledProcessError
Subclass of *SubprocessError*, raised when a process run by *check_call()* or *check_output()* returns a non-zero exit status.

returncode
Exit status of the child process. If the process exited due to a signal, this will be the negative signal number.

cmd
Command that was used to spawn the child process.

output
Output of the child process if it was captured by *run()* or *check_output()*. Otherwise, None.

stdout
Alias for output, for symmetry with *stderr*.

stderr
Stderr output of the child process if it was captured by *run()*. Otherwise, None.

Changed in version 3.5: *stdout* and *stderr* attributes added

Frequently Used Arguments

To support a wide variety of use cases, the *Popen* constructor (and the convenience functions) accept a large number of optional arguments. For most typical use cases, many of these arguments can be safely left at their default values. The arguments that are most commonly needed are:

args is required for all calls and should be a string, or a sequence of program arguments. Providing a sequence of arguments is generally preferred, as it allows the module to take care of any required escaping and quoting of arguments (e.g. to permit spaces in file names). If passing a single string, either *shell* must be *True* (see below) or else the string must simply name the program to be executed without specifying any arguments.

stdin, *stdout* and *stderr* specify the executed program's standard input, standard output and standard error file handles, respectively. Valid values are *PIPE*, *DEVNULL*, an existing file descriptor (a positive integer), an existing file object, and None. *PIPE* indicates that a new pipe to the child should be created. *DEVNULL* indicates that the special file *os.devnull* will be used. With the default settings of None, no redirection will occur; the child's file handles will be inherited from the parent. Additionally, *stderr* can be *STDOUT*, which indicates that the stderr data from the child process should be captured into the same file handle as for *stdout*.

If *encoding* or *errors* are specified, or *text* (also known as *universal_newlines*) is true, the file objects *stdin*, *stdout* and *stderr* will be opened in text mode using the *encoding* and *errors* specified in the call or the defaults for *io.TextIOWrapper*.

For *stdin*, line ending characters '\n' in the input will be converted to the default line separator *os.linesep*. For *stdout* and *stderr*, all line endings in the output will be converted to '\n'. For more information see the documentation of the *io.TextIOWrapper* class when the *newline* argument to its constructor is None.

If text mode is not used, *stdin*, *stdout* and *stderr* will be opened as binary streams. No encoding or line ending conversion is performed.

New in version 3.6: Added *encoding* and *errors* parameters.

New in version 3.7: Added the *text* parameter as an alias for *universal_newlines*.

Note: The newlines attribute of the file objects *Popen.stdin*, *Popen.stdout* and *Popen.stderr* are not updated by the *Popen.communicate()* method.

If *shell* is True, the specified command will be executed through the shell. This can be useful if you are using Python primarily for the enhanced control flow it offers over most system shells and still want convenient access to other shell features such as shell pipes, filename wildcards, environment variable expansion, and expansion of ~ to a user's home directory. However, note that Python itself offers implementations of many shell-like features (in particular, *glob*, *fnmatch*, *os.walk()*, *os.path.expandvars()*, *os.path.expanduser()*, and *shutil*).

Changed in version 3.3: When *universal_newlines* is `True`, the class uses the encoding *locale.getpreferredencoding(False)* instead of `locale.getpreferredencoding()`. See the *io.TextIOWrapper* class for more information on this change.

Note: Read the *Security Considerations* section before using `shell=True`.

These options, along with all of the other options, are described in more detail in the *Popen* constructor documentation.

Popen Constructor

The underlying process creation and management in this module is handled by the *Popen* class. It offers a lot of flexibility so that developers are able to handle the less common cases not covered by the convenience functions.

`class subprocess.Popen`(*args*, *bufsize=-1*, *executable=None*, *stdin=None*, *stdout=None*, *stderr=None*, *preexec_fn=None*, *close_fds=True*, *shell=False*, *cwd=None*, *env=None*, *universal_newlines=False*, *startupinfo=None*, *creationflags=0*, *restore_signals=True*, *start_new_session=False*, *pass_fds=()*, ***, *encoding=None*, *errors=None*, *text=None*)

Execute a child program in a new process. On POSIX, the class uses *os.execvp()*-like behavior to execute the child program. On Windows, the class uses the Windows `CreateProcess()` function. The arguments to *Popen* are as follows.

args should be a sequence of program arguments or else a single string. By default, the program to execute is the first item in *args* if *args* is a sequence. If *args* is a string, the interpretation is platform-dependent and described below. See the *shell* and *executable* arguments for additional differences from the default behavior. Unless otherwise stated, it is recommended to pass *args* as a sequence.

On POSIX, if *args* is a string, the string is interpreted as the name or path of the program to execute. However, this can only be done if not passing arguments to the program.

Note: *shlex.split()* can be useful when determining the correct tokenization for *args*, especially in complex cases:

```
>>> import shlex, subprocess
>>> command_line = input()
/bin/vikings -input eggs.txt -output "spam spam.txt" -cmd "echo '$MONEY'"
>>> args = shlex.split(command_line)
>>> print(args)
['/bin/vikings', '-input', 'eggs.txt', '-output', 'spam spam.txt', '-cmd', "echo '$MONEY'"]
>>> p = subprocess.Popen(args) # Success!
```

Note in particular that options (such as *-input*) and arguments (such as *eggs.txt*) that are separated by whitespace in the shell go in separate list elements, while arguments that need quoting or backslash escaping when used in the shell (such as filenames containing spaces or the *echo* command shown above) are single list elements.

On Windows, if *args* is a sequence, it will be converted to a string in a manner described in *Converting an argument sequence to a string on Windows*. This is because the underlying `CreateProcess()` operates on strings.

The *shell* argument (which defaults to `False`) specifies whether to use the shell as the program to execute. If *shell* is `True`, it is recommended to pass *args* as a string rather than as a sequence.

On POSIX with `shell=True`, the shell defaults to `/bin/sh`. If *args* is a string, the string specifies the command to execute through the shell. This means that the string must be formatted exactly as it would be when typed at the shell prompt. This includes, for example, quoting or backslash escaping filenames with spaces in them. If *args* is a sequence, the first item specifies the command string, and any additional items will be treated as additional arguments to the shell itself. That is to say, *Popen* does the equivalent of:

```
Popen(['/bin/sh', '-c', args[0], args[1], ...])
```

On Windows with `shell=True`, the `COMSPEC` environment variable specifies the default shell. The only time you need to specify `shell=True` on Windows is when the command you wish to execute is built into the shell (e.g. `dir` or `copy`). You do not need `shell=True` to run a batch file or console-based executable.

Note: Read the *Security Considerations* section before using `shell=True`.

---

bufsize will be supplied as the corresponding argument to the *open()* function when creating the stdin/stdout/stderr pipe file objects:

- `0` means unbuffered (read and write are one system call and can return short)
- `1` means line buffered (only usable if `universal_newlines=True` i.e., in a text mode)
- any other positive value means use a buffer of approximately that size
- negative bufsize (the default) means the system default of io.DEFAULT_BUFFER_SIZE will be used.

Changed in version 3.3.1: *bufsize* now defaults to -1 to enable buffering by default to match the behavior that most code expects. In versions prior to Python 3.2.4 and 3.3.1 it incorrectly defaulted to `0` which was unbuffered and allowed short reads. This was unintentional and did not match the behavior of Python 2 as most code expected.

The *executable* argument specifies a replacement program to execute. It is very seldom needed. When `shell=False`, *executable* replaces the program to execute specified by *args*. However, the original *args* is still passed to the program. Most programs treat the program specified by *args* as the command name, which can then be different from the program actually executed. On POSIX, the *args* name becomes the display name for the executable in utilities such as `ps`. If `shell=True`, on POSIX the *executable* argument specifies a replacement shell for the default `/bin/sh`.

stdin, *stdout* and *stderr* specify the executed program's standard input, standard output and standard error file handles, respectively. Valid values are *PIPE*, *DEVNULL*, an existing file descriptor (a positive integer), an existing *file object*, and `None`. *PIPE* indicates that a new pipe to the child should be created. *DEVNULL* indicates that the special file *os.devnull* will be used. With the default settings of `None`, no redirection will occur; the child's file handles will be inherited from the parent. Additionally, *stderr* can be *STDOUT*, which indicates that the stderr data from the applications should be captured into the same file handle as for stdout.

If *preexec_fn* is set to a callable object, this object will be called in the child process just before the child is executed. (POSIX only)

Warning: The *preexec_fn* parameter is not safe to use in the presence of threads in your application. The child process could deadlock before exec is called. If you must use it, keep it trivial! Minimize the number of libraries you call into.

Note: If you need to modify the environment for the child use the *env* parameter rather than doing

it in a *preexec_fn*. The *start_new_session* parameter can take the place of a previously common use of *preexec_fn* to call os.setsid() in the child.

If *close_fds* is true, all file descriptors except `0`, `1` and `2` will be closed before the child process is executed. Otherwise when *close_fds* is false, file descriptors obey their inheritable flag as described in *Inheritance of File Descriptors*.

On Windows, if *close_fds* is true then no handles will be inherited by the child process unless explicitly passed in the `handle_list` element of *STARTUPINFO.lpAttributeList*, or by standard handle redirection.

Changed in version 3.2: The default for *close_fds* was changed from *False* to what is described above.

Changed in version 3.7: On Windows the default for *close_fds* was changed from *False* to *True* when redirecting the standard handles. It's now possible to set *close_fds* to *True* when redirecting the standard handles.

pass_fds is an optional sequence of file descriptors to keep open between the parent and child. Providing any *pass_fds* forces *close_fds* to be *True*. (POSIX only)

New in version 3.2: The *pass_fds* parameter was added.

If *cwd* is not `None`, the function changes the working directory to *cwd* before executing the child. *cwd* can be a *str* and *path-like* object. In particular, the function looks for *executable* (or for the first item in *args*) relative to *cwd* if the executable path is a relative path.

Changed in version 3.6: *cwd* parameter accepts a *path-like object*.

If *restore_signals* is true (the default) all signals that Python has set to SIG_IGN are restored to SIG_DFL in the child process before the exec. Currently this includes the SIGPIPE, SIGXFZ and SIGXFSZ signals. (POSIX only)

Changed in version 3.2: *restore_signals* was added.

If *start_new_session* is true the setsid() system call will be made in the child process prior to the execution of the subprocess. (POSIX only)

Changed in version 3.2: *start_new_session* was added.

If *env* is not `None`, it must be a mapping that defines the environment variables for the new process; these are used instead of the default behavior of inheriting the current process' environment.

Note: If specified, *env* must provide any variables required for the program to execute. On Windows, in order to run a side-by-side assembly the specified *env* **must** include a valid `SystemRoot`.

If *encoding* or *errors* are specified, or *text* is true, the file objects *stdin*, *stdout* and *stderr* are opened in text mode with the specified encoding and *errors*, as described above in *Frequently Used Arguments*. The *universal_newlines* argument is equivalent to *text* and is provided for backwards compatibility. By default, file objects are opened in binary mode.

New in version 3.6: *encoding* and *errors* were added.

New in version 3.7: *text* was added as a more readable alias for *universal_newlines*.

If given, *startupinfo* will be a *STARTUPINFO* object, which is passed to the underlying `CreateProcess` function. *creationflags*, if given, can be one or more of the following flags:

- *CREATE_NEW_CONSOLE*
- *CREATE_NEW_PROCESS_GROUP*
- *ABOVE_NORMAL_PRIORITY_CLASS*
- *BELOW_NORMAL_PRIORITY_CLASS*

- *HIGH_PRIORITY_CLASS*
- *IDLE_PRIORITY_CLASS*
- *NORMAL_PRIORITY_CLASS*
- *REALTIME_PRIORITY_CLASS*
- *CREATE_NO_WINDOW*
- *DETACHED_PROCESS*
- *CREATE_DEFAULT_ERROR_MODE*
- *CREATE_BREAKAWAY_FROM_JOB*

Popen objects are supported as context managers via the `with` statement: on exit, standard file descriptors are closed, and the process is waited for.

```
with Popen(["ifconfig"], stdout=PIPE) as proc:
    log.write(proc.stdout.read())
```

Changed in version 3.2: Added context manager support.

Changed in version 3.6: Popen destructor now emits a *ResourceWarning* warning if the child process is still running.

Exceptions

Exceptions raised in the child process, before the new program has started to execute, will be re-raised in the parent. Additionally, the exception object will have one extra attribute called `child_traceback`, which is a string containing traceback information from the child's point of view.

The most common exception raised is *OSError*. This occurs, for example, when trying to execute a non-existent file. Applications should prepare for *OSError* exceptions.

A *ValueError* will be raised if *Popen* is called with invalid arguments.

check_call() and *check_output()* will raise *CalledProcessError* if the called process returns a non-zero return code.

All of the functions and methods that accept a *timeout* parameter, such as *call()* and *Popen.communicate()* will raise *TimeoutExpired* if the timeout expires before the process exits.

Exceptions defined in this module all inherit from *SubprocessError*.

New in version 3.3: The *SubprocessError* base class was added.

17.5.2 Security Considerations

Unlike some other popen functions, this implementation will never implicitly call a system shell. This means that all characters, including shell metacharacters, can safely be passed to child processes. If the shell is invoked explicitly, via `shell=True`, it is the application's responsibility to ensure that all whitespace and metacharacters are quoted appropriately to avoid shell injection vulnerabilities.

When using `shell=True`, the *shlex.quote()* function can be used to properly escape whitespace and shell metacharacters in strings that are going to be used to construct shell commands.

17.5.3 Popen Objects

Instances of the *Popen* class have the following methods:

`Popen.poll()`
Check if child process has terminated. Set and return *returncode* attribute. Otherwise, returns `None`.

`Popen.wait(`*timeout=None*`)`
Wait for child process to terminate. Set and return *returncode* attribute.

If the process does not terminate after *timeout* seconds, raise a *TimeoutExpired* exception. It is safe to catch this exception and retry the wait.

Note: This will deadlock when using `stdout=PIPE` or `stderr=PIPE` and the child process generates enough output to a pipe such that it blocks waiting for the OS pipe buffer to accept more data. Use *Popen.communicate()* when using pipes to avoid that.

Note: The function is implemented using a busy loop (non-blocking call and short sleeps). Use the *asyncio* module for an asynchronous wait: see *asyncio.create_subprocess_exec*.

Changed in version 3.3: *timeout* was added.

`Popen.communicate(`*input=None*, *timeout=None*`)`
Interact with process: Send data to stdin. Read data from stdout and stderr, until end-of-file is reached. Wait for process to terminate. The optional *input* argument should be data to be sent to the child process, or `None`, if no data should be sent to the child. If streams were opened in text mode, *input* must be a string. Otherwise, it must be bytes.

communicate() returns a tuple `(stdout_data, stderr_data)`. The data will be strings if streams were opened in text mode; otherwise, bytes.

Note that if you want to send data to the process's stdin, you need to create the Popen object with `stdin=PIPE`. Similarly, to get anything other than `None` in the result tuple, you need to give `stdout=PIPE` and/or `stderr=PIPE` too.

If the process does not terminate after *timeout* seconds, a *TimeoutExpired* exception will be raised. Catching this exception and retrying communication will not lose any output.

The child process is not killed if the timeout expires, so in order to cleanup properly a well-behaved application should kill the child process and finish communication:

```
proc = subprocess.Popen(...)
try:
    outs, errs = proc.communicate(timeout=15)
except TimeoutExpired:
    proc.kill()
    outs, errs = proc.communicate()
```

Note: The data read is buffered in memory, so do not use this method if the data size is large or unlimited.

Changed in version 3.3: *timeout* was added.

`Popen.send_signal(`*signal*`)`
Sends the signal *signal* to the child.

Note: On Windows, SIGTERM is an alias for *terminate()*. CTRL_C_EVENT and CTRL_BREAK_EVENT can be sent to processes started with a *creationflags* parameter which includes *CREATE_NEW_PROCESS_GROUP*.

`Popen.terminate()`
Stop the child. On Posix OSs the method sends SIGTERM to the child. On Windows the Win32 API function `TerminateProcess()` is called to stop the child.

`Popen.kill()`
Kills the child. On Posix OSs the function sends SIGKILL to the child. On Windows *kill()* is an alias for *terminate()*.

The following attributes are also available:

`Popen.args`
The *args* argument as it was passed to *Popen* – a sequence of program arguments or else a single string.

New in version 3.3.

`Popen.stdin`
If the *stdin* argument was *PIPE*, this attribute is a writeable stream object as returned by *open()*. If the *encoding* or *errors* arguments were specified or the *universal_newlines* argument was `True`, the stream is a text stream, otherwise it is a byte stream. If the *stdin* argument was not *PIPE*, this attribute is `None`.

`Popen.stdout`
If the *stdout* argument was *PIPE*, this attribute is a readable stream object as returned by *open()*. Reading from the stream provides output from the child process. If the *encoding* or *errors* arguments were specified or the *universal_newlines* argument was `True`, the stream is a text stream, otherwise it is a byte stream. If the *stdout* argument was not *PIPE*, this attribute is `None`.

`Popen.stderr`
If the *stderr* argument was *PIPE*, this attribute is a readable stream object as returned by *open()*. Reading from the stream provides error output from the child process. If the *encoding* or *errors* arguments were specified or the *universal_newlines* argument was `True`, the stream is a text stream, otherwise it is a byte stream. If the *stderr* argument was not *PIPE*, this attribute is `None`.

Warning: Use *communicate()* rather than *.stdin.write*, *.stdout.read* or *.stderr.read* to avoid deadlocks due to any of the other OS pipe buffers filling up and blocking the child process.

`Popen.pid`
The process ID of the child process.

Note that if you set the *shell* argument to `True`, this is the process ID of the spawned shell.

`Popen.returncode`
The child return code, set by *poll()* and *wait()* (and indirectly by *communicate()*). A `None` value indicates that the process hasn't terminated yet.

A negative value `-N` indicates that the child was terminated by signal `N` (POSIX only).

17.5.4 Windows Popen Helpers

The *STARTUPINFO* class and following constants are only available on Windows.

class subprocess.STARTUPINFO(*, *dwFlags=0*, *hStdInput=None*, *hStdOutput=None*, *hStdError=None*, *wShowWindow=0*, *lpAttributeList=None*)

Partial support of the Windows STARTUPINFO structure is used for *Popen* creation. The following attributes can be set by passing them as keyword-only arguments.

Changed in version 3.7: Keyword-only argument support was added.

dwFlags

A bit field that determines whether certain *STARTUPINFO* attributes are used when the process creates a window.

```
si = subprocess.STARTUPINFO()
si.dwFlags = subprocess.STARTF_USESTDHANDLES | subprocess.STARTF_USESHOWWINDOW
```

hStdInput

If *dwFlags* specifies *STARTF_USESTDHANDLES*, this attribute is the standard input handle for the process. If *STARTF_USESTDHANDLES* is not specified, the default for standard input is the keyboard buffer.

hStdOutput

If *dwFlags* specifies *STARTF_USESTDHANDLES*, this attribute is the standard output handle for the process. Otherwise, this attribute is ignored and the default for standard output is the console window's buffer.

hStdError

If *dwFlags* specifies *STARTF_USESTDHANDLES*, this attribute is the standard error handle for the process. Otherwise, this attribute is ignored and the default for standard error is the console window's buffer.

wShowWindow

If *dwFlags* specifies *STARTF_USESHOWWINDOW*, this attribute can be any of the values that can be specified in the `nCmdShow` parameter for the ShowWindow function, except for `SW_SHOWDEFAULT`. Otherwise, this attribute is ignored.

SW_HIDE is provided for this attribute. It is used when *Popen* is called with `shell=True`.

lpAttributeList

A dictionary of additional attributes for process creation as given in `STARTUPINFOEX`, see UpdateProcThreadAttribute.

Supported attributes:

handle_list Sequence of handles that will be inherited. *close_fds* must be true if non-empty.

The handles must be temporarily made inheritable by *os.set_handle_inheritable()* when passed to the *Popen* constructor, else *OSError* will be raised with Windows error `ERROR_INVALID_PARAMETER` (87).

> **Warning:** In a multithreaded process, use caution to avoid leaking handles that are marked inheritable when combining this feature with concurrent calls to other process creation functions that inherit all handles such as *os.system()*. This also applies to standard handle redirection, which temporarily creates inheritable handles.

New in version 3.7.

Windows Constants

The *subprocess* module exposes the following constants.

subprocess.STD_INPUT_HANDLE
The standard input device. Initially, this is the console input buffer, CONIN$.

subprocess.STD_OUTPUT_HANDLE
The standard output device. Initially, this is the active console screen buffer, CONOUT$.

subprocess.STD_ERROR_HANDLE
The standard error device. Initially, this is the active console screen buffer, CONOUT$.

subprocess.SW_HIDE
Hides the window. Another window will be activated.

subprocess.STARTF_USESTDHANDLES
Specifies that the *STARTUPINFO.hStdInput*, *STARTUPINFO.hStdOutput*, and *STARTUPINFO.hStdError* attributes contain additional information.

subprocess.STARTF_USESHOWWINDOW
Specifies that the *STARTUPINFO.wShowWindow* attribute contains additional information.

subprocess.CREATE_NEW_CONSOLE
The new process has a new console, instead of inheriting its parent's console (the default).

subprocess.CREATE_NEW_PROCESS_GROUP
A *Popen* `creationflags` parameter to specify that a new process group will be created. This flag is necessary for using *os.kill()* on the subprocess.

This flag is ignored if *CREATE_NEW_CONSOLE* is specified.

subprocess.ABOVE_NORMAL_PRIORITY_CLASS
A *Popen* `creationflags` parameter to specify that a new process will have an above average priority.

New in version 3.7.

subprocess.BELOW_NORMAL_PRIORITY_CLASS
A *Popen* `creationflags` parameter to specify that a new process will have a below average priority.

New in version 3.7.

subprocess.HIGH_PRIORITY_CLASS
A *Popen* `creationflags` parameter to specify that a new process will have a high priority.

New in version 3.7.

subprocess.IDLE_PRIORITY_CLASS
A *Popen* `creationflags` parameter to specify that a new process will have an idle (lowest) priority.

New in version 3.7.

subprocess.NORMAL_PRIORITY_CLASS
A *Popen* `creationflags` parameter to specify that a new process will have an normal priority. (default)

New in version 3.7.

subprocess.REALTIME_PRIORITY_CLASS
A *Popen* `creationflags` parameter to specify that a new process will have realtime priority. You should almost never use REALTIME_PRIORITY_CLASS, because this interrupts system threads that manage mouse input, keyboard input, and background disk flushing. This class can be appropriate for applications that "talk" directly to hardware or that perform brief tasks that should have limited interruptions.

New in version 3.7.

subprocess.CREATE_NO_WINDOW
A *Popen* `creationflags` parameter to specify that a new process will not create a window

New in version 3.7.

subprocess.DETACHED_PROCESS
A *Popen* creationflags parameter to specify that a new process will not inherit its parent's console. This value cannot be used with CREATE_NEW_CONSOLE.

New in version 3.7.

subprocess.CREATE_DEFAULT_ERROR_MODE
A *Popen* creationflags parameter to specify that a new process does not inherit the error mode of the calling process. Instead, the new process gets the default error mode. This feature is particularly useful for multithreaded shell applications that run with hard errors disabled.

New in version 3.7.

subprocess.CREATE_BREAKAWAY_FROM_JOB
A *Popen* creationflags parameter to specify that a new process is not associated with the job.

New in version 3.7.

17.5.5 Older high-level API

Prior to Python 3.5, these three functions comprised the high level API to subprocess. You can now use *run()* in many cases, but lots of existing code calls these functions.

subprocess.call(*args*, ***, *stdin=None*, *stdout=None*, *stderr=None*, *shell=False*, *cwd=None*, *timeout=None*)
Run the command described by *args*. Wait for command to complete, then return the *returncode* attribute.

This is equivalent to:

```
run(...).returncode
```

(except that the *input* and *check* parameters are not supported)

The arguments shown above are merely the most common ones. The full function signature is largely the same as that of the *Popen* constructor - this function passes all supplied arguments other than *timeout* directly through to that interface.

Note: Do not use stdout=PIPE or stderr=PIPE with this function. The child process will block if it generates enough output to a pipe to fill up the OS pipe buffer as the pipes are not being read from.

Changed in version 3.3: *timeout* was added.

subprocess.check_call(*args*, ***, *stdin=None*, *stdout=None*, *stderr=None*, *shell=False*, *cwd=None*, *timeout=None*)
Run command with arguments. Wait for command to complete. If the return code was zero then return, otherwise raise *CalledProcessError*. The *CalledProcessError* object will have the return code in the *returncode* attribute.

This is equivalent to:

```
run(..., check=True)
```

(except that the *input* parameter is not supported)

The arguments shown above are merely the most common ones. The full function signature is largely the same as that of the *Popen* constructor - this function passes all supplied arguments other than *timeout* directly through to that interface.

Note: Do not use `stdout=PIPE` or `stderr=PIPE` with this function. The child process will block if it generates enough output to a pipe to fill up the OS pipe buffer as the pipes are not being read from.

Changed in version 3.3: *timeout* was added.

subprocess.check_output(*args*, ***, *stdin=None*, *stderr=None*, *shell=False*, *cwd=None*, *encoding=None*, *errors=None*, *universal_newlines=False*, *timeout=None*)

Run command with arguments and return its output.

If the return code was non-zero it raises a *CalledProcessError*. The *CalledProcessError* object will have the return code in the *returncode* attribute and any output in the *output* attribute.

This is equivalent to:

```
run(..., check=True, stdout=PIPE).stdout
```

The arguments shown above are merely the most common ones. The full function signature is largely the same as that of *run()* - most arguments are passed directly through to that interface. However, explicitly passing `input=None` to inherit the parent's standard input file handle is not supported.

By default, this function will return the data as encoded bytes. The actual encoding of the output data may depend on the command being invoked, so the decoding to text will often need to be handled at the application level.

This behaviour may be overridden by setting *universal_newlines* to `True` as described above in *Frequently Used Arguments*.

To also capture standard error in the result, use `stderr=subprocess.STDOUT`:

```
>>> subprocess.check_output(
...     "ls non_existent_file; exit 0",
...     stderr=subprocess.STDOUT,
...     shell=True)
'ls: non_existent_file: No such file or directory\n'
```

New in version 3.1.

Changed in version 3.3: *timeout* was added.

Changed in version 3.4: Support for the *input* keyword argument was added.

Changed in version 3.6: *encoding* and *errors* were added. See *run()* for details.

17.5.6 Replacing Older Functions with the subprocess Module

In this section, "a becomes b" means that b can be used as a replacement for a.

Note: All "a" functions in this section fail (more or less) silently if the executed program cannot be found; the "b" replacements raise *OSError* instead.

In addition, the replacements using *check_output()* will fail with a *CalledProcessError* if the requested operation produces a non-zero return code. The output is still available as the *output* attribute of the raised exception.

In the following examples, we assume that the relevant functions have already been imported from the *subprocess* module.

Replacing /bin/sh shell backquote

```
output=`mycmd myarg`
```

becomes:

```
output = check_output(["mycmd", "myarg"])
```

Replacing shell pipeline

```
output=`dmesg | grep hda`
```

becomes:

```
p1 = Popen(["dmesg"], stdout=PIPE)
p2 = Popen(["grep", "hda"], stdin=p1.stdout, stdout=PIPE)
p1.stdout.close()  # Allow p1 to receive a SIGPIPE if p2 exits.
output = p2.communicate()[0]
```

The p1.stdout.close() call after starting the p2 is important in order for p1 to receive a SIGPIPE if p2 exits before p1.

Alternatively, for trusted input, the shell's own pipeline support may still be used directly:

```
output=`dmesg | grep hda`
```

becomes:

```
output=check_output("dmesg | grep hda", shell=True)
```

Replacing `os.system()`

```
sts = os.system("mycmd" + " myarg")
# becomes
sts = call("mycmd" + " myarg", shell=True)
```

Notes:

- Calling the program through the shell is usually not required.

A more realistic example would look like this:

```
try:
    retcode = call("mycmd" + " myarg", shell=True)
    if retcode < 0:
        print("Child was terminated by signal", -retcode, file=sys.stderr)
    else:
        print("Child returned", retcode, file=sys.stderr)
except OSError as e:
    print("Execution failed:", e, file=sys.stderr)
```

Replacing the `os.spawn` family

P_NOWAIT example:

```
pid = os.spawnlp(os.P_NOWAIT, "/bin/mycmd", "mycmd", "myarg")
==>
pid = Popen(["/bin/mycmd", "myarg"]).pid
```

P_WAIT example:

```
retcode = os.spawnlp(os.P_WAIT, "/bin/mycmd", "mycmd", "myarg")
==>
retcode = call(["/bin/mycmd", "myarg"])
```

Vector example:

```
os.spawnvp(os.P_NOWAIT, path, args)
==>
Popen([path] + args[1:])
```

Environment example:

```
os.spawnlpe(os.P_NOWAIT, "/bin/mycmd", "mycmd", "myarg", env)
==>
Popen(["/bin/mycmd", "myarg"], env={"PATH": "/usr/bin"})
```

Replacing `os.popen()`, `os.popen2()`, `os.popen3()`

```
(child_stdin, child_stdout) = os.popen2(cmd, mode, bufsize)
==>
p = Popen(cmd, shell=True, bufsize=bufsize,
          stdin=PIPE, stdout=PIPE, close_fds=True)
(child_stdin, child_stdout) = (p.stdin, p.stdout)
```

```
(child_stdin,
 child_stdout,
 child_stderr) = os.popen3(cmd, mode, bufsize)
==>
p = Popen(cmd, shell=True, bufsize=bufsize,
          stdin=PIPE, stdout=PIPE, stderr=PIPE, close_fds=True)
(child_stdin,
 child_stdout,
 child_stderr) = (p.stdin, p.stdout, p.stderr)
```

```
(child_stdin, child_stdout_and_stderr) = os.popen4(cmd, mode, bufsize)
==>
p = Popen(cmd, shell=True, bufsize=bufsize,
          stdin=PIPE, stdout=PIPE, stderr=STDOUT, close_fds=True)
(child_stdin, child_stdout_and_stderr) = (p.stdin, p.stdout)
```

Return code handling translates as follows:

```
pipe = os.popen(cmd, 'w')
...
rc = pipe.close()
if rc is not None and rc >> 8:
    print("There were some errors")
==>
process = Popen(cmd, stdin=PIPE)
```

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```
...
process.stdin.close()
if process.wait() != 0:
    print("There were some errors")
```

Replacing functions from the popen2 module

Note: If the cmd argument to popen2 functions is a string, the command is executed through /bin/sh. If it is a list, the command is directly executed.

```
(child_stdout, child_stdin) = popen2.popen2("somestring", bufsize, mode)
==>
p = Popen("somestring", shell=True, bufsize=bufsize,
          stdin=PIPE, stdout=PIPE, close_fds=True)
(child_stdout, child_stdin) = (p.stdout, p.stdin)
```

```
(child_stdout, child_stdin) = popen2.popen2(["mycmd", "myarg"], bufsize, mode)
==>
p = Popen(["mycmd", "myarg"], bufsize=bufsize,
          stdin=PIPE, stdout=PIPE, close_fds=True)
(child_stdout, child_stdin) = (p.stdout, p.stdin)
```

popen2.Popen3 and popen2.Popen4 basically work as *subprocess.Popen*, except that:

- *Popen* raises an exception if the execution fails.
- the *capturestderr* argument is replaced with the *stderr* argument.
- stdin=PIPE and stdout=PIPE must be specified.
- popen2 closes all file descriptors by default, but you have to specify close_fds=True with *Popen* to guarantee this behavior on all platforms or past Python versions.

17.5.7 Legacy Shell Invocation Functions

This module also provides the following legacy functions from the 2.x commands module. These operations implicitly invoke the system shell and none of the guarantees described above regarding security and exception handling consistency are valid for these functions.

subprocess.getstatusoutput(*cmd*)

Return (exitcode, output) of executing *cmd* in a shell.

Execute the string *cmd* in a shell with Popen.check_output() and return a 2-tuple (exitcode, output). The locale encoding is used; see the notes on *Frequently Used Arguments* for more details.

A trailing newline is stripped from the output. The exit code for the command can be interpreted as the return code of subprocess. Example:

```
>>> subprocess.getstatusoutput('ls /bin/ls')
(0, '/bin/ls')
>>> subprocess.getstatusoutput('cat /bin/junk')
(1, 'cat: /bin/junk: No such file or directory')
>>> subprocess.getstatusoutput('/bin/junk')
(127, 'sh: /bin/junk: not found')
```

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```
>>> subprocess.getstatusoutput('/bin/kill $$')
(-15, '')
```

Availability: POSIX & Windows

Changed in version 3.3.4: Windows support was added.

The function now returns (exitcode, output) instead of (status, output) as it did in Python 3.3.3 and earlier. See `WEXITSTATUS()`.

`subprocess.getoutput(`*cmd*`)`
Return output (stdout and stderr) of executing *cmd* in a shell.

Like *`getstatusoutput()`*, except the exit status is ignored and the return value is a string containing the command's output. Example:

```
>>> subprocess.getoutput('ls /bin/ls')
'/bin/ls'
```

Availability: POSIX & Windows

Changed in version 3.3.4: Windows support added

17.5.8 Notes

Converting an argument sequence to a string on Windows

On Windows, an *args* sequence is converted to a string that can be parsed using the following rules (which correspond to the rules used by the MS C runtime):

1. Arguments are delimited by white space, which is either a space or a tab.
2. A string surrounded by double quotation marks is interpreted as a single argument, regardless of white space contained within. A quoted string can be embedded in an argument.
3. A double quotation mark preceded by a backslash is interpreted as a literal double quotation mark.
4. Backslashes are interpreted literally, unless they immediately precede a double quotation mark.
5. If backslashes immediately precede a double quotation mark, every pair of backslashes is interpreted as a literal backslash. If the number of backslashes is odd, the last backslash escapes the next double quotation mark as described in rule 3.

See also:

`shlex` Module which provides function to parse and escape command lines.

17.6 `sched` — Event scheduler

Source code: Lib/sched.py

The *`sched`* module defines a class which implements a general purpose event scheduler:

`class sched.scheduler(`*timefunc=time.monotonic*, *delayfunc=time.sleep*`)`
The *`scheduler`* class defines a generic interface to scheduling events. It needs two functions to actually deal with the "outside world" — *timefunc* should be callable without arguments, and return a number (the "time", in any units whatsoever). If time.monotonic is not available, the *timefunc* default is

time.time instead. The *delayfunc* function should be callable with one argument, compatible with the output of *timefunc*, and should delay that many time units. *delayfunc* will also be called with the argument `0` after each event is run to allow other threads an opportunity to run in multi-threaded applications.

Changed in version 3.3: *timefunc* and *delayfunc* parameters are optional.

Changed in version 3.3: *scheduler* class can be safely used in multi-threaded environments.

Example:

```
>>> import sched, time
>>> s = sched.scheduler(time.time, time.sleep)
>>> def print_time(a='default'):
...     print("From print_time", time.time(), a)
...
>>> def print_some_times():
...     print(time.time())
...     s.enter(10, 1, print_time)
...     s.enter(5, 2, print_time, argument=('positional',))
...     s.enter(5, 1, print_time, kwargs={'a': 'keyword'})
...     s.run()
...     print(time.time())
...
>>> print_some_times()
930343690.257
From print_time 930343695.274 positional
From print_time 930343695.275 keyword
From print_time 930343700.273 default
930343700.276
```

17.6.1 Scheduler Objects

scheduler instances have the following methods and attributes:

scheduler.enterabs(*time*, *priority*, *action*, *argument=()*, *kwargs={}*)

Schedule a new event. The *time* argument should be a numeric type compatible with the return value of the *timefunc* function passed to the constructor. Events scheduled for the same *time* will be executed in the order of their *priority*. A lower number represents a higher priority.

Executing the event means executing `action(*argument, **kwargs)`. *argument* is a sequence holding the positional arguments for *action*. *kwargs* is a dictionary holding the keyword arguments for *action*.

Return value is an event which may be used for later cancellation of the event (see *cancel()*).

Changed in version 3.3: *argument* parameter is optional.

New in version 3.3: *kwargs* parameter was added.

scheduler.enter(*delay*, *priority*, *action*, *argument=()*, *kwargs={}*)

Schedule an event for *delay* more time units. Other than the relative time, the other arguments, the effect and the return value are the same as those for *enterabs()*.

Changed in version 3.3: *argument* parameter is optional.

New in version 3.3: *kwargs* parameter was added.

scheduler.cancel(*event*)

Remove the event from the queue. If *event* is not an event currently in the queue, this method will raise a *ValueError*.

`scheduler.empty()`
Return true if the event queue is empty.

`scheduler.run(`*blocking=True*`)`
Run all scheduled events. This method will wait (using the `delayfunc()` function passed to the constructor) for the next event, then execute it and so on until there are no more scheduled events.

If *blocking* is false executes the scheduled events due to expire soonest (if any) and then return the deadline of the next scheduled call in the scheduler (if any).

Either *action* or *delayfunc* can raise an exception. In either case, the scheduler will maintain a consistent state and propagate the exception. If an exception is raised by *action*, the event will not be attempted in future calls to *run()*.

If a sequence of events takes longer to run than the time available before the next event, the scheduler will simply fall behind. No events will be dropped; the calling code is responsible for canceling events which are no longer pertinent.

New in version 3.3: *blocking* parameter was added.

`scheduler.queue`
Read-only attribute returning a list of upcoming events in the order they will be run. Each event is shown as a *named tuple* with the following fields: time, priority, action, argument, kwargs.

17.7 queue — A synchronized queue class

Source code: Lib/queue.py

The *queue* module implements multi-producer, multi-consumer queues. It is especially useful in threaded programming when information must be exchanged safely between multiple threads. The *Queue* class in this module implements all the required locking semantics. It depends on the availability of thread support in Python; see the *threading* module.

The module implements three types of queue, which differ only in the order in which the entries are retrieved. In a FIFO queue, the first tasks added are the first retrieved. In a LIFO queue, the most recently added entry is the first retrieved (operating like a stack). With a priority queue, the entries are kept sorted (using the *heapq* module) and the lowest valued entry is retrieved first.

Internally, those three types of queues use locks to temporarily block competing threads; however, they are not designed to handle reentrancy within a thread.

In addition, the module implements a "simple" FIFO queue type where specific implementations can provide additional guarantees in exchange for the smaller functionality.

The *queue* module defines the following classes and exceptions:

`class queue.Queue(`*maxsize=0*`)`
Constructor for a FIFO queue. *maxsize* is an integer that sets the upperbound limit on the number of items that can be placed in the queue. Insertion will block once this size has been reached, until queue items are consumed. If *maxsize* is less than or equal to zero, the queue size is infinite.

`class queue.LifoQueue(`*maxsize=0*`)`
Constructor for a LIFO queue. *maxsize* is an integer that sets the upperbound limit on the number of items that can be placed in the queue. Insertion will block once this size has been reached, until queue items are consumed. If *maxsize* is less than or equal to zero, the queue size is infinite.

`class queue.PriorityQueue(`*maxsize=0*`)`
Constructor for a priority queue. *maxsize* is an integer that sets the upperbound limit on the number

of items that can be placed in the queue. Insertion will block once this size has been reached, until queue items are consumed. If *maxsize* is less than or equal to zero, the queue size is infinite.

The lowest valued entries are retrieved first (the lowest valued entry is the one returned by `sorted(list(entries))[0]`). A typical pattern for entries is a tuple in the form: `(priority_number, data)`.

If the *data* elements are not comparable, the data can be wrapped in a class that ignores the data item and only compares the priority number:

```
from dataclasses import dataclass, field
from typing import Any

@dataclass(order=True)
class PrioritizedItem:
    priority: int
    item: Any=field(compare=False)
```

class queue.SimpleQueue
Constructor for an unbounded FIFO queue. Simple queues lack advanced functionality such as task tracking.

New in version 3.7.

exception queue.Empty
Exception raised when non-blocking *get()* (or *get_nowait()*) is called on a *Queue* object which is empty.

exception queue.Full
Exception raised when non-blocking *put()* (or *put_nowait()*) is called on a *Queue* object which is full.

17.7.1 Queue Objects

Queue objects (*Queue*, *LifoQueue*, or *PriorityQueue*) provide the public methods described below.

Queue.qsize()
Return the approximate size of the queue. Note, qsize() > 0 doesn't guarantee that a subsequent get() will not block, nor will qsize() < maxsize guarantee that put() will not block.

Queue.empty()
Return `True` if the queue is empty, `False` otherwise. If empty() returns `True` it doesn't guarantee that a subsequent call to put() will not block. Similarly, if empty() returns `False` it doesn't guarantee that a subsequent call to get() will not block.

Queue.full()
Return `True` if the queue is full, `False` otherwise. If full() returns `True` it doesn't guarantee that a subsequent call to get() will not block. Similarly, if full() returns `False` it doesn't guarantee that a subsequent call to put() will not block.

Queue.put(*item*, *block=True*, *timeout=None*)
Put *item* into the queue. If optional args *block* is true and *timeout* is `None` (the default), block if necessary until a free slot is available. If *timeout* is a positive number, it blocks at most *timeout* seconds and raises the *Full* exception if no free slot was available within that time. Otherwise (*block* is false), put an item on the queue if a free slot is immediately available, else raise the *Full* exception (*timeout* is ignored in that case).

Queue.put_nowait(*item*)
Equivalent to `put(item, False)`.

`Queue.get`(*block=True*, *timeout=None*)
Remove and return an item from the queue. If optional args *block* is true and *timeout* is `None` (the default), block if necessary until an item is available. If *timeout* is a positive number, it blocks at most *timeout* seconds and raises the *Empty* exception if no item was available within that time. Otherwise (*block* is false), return an item if one is immediately available, else raise the *Empty* exception (*timeout* is ignored in that case).

`Queue.get_nowait()`
Equivalent to `get(False)`.

Two methods are offered to support tracking whether enqueued tasks have been fully processed by daemon consumer threads.

`Queue.task_done()`
Indicate that a formerly enqueued task is complete. Used by queue consumer threads. For each *get()* used to fetch a task, a subsequent call to *task_done()* tells the queue that the processing on the task is complete.

If a *join()* is currently blocking, it will resume when all items have been processed (meaning that a *task_done()* call was received for every item that had been *put()* into the queue).

Raises a *ValueError* if called more times than there were items placed in the queue.

`Queue.join()`
Blocks until all items in the queue have been gotten and processed.

The count of unfinished tasks goes up whenever an item is added to the queue. The count goes down whenever a consumer thread calls *task_done()* to indicate that the item was retrieved and all work on it is complete. When the count of unfinished tasks drops to zero, *join()* unblocks.

Example of how to wait for enqueued tasks to be completed:

```
def worker():
    while True:
        item = q.get()
        if item is None:
            break
        do_work(item)
        q.task_done()

q = queue.Queue()
threads = []
for i in range(num_worker_threads):
    t = threading.Thread(target=worker)
    t.start()
    threads.append(t)

for item in source():
    q.put(item)

# block until all tasks are done
q.join()

# stop workers
for i in range(num_worker_threads):
    q.put(None)
for t in threads:
    t.join()
```

17.7.2 SimpleQueue Objects

SimpleQueue objects provide the public methods described below.

`SimpleQueue.qsize()`
Return the approximate size of the queue. Note, qsize() > 0 doesn't guarantee that a subsequent get() will not block.

`SimpleQueue.empty()`
Return `True` if the queue is empty, `False` otherwise. If empty() returns `False` it doesn't guarantee that a subsequent call to get() will not block.

`SimpleQueue.put(`*item*, *block=True*, *timeout=None*`)`
Put *item* into the queue. The method never blocks and always succeeds (except for potential low-level errors such as failure to allocate memory). The optional args *block* and *timeout* are ignored and only provided for compatibility with *Queue.put()*.

CPython implementation detail: This method has a C implementation which is reentrant. That is, a `put()` or `get()` call can be interrupted by another `put()` call in the same thread without deadlocking or corrupting internal state inside the queue. This makes it appropriate for use in destructors such as `__del__` methods or *weakref* callbacks.

`SimpleQueue.put_nowait(`*item*`)`
Equivalent to `put(item)`, provided for compatibility with *Queue.put_nowait()*.

`SimpleQueue.get(`*block=True*, *timeout=None*`)`
Remove and return an item from the queue. If optional args *block* is true and *timeout* is `None` (the default), block if necessary until an item is available. If *timeout* is a positive number, it blocks at most *timeout* seconds and raises the *Empty* exception if no item was available within that time. Otherwise (*block* is false), return an item if one is immediately available, else raise the *Empty* exception (*timeout* is ignored in that case).

`SimpleQueue.get_nowait()`
Equivalent to `get(False)`.

See also:

Class *multiprocessing.Queue* A queue class for use in a multi-processing (rather than multi-threading) context.

collections.deque is an alternative implementation of unbounded queues with fast atomic *append()* and *popleft()* operations that do not require locking.

The following are support modules for some of the above services:

17.8 _thread — Low-level threading API

This module provides low-level primitives for working with multiple threads (also called *light-weight processes* or *tasks*) — multiple threads of control sharing their global data space. For synchronization, simple locks (also called *mutexes* or *binary semaphores*) are provided. The *threading* module provides an easier to use and higher-level threading API built on top of this module.

Changed in version 3.7: This module used to be optional, it is now always available.

This module defines the following constants and functions:

`exception _thread.error`
Raised on thread-specific errors.

Changed in version 3.3: This is now a synonym of the built-in *RuntimeError*.

_thread.LockType
: This is the type of lock objects.

_thread.start_new_thread(*function*, *args*[, *kwargs*])
: Start a new thread and return its identifier. The thread executes the function *function* with the argument list *args* (which must be a tuple). The optional *kwargs* argument specifies a dictionary of keyword arguments. When the function returns, the thread silently exits. When the function terminates with an unhandled exception, a stack trace is printed and then the thread exits (but other threads continue to run).

_thread.interrupt_main()
: Raise a *KeyboardInterrupt* exception in the main thread. A subthread can use this function to interrupt the main thread.

_thread.exit()
: Raise the *SystemExit* exception. When not caught, this will cause the thread to exit silently.

_thread.allocate_lock()
: Return a new lock object. Methods of locks are described below. The lock is initially unlocked.

_thread.get_ident()
: Return the 'thread identifier' of the current thread. This is a nonzero integer. Its value has no direct meaning; it is intended as a magic cookie to be used e.g. to index a dictionary of thread-specific data. Thread identifiers may be recycled when a thread exits and another thread is created.

_thread.stack_size([*size*])
: Return the thread stack size used when creating new threads. The optional *size* argument specifies the stack size to be used for subsequently created threads, and must be 0 (use platform or configured default) or a positive integer value of at least 32,768 (32 KiB). If *size* is not specified, 0 is used. If changing the thread stack size is unsupported, a *RuntimeError* is raised. If the specified stack size is invalid, a *ValueError* is raised and the stack size is unmodified. 32 KiB is currently the minimum supported stack size value to guarantee sufficient stack space for the interpreter itself. Note that some platforms may have particular restrictions on values for the stack size, such as requiring a minimum stack size > 32 KiB or requiring allocation in multiples of the system memory page size - platform documentation should be referred to for more information (4 KiB pages are common; using multiples of 4096 for the stack size is the suggested approach in the absence of more specific information). Availability: Windows, systems with POSIX threads.

_thread.TIMEOUT_MAX
: The maximum value allowed for the *timeout* parameter of `Lock.acquire()`. Specifying a timeout greater than this value will raise an *OverflowError*.

  New in version 3.2.

Lock objects have the following methods:

lock.acquire(*waitflag=1*, *timeout=-1*)
: Without any optional argument, this method acquires the lock unconditionally, if necessary waiting until it is released by another thread (only one thread at a time can acquire a lock — that's their reason for existence).

  If the integer *waitflag* argument is present, the action depends on its value: if it is zero, the lock is only acquired if it can be acquired immediately without waiting, while if it is nonzero, the lock is acquired unconditionally as above.

  If the floating-point *timeout* argument is present and positive, it specifies the maximum wait time in seconds before returning. A negative *timeout* argument specifies an unbounded wait. You cannot specify a *timeout* if *waitflag* is zero.

  The return value is `True` if the lock is acquired successfully, `False` if not.

  Changed in version 3.2: The *timeout* parameter is new.

Changed in version 3.2: Lock acquires can now be interrupted by signals on POSIX.

`lock.release()`
Releases the lock. The lock must have been acquired earlier, but not necessarily by the same thread.

`lock.locked()`
Return the status of the lock: `True` if it has been acquired by some thread, `False` if not.

In addition to these methods, lock objects can also be used via the `with` statement, e.g.:

```
import _thread

a_lock = _thread.allocate_lock()

with a_lock:
    print("a_lock is locked while this executes")
```

Caveats:

- Threads interact strangely with interrupts: the *KeyboardInterrupt* exception will be received by an arbitrary thread. (When the *signal* module is available, interrupts always go to the main thread.)
- Calling *sys.exit()* or raising the *SystemExit* exception is equivalent to calling *_thread.exit()*.
- It is not possible to interrupt the `acquire()` method on a lock — the *KeyboardInterrupt* exception will happen after the lock has been acquired.
- When the main thread exits, it is system defined whether the other threads survive. On most systems, they are killed without executing `try` … `finally` clauses or executing object destructors.
- When the main thread exits, it does not do any of its usual cleanup (except that `try` … `finally` clauses are honored), and the standard I/O files are not flushed.

17.9 `_dummy_thread` — Drop-in replacement for the `_thread` module

Source code: Lib/_dummy_thread.py

Deprecated since version 3.7: Python now always has threading enabled. Please use *_thread* (or, better, *threading*) instead.

This module provides a duplicate interface to the *_thread* module. It was meant to be imported when the *_thread* module was not provided on a platform.

Be careful to not use this module where deadlock might occur from a thread being created that blocks waiting for another thread to be created. This often occurs with blocking I/O.

17.10 `dummy_threading` — Drop-in replacement for the `threading` module

Source code: Lib/dummy_threading.py

Deprecated since version 3.7: Python now always has threading enabled. Please use *threading* instead.

This module provides a duplicate interface to the *threading* module. It was meant to be imported when the *_thread* module was not provided on a platform.

Be careful to not use this module where deadlock might occur from a thread being created that blocks waiting for another thread to be created. This often occurs with blocking I/O.

CHAPTER

EIGHTEEN

CONTEXTVARS — CONTEXT VARIABLES

This module provides APIs to manage, store, and access context-local state. The *ContextVar* class is used to declare and work with *Context Variables*. The *copy_context()* function and the *Context* class should be used to manage the current context in asynchronous frameworks.

Context managers that have state should use Context Variables instead of *threading.local()* to prevent their state from bleeding to other code unexpectedly, when used in concurrent code.

See also **PEP 567** for additional details.

New in version 3.7.

18.1 Context Variables

class contextvars.**ContextVar**(*name*[, *, *default*])

This class is used to declare a new Context Variable, e.g.:

```
var: ContextVar[int] = ContextVar('var', default=42)
```

The required *name* parameter is used for introspection and debug purposes.

The optional keyword-only *default* parameter is returned by *ContextVar.get()* when no value for the variable is found in the current context.

Important: Context Variables should be created at the top module level and never in closures. *Context* objects hold strong references to context variables which prevents context variables from being properly garbage collected.

name

The name of the variable. This is a read-only property.

New in version 3.7.1.

get([*default*])

Return a value for the context variable for the current context.

If there is no value for the variable in the current context, the method will:

- return the value of the *default* argument of the method, if provided; or
- return the default value for the context variable, if it was created with one; or
- raise a *LookupError*.

set(*value*)
Call to set a new value for the context variable in the current context.

The required *value* argument is the new value for the context variable.

Returns a *Token* object that can be used to restore the variable to its previous value via the *ContextVar.reset()* method.

reset(*token*)
Reset the context variable to the value it had before the *ContextVar.set()* that created the *token* was used.

For example:

```
var = ContextVar('var')

token = var.set('new value')
# code that uses 'var'; var.get() returns 'new value'.
var.reset(token)

# After the reset call the var has no value again, so
# var.get() would raise a LookupError.
```

class contextvars.Token
Token objects are returned by the *ContextVar.set()* method. They can be passed to the *ContextVar.reset()* method to revert the value of the variable to what it was before the corresponding *set*.

Token.var
A read-only property. Points to the *ContextVar* object that created the token.

Token.old_value
A read-only property. Set to the value the variable had before the *ContextVar.set()* method call that created the token. It points to `Token.MISSING` is the variable was not set before the call.

Token.MISSING
A marker object used by `Token.old_value`.

18.2 Manual Context Management

contextvars.copy_context()
Returns a copy of the current *Context* object.

The following snippet gets a copy of the current context and prints all variables and their values that are set in it:

```
ctx: Context = copy_context()
print(list(ctx.items()))
```

The function has an O(1) complexity, i.e. works equally fast for contexts with a few context variables and for contexts that have a lot of them.

class contextvars.Context
A mapping of *ContextVars* to their values.

`Context()` creates an empty context with no values in it. To get a copy of the current context use the *copy_context()* function.

Context implements the *collections.abc.Mapping* interface.

run(*callable*, **args*, ***kwargs*)
Execute `callable(*args, **kwargs)` code in the context object the *run* method is called on. Return the result of the execution or propagate an exception if one occurred.

Any changes to any context variables that *callable* makes will be contained in the context object:

```
var = ContextVar('var')
var.set('spam')

def main():
    # 'var' was set to 'spam' before
    # calling 'copy_context()' and 'ctx.run(main)', so:
    # var.get() == ctx[var] == 'spam'

    var.set('ham')

    # Now, after setting 'var' to 'ham':
    # var.get() == ctx[var] == 'ham'

ctx = copy_context()

# Any changes that the 'main' function makes to 'var'
# will be contained in 'ctx'.
ctx.run(main)

# The 'main()' function was run in the 'ctx' context,
# so changes to 'var' are contained in it:
# ctx[var] == 'ham'

# However, outside of 'ctx', 'var' is still set to 'spam':
# var.get() == 'spam'
```

The method raises a *RuntimeError* when called on the same context object from more than one OS thread, or when called recursively.

copy()
Return a shallow copy of the context object.

var in context
Return `True` if the *context* has a value for *var* set; return `False` otherwise.

context[var]
Return the value of the *var* *ContextVar* variable. If the variable is not set in the context object, a *KeyError* is raised.

get(*var*[, *default*])
Return the value for *var* if *var* has the value in the context object. Return *default* otherwise. If *default* is not given, return `None`.

iter(context)
Return an iterator over the variables stored in the context object.

len(proxy)
Return the number of variables set in the context object.

keys()
Return a list of all variables in the context object.

values()
Return a list of all variables' values in the context object.

`items()`
Return a list of 2-tuples containing all variables and their values in the context object.

18.3 asyncio support

Context variables are natively supported in *asyncio* and are ready to be used without any extra configuration. For example, here is a simple echo server, that uses a context variable to make the address of a remote client available in the Task that handles that client:

```
import asyncio
import contextvars

client_addr_var = contextvars.ContextVar('client_addr')

def render_goodbye():
    # The address of the currently handled client can be accessed
    # without passing it explicitly to this function.

    client_addr = client_addr_var.get()
    return f'Good bye, client @ {client_addr}\n'.encode()

async def handle_request(reader, writer):
    addr = writer.transport.get_extra_info('socket').getpeername()
    client_addr_var.set(addr)

    # In any code that we call is now possible to get
    # client's address by calling 'client_addr_var.get()'.

    while True:
        line = await reader.readline()
        print(line)
        if not line.strip():
            break
        writer.write(line)

    writer.write(render_goodbye())
    writer.close()

async def main():
    srv = await asyncio.start_server(
        handle_request, '127.0.0.1', 8081)

    async with srv:
        await srv.serve_forever()

asyncio.run(main())

# To test it you can use telnet:
#     telnet 127.0.0.1 8081
```

CHAPTER

NINETEEN

INTERPROCESS COMMUNICATION AND NETWORKING

The modules described in this chapter provide mechanisms for different processes to communicate.

Some modules only work for two processes that are on the same machine, e.g. *signal* and *mmap*. Other modules support networking protocols that two or more processes can use to communicate across machines.

The list of modules described in this chapter is:

19.1 socket — Low-level networking interface

Source code: Lib/socket.py

This module provides access to the BSD *socket* interface. It is available on all modern Unix systems, Windows, MacOS, and probably additional platforms.

Note: Some behavior may be platform dependent, since calls are made to the operating system socket APIs.

The Python interface is a straightforward transliteration of the Unix system call and library interface for sockets to Python's object-oriented style: the *socket()* function returns a *socket object* whose methods implement the various socket system calls. Parameter types are somewhat higher-level than in the C interface: as with `read()` and `write()` operations on Python files, buffer allocation on receive operations is automatic, and buffer length is implicit on send operations.

See also:

Module *socketserver* Classes that simplify writing network servers.

Module *ssl* A TLS/SSL wrapper for socket objects.

19.1.1 Socket families

Depending on the system and the build options, various socket families are supported by this module.

The address format required by a particular socket object is automatically selected based on the address family specified when the socket object was created. Socket addresses are represented as follows:

- The address of an *AF_UNIX* socket bound to a file system node is represented as a string, using the file system encoding and the `'surrogateescape'` error handler (see **PEP 383**). An address in Linux's abstract namespace is returned as a *bytes-like object* with an initial null byte; note that sockets in this namespace can communicate with normal file system sockets, so programs intended to run on Linux may need to deal with both types of address. A string or bytes-like object can be used for either type of address when passing it as an argument.

Changed in version 3.3: Previously, *AF_UNIX* socket paths were assumed to use UTF-8 encoding.

Changed in version 3.5: Writable *bytes-like object* is now accepted.

- A pair `(host, port)` is used for the *AF_INET* address family, where *host* is a string representing either a hostname in Internet domain notation like `'daring.cwi.nl'` or an IPv4 address like `'100.50.200.5'`, and *port* is an integer.
- For *AF_INET6* address family, a four-tuple `(host, port, flowinfo, scopeid)` is used, where *flowinfo* and *scopeid* represent the `sin6_flowinfo` and `sin6_scope_id` members in `struct sockaddr_in6` in C. For *socket* module methods, *flowinfo* and *scopeid* can be omitted just for backward compatibility. Note, however, omission of *scopeid* can cause problems in manipulating scoped IPv6 addresses.

  Changed in version 3.7: For multicast addresses (with *scopeid* meaningful) *address* may not contain `%scope` (or `zone id`) part. This information is superfluous and may be safely omitted (recommended).
- `AF_NETLINK` sockets are represented as pairs `(pid, groups)`.
- Linux-only support for TIPC is available using the `AF_TIPC` address family. TIPC is an open, non-IP based networked protocol designed for use in clustered computer environments. Addresses are represented by a tuple, and the fields depend on the address type. The general tuple form is `(addr_type, v1, v2, v3 [, scope])`, where:
  - *addr_type* is one of `TIPC_ADDR_NAMESEQ`, `TIPC_ADDR_NAME`, or `TIPC_ADDR_ID`.
  - *scope* is one of `TIPC_ZONE_SCOPE`, `TIPC_CLUSTER_SCOPE`, and `TIPC_NODE_SCOPE`.
  - If *addr_type* is `TIPC_ADDR_NAME`, then *v1* is the server type, *v2* is the port identifier, and *v3* should be 0.

    If *addr_type* is `TIPC_ADDR_NAMESEQ`, then *v1* is the server type, *v2* is the lower port number, and *v3* is the upper port number.

    If *addr_type* is `TIPC_ADDR_ID`, then *v1* is the node, *v2* is the reference, and *v3* should be set to 0.
- A tuple `(interface, )` is used for the *AF_CAN* address family, where *interface* is a string representing a network interface name like `'can0'`. The network interface name `''` can be used to receive packets from all network interfaces of this family.
  - *CAN_ISOTP* protocol require a tuple `(interface, rx_addr, tx_addr)` where both additional parameters are unsigned long integer that represent a CAN identifier (standard or extended).
- A string or a tuple `(id, unit)` is used for the `SYSPROTO_CONTROL` protocol of the `PF_SYSTEM` family. The string is the name of a kernel control using a dynamically-assigned ID. The tuple can be used if ID and unit number of the kernel control are known or if a registered ID is used.

  New in version 3.3.
- `AF_BLUETOOTH` supports the following protocols and address formats:
  - `BTPROTO_L2CAP` accepts `(bdaddr, psm)` where `bdaddr` is the Bluetooth address as a string and `psm` is an integer.
  - `BTPROTO_RFCOMM` accepts `(bdaddr, channel)` where `bdaddr` is the Bluetooth address as a string and `channel` is an integer.
  - `BTPROTO_HCI` accepts `(device_id,)` where `device_id` is either an integer or a string with the Bluetooth address of the interface. (This depends on your OS; NetBSD and DragonFlyBSD expect a Bluetooth address while everything else expects an integer.)

    Changed in version 3.2: NetBSD and DragonFlyBSD support added.
  - `BTPROTO_SCO` accepts `bdaddr` where `bdaddr` is a *bytes* object containing the Bluetooth address in a string format. (ex. `b'12:23:34:45:56:67'`) This protocol is not supported under FreeBSD.

- *AF_ALG* is a Linux-only socket based interface to Kernel cryptography. An algorithm socket is configured with a tuple of two to four elements `(type, name [, feat [, mask]])`, where:
  - *type* is the algorithm type as string, e.g. `aead`, `hash`, `skcipher` or `rng`.
  - *name* is the algorithm name and operation mode as string, e.g. `sha256`, `hmac(sha256)`, `cbc(aes)` or `drbg_nopr_ctr_aes256`.
  - *feat* and *mask* are unsigned 32bit integers.

  Availability Linux 2.6.38, some algorithm types require more recent Kernels.

  New in version 3.6.
- *AF_VSOCK* allows communication between virtual machines and their hosts. The sockets are represented as a `(CID, port)` tuple where the context ID or CID and port are integers.

  Availability: Linux >= 4.8 QEMU >= 2.8 ESX >= 4.0 ESX Workstation >= 6.5

  New in version 3.7.
- Certain other address families (`AF_PACKET`, *AF_CAN*) support specific representations.

For IPv4 addresses, two special forms are accepted instead of a host address: the empty string represents `INADDR_ANY`, and the string `'<broadcast>'` represents `INADDR_BROADCAST`. This behavior is not compatible with IPv6, therefore, you may want to avoid these if you intend to support IPv6 with your Python programs.

If you use a hostname in the *host* portion of IPv4/v6 socket address, the program may show a nondeterministic behavior, as Python uses the first address returned from the DNS resolution. The socket address will be resolved differently into an actual IPv4/v6 address, depending on the results from DNS resolution and/or the host configuration. For deterministic behavior use a numeric address in *host* portion.

All errors raise exceptions. The normal exceptions for invalid argument types and out-of-memory conditions can be raised; starting from Python 3.3, errors related to socket or address semantics raise *OSError* or one of its subclasses (they used to raise *socket.error*).

Non-blocking mode is supported through *setblocking()*. A generalization of this based on timeouts is supported through *settimeout()*.

19.1.2 Module contents

The module *socket* exports the following elements.

Exceptions

exception socket.error
A deprecated alias of *OSError*.

Changed in version 3.3: Following **PEP 3151**, this class was made an alias of *OSError*.

exception socket.herror
A subclass of *OSError*, this exception is raised for address-related errors, i.e. for functions that use *h_errno* in the POSIX C API, including *gethostbyname_ex()* and *gethostbyaddr()*. The accompanying value is a pair `(h_errno, string)` representing an error returned by a library call. *h_errno* is a numeric value, while *string* represents the description of *h_errno*, as returned by the `hstrerror()` C function.

Changed in version 3.3: This class was made a subclass of *OSError*.

exception socket.gaierror
A subclass of *OSError*, this exception is raised for address-related errors by *getaddrinfo()* and *getnameinfo()*. The accompanying value is a pair `(error, string)` representing an error returned

by a library call. *string* represents the description of *error*, as returned by the `gai_strerror()` C function. The numeric *error* value will match one of the `EAI_*` constants defined in this module.

Changed in version 3.3: This class was made a subclass of *OSError*.

exception socket.timeout

A subclass of *OSError*, this exception is raised when a timeout occurs on a socket which has had timeouts enabled via a prior call to *settimeout()* (or implicitly through *setdefaulttimeout()*). The accompanying value is a string whose value is currently always "timed out".

Changed in version 3.3: This class was made a subclass of *OSError*.

Constants

The AF_* and SOCK_* constants are now `AddressFamily` and `SocketKind` *IntEnum* collections.

New in version 3.4.

socket.AF_UNIX
socket.AF_INET
socket.AF_INET6

These constants represent the address (and protocol) families, used for the first argument to *socket()*. If the *AF_UNIX* constant is not defined then this protocol is unsupported. More constants may be available depending on the system.

socket.SOCK_STREAM
socket.SOCK_DGRAM
socket.SOCK_RAW
socket.SOCK_RDM
socket.SOCK_SEQPACKET

These constants represent the socket types, used for the second argument to *socket()*. More constants may be available depending on the system. (Only *SOCK_STREAM* and *SOCK_DGRAM* appear to be generally useful.)

socket.SOCK_CLOEXEC
socket.SOCK_NONBLOCK

These two constants, if defined, can be combined with the socket types and allow you to set some flags atomically (thus avoiding possible race conditions and the need for separate calls).

See also:

Secure File Descriptor Handling for a more thorough explanation.

Availability: Linux >= 2.6.27.

New in version 3.2.

SO_*
socket.SOMAXCONN
MSG_*
SOL_*
SCM_*
IPPROTO_*
IPPORT_*
INADDR_*
IP_*
IPV6_*
EAI_*
AI_*
NI_*

TCP_*
: Many constants of these forms, documented in the Unix documentation on sockets and/or the IP protocol, are also defined in the socket module. They are generally used in arguments to the `setsockopt()` and `getsockopt()` methods of socket objects. In most cases, only those symbols that are defined in the Unix header files are defined; for a few symbols, default values are provided.

  Changed in version 3.6: `SO_DOMAIN`, `SO_PROTOCOL`, `SO_PEERSEC`, `SO_PASSSEC`, `TCP_USER_TIMEOUT`, `TCP_CONGESTION` were added.

  Changed in version 3.6.5: On Windows, `TCP_FASTOPEN`, `TCP_KEEPCNT` appear if run-time Windows supports.

  Changed in version 3.7: `TCP_NOTSENT_LOWAT` was added.

  On Windows, `TCP_KEEPIDLE`, `TCP_KEEPINTVL` appear if run-time Windows supports.

socket.AF_CAN
socket.PF_CAN
SOL_CAN_*
CAN_*
: Many constants of these forms, documented in the Linux documentation, are also defined in the socket module.

  Availability: Linux >= 2.6.25.

  New in version 3.3.

socket.CAN_BCM
CAN_BCM_*
: CAN_BCM, in the CAN protocol family, is the broadcast manager (BCM) protocol. Broadcast manager constants, documented in the Linux documentation, are also defined in the socket module.

  Availability: Linux >= 2.6.25.

  New in version 3.4.

socket.CAN_RAW_FD_FRAMES
: Enables CAN FD support in a CAN_RAW socket. This is disabled by default. This allows your application to send both CAN and CAN FD frames; however, you one must accept both CAN and CAN FD frames when reading from the socket.

  This constant is documented in the Linux documentation.

  Availability: Linux >= 3.6.

  New in version 3.5.

socket.CAN_ISOTP
: CAN_ISOTP, in the CAN protocol family, is the ISO-TP (ISO 15765-2) protocol. ISO-TP constants, documented in the Linux documentation.

  Availability: Linux >= 2.6.25

  New in version 3.7.

socket.AF_RDS
socket.PF_RDS
socket.SOL_RDS
RDS_*
: Many constants of these forms, documented in the Linux documentation, are also defined in the socket module.

  Availability: Linux >= 2.6.30.

  New in version 3.3.

socket.SIO_RCVALL
socket.SIO_KEEPALIVE_VALS
socket.SIO_LOOPBACK_FAST_PATH
RCVALL_*
: Constants for Windows' WSAIoctl(). The constants are used as arguments to the *ioctl()* method of socket objects.

  Changed in version 3.6: SIO_LOOPBACK_FAST_PATH was added.

TIPC_*
: TIPC related constants, matching the ones exported by the C socket API. See the TIPC documentation for more information.

socket.AF_ALG
socket.SOL_ALG
ALG_*
: Constants for Linux Kernel cryptography.

  Availability: Linux >= 2.6.38.

  New in version 3.6.

socket.AF_VSOCK
socket.IOCTL_VM_SOCKETS_GET_LOCAL_CID
VMADDR*
SO_VM*
: Constants for Linux host/guest communication.

  Availability: Linux >= 4.8.

  New in version 3.7.

socket.AF_LINK
: Availability: BSD, OSX.

  New in version 3.4.

socket.has_ipv6
: This constant contains a boolean value which indicates if IPv6 is supported on this platform.

socket.BDADDR_ANY
socket.BDADDR_LOCAL
: These are string constants containing Bluetooth addresses with special meanings. For example, *BDADDR_ANY* can be used to indicate any address when specifying the binding socket with BTPROTO_RFCOMM.

socket.HCI_FILTER
socket.HCI_TIME_STAMP
socket.HCI_DATA_DIR
: For use with BTPROTO_HCI. *HCI_FILTER* is not available for NetBSD or DragonFlyBSD. *HCI_TIME_STAMP* and *HCI_DATA_DIR* are not available for FreeBSD, NetBSD, or DragonFlyBSD.

Functions

Creating sockets

The following functions all create *socket objects*.

socket.socket(*family=AF_INET*, *type=SOCK_STREAM*, *proto=0*, *fileno=None*)
: Create a new socket using the given address family, socket type and protocol number. The address family should be *AF_INET* (the default), *AF_INET6*, *AF_UNIX*, *AF_CAN* or *AF_RDS*. The socket type should

be *SOCK_STREAM* (the default), *SOCK_DGRAM*, *SOCK_RAW* or perhaps one of the other `SOCK_` constants. The protocol number is usually zero and may be omitted or in the case where the address family is *AF_CAN* the protocol should be one of `CAN_RAW`, *CAN_BCM* or *CAN_ISOTP*

If *fileno* is specified, the values for *family*, *type*, and *proto* are auto-detected from the specified file descriptor. Auto-detection can be overruled by calling the function with explicit *family*, *type*, or *proto* arguments. This only affects how Python represents e.g. the return value of *socket.getpeername()* but not the actual OS resource. Unlike *socket.fromfd()*, *fileno* will return the same socket and not a duplicate. This may help close a detached socket using *socket.close()*.

The newly created socket is *non-inheritable*.

Changed in version 3.3: The AF_CAN family was added. The AF_RDS family was added.

Changed in version 3.4: The CAN_BCM protocol was added.

Changed in version 3.4: The returned socket is now non-inheritable.

Changed in version 3.7: The CAN_ISOTP protocol was added.

Changed in version 3.7: When *SOCK_NONBLOCK* or *SOCK_CLOEXEC* bit flags are applied to *type* they are cleared, and *socket.type* will not reflect them. They are still passed to the underlying system *socket()* call. Therefore::

sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM | socket.SOCK_NONBLOCK)

will still create a non-blocking socket on OSes that support `SOCK_NONBLOCK`, but `sock.type` will be set to `socket.SOCK_STREAM`.

`socket.socketpair`([*family*[, *type*[, *proto*]]])
Build a pair of connected socket objects using the given address family, socket type, and protocol number. Address family, socket type, and protocol number are as for the *socket()* function above. The default family is *AF_UNIX* if defined on the platform; otherwise, the default is *AF_INET*.

The newly created sockets are *non-inheritable*.

Changed in version 3.2: The returned socket objects now support the whole socket API, rather than a subset.

Changed in version 3.4: The returned sockets are now non-inheritable.

Changed in version 3.5: Windows support added.

`socket.create_connection`(*address*[, *timeout*[, *source_address*]])
Connect to a TCP service listening on the Internet *address* (a 2-tuple `(host, port)`), and return the socket object. This is a higher-level function than *socket.connect()*: if *host* is a non-numeric hostname, it will try to resolve it for both *AF_INET* and *AF_INET6*, and then try to connect to all possible addresses in turn until a connection succeeds. This makes it easy to write clients that are compatible to both IPv4 and IPv6.

Passing the optional *timeout* parameter will set the timeout on the socket instance before attempting to connect. If no *timeout* is supplied, the global default timeout setting returned by *getdefaulttimeout()* is used.

If supplied, *source_address* must be a 2-tuple `(host, port)` for the socket to bind to as its source address before connecting. If host or port are '' or 0 respectively the OS default behavior will be used.

Changed in version 3.2: *source_address* was added.

`socket.fromfd`(*fd*, *family*, *type*, *proto=0*)
Duplicate the file descriptor *fd* (an integer as returned by a file object's `fileno()` method) and build a socket object from the result. Address family, socket type and protocol number are as for the *socket()* function above. The file descriptor should refer to a socket, but this is not checked — subsequent operations on the object may fail if the file descriptor is invalid. This function is rarely

needed, but can be used to get or set socket options on a socket passed to a program as standard input or output (such as a server started by the Unix inet daemon). The socket is assumed to be in blocking mode.

The newly created socket is *non-inheritable*.

Changed in version 3.4: The returned socket is now non-inheritable.

`socket.fromshare`(*data*)
Instantiate a socket from data obtained from the *socket.share()* method. The socket is assumed to be in blocking mode.

Availability: Windows.

New in version 3.3.

`socket.SocketType`
This is a Python type object that represents the socket object type. It is the same as `type(socket(...))`.

Other functions

The *socket* module also offers various network-related services:

`socket.close`(*fd*)
Close a socket file descriptor. This is like *os.close()*, but for sockets. On some platforms (most noticeable Windows) *os.close()* does not work for socket file descriptors.

New in version 3.7.

`socket.getaddrinfo`(*host*, *port*, *family=0*, *type=0*, *proto=0*, *flags=0*)
Translate the *host*/*port* argument into a sequence of 5-tuples that contain all the necessary arguments for creating a socket connected to that service. *host* is a domain name, a string representation of an IPv4/v6 address or `None`. *port* is a string service name such as `'http'`, a numeric port number or `None`. By passing `None` as the value of *host* and *port*, you can pass `NULL` to the underlying C API.

The *family*, *type* and *proto* arguments can be optionally specified in order to narrow the list of addresses returned. Passing zero as a value for each of these arguments selects the full range of results. The *flags* argument can be one or several of the `AI_*` constants, and will influence how results are computed and returned. For example, `AI_NUMERICHOST` will disable domain name resolution and will raise an error if *host* is a domain name.

The function returns a list of 5-tuples with the following structure:

`(family, type, proto, canonname, sockaddr)`

In these tuples, *family*, *type*, *proto* are all integers and are meant to be passed to the *socket()* function. *canonname* will be a string representing the canonical name of the *host* if `AI_CANONNAME` is part of the *flags* argument; else *canonname* will be empty. *sockaddr* is a tuple describing a socket address, whose format depends on the returned *family* (a `(address, port)` 2-tuple for *AF_INET*, a `(address, port, flow info, scope id)` 4-tuple for *AF_INET6*), and is meant to be passed to the *socket.connect()* method.

The following example fetches address information for a hypothetical TCP connection to `example.org` on port 80 (results may differ on your system if IPv6 isn't enabled):

```
>>> socket.getaddrinfo("example.org", 80, proto=socket.IPPROTO_TCP)
[(<AddressFamily.AF_INET6: 10>, <SocketType.SOCK_STREAM: 1>,
 6, '', ('2606:2800:220:1:248:1893:25c8:1946', 80, 0, 0)),
 (<AddressFamily.AF_INET: 2>, <SocketType.SOCK_STREAM: 1>,
 6, '', ('93.184.216.34', 80))]
```

Changed in version 3.2: parameters can now be passed using keyword arguments.

Changed in version 3.7: for IPv6 multicast addresses, string representing an address will not contain `%scope` part.

`socket.getfqdn([name])`
Return a fully qualified domain name for *name*. If *name* is omitted or empty, it is interpreted as the local host. To find the fully qualified name, the hostname returned by *gethostbyaddr()* is checked, followed by aliases for the host, if available. The first name which includes a period is selected. In case no fully qualified domain name is available, the hostname as returned by *gethostname()* is returned.

`socket.gethostbyname(hostname)`
Translate a host name to IPv4 address format. The IPv4 address is returned as a string, such as `'100.50.200.5'`. If the host name is an IPv4 address itself it is returned unchanged. See *gethostbyname_ex()* for a more complete interface. *gethostbyname()* does not support IPv6 name resolution, and *getaddrinfo()* should be used instead for IPv4/v6 dual stack support.

`socket.gethostbyname_ex(hostname)`
Translate a host name to IPv4 address format, extended interface. Return a triple `(hostname, aliaslist, ipaddrlist)` where *hostname* is the primary host name responding to the given *ip_address*, *aliaslist* is a (possibly empty) list of alternative host names for the same address, and *ipaddrlist* is a list of IPv4 addresses for the same interface on the same host (often but not always a single address). *gethostbyname_ex()* does not support IPv6 name resolution, and *getaddrinfo()* should be used instead for IPv4/v6 dual stack support.

`socket.gethostname()`
Return a string containing the hostname of the machine where the Python interpreter is currently executing.

Note: *gethostname()* doesn't always return the fully qualified domain name; use *getfqdn()* for that.

`socket.gethostbyaddr(ip_address)`
Return a triple `(hostname, aliaslist, ipaddrlist)` where *hostname* is the primary host name responding to the given *ip_address*, *aliaslist* is a (possibly empty) list of alternative host names for the same address, and *ipaddrlist* is a list of IPv4/v6 addresses for the same interface on the same host (most likely containing only a single address). To find the fully qualified domain name, use the function *getfqdn()*. *gethostbyaddr()* supports both IPv4 and IPv6.

`socket.getnameinfo(sockaddr, flags)`
Translate a socket address *sockaddr* into a 2-tuple `(host, port)`. Depending on the settings of *flags*, the result can contain a fully-qualified domain name or numeric address representation in *host*. Similarly, *port* can contain a string port name or a numeric port number.

For IPv6 addresses, `%scope` is appended to the host part if *sockaddr* contains meaningful *scopeid*. Usually this happens for multicast addresses.

`socket.getprotobyname(protocolname)`
Translate an Internet protocol name (for example, `'icmp'`) to a constant suitable for passing as the (optional) third argument to the *socket()* function. This is usually only needed for sockets opened in "raw" mode (*SOCK_RAW*); for the normal socket modes, the correct protocol is chosen automatically if the protocol is omitted or zero.

`socket.getservbyname(servicename[, protocolname])`
Translate an Internet service name and protocol name to a port number for that service. The optional protocol name, if given, should be `'tcp'` or `'udp'`, otherwise any protocol will match.

`socket.getservbyport(port[, protocolname])`
Translate an Internet port number and protocol name to a service name for that service. The optional protocol name, if given, should be `'tcp'` or `'udp'`, otherwise any protocol will match.

socket.ntohl(*x*)
Convert 32-bit positive integers from network to host byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 4-byte swap operation.

socket.ntohs(*x*)
Convert 16-bit positive integers from network to host byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 2-byte swap operation.

Deprecated since version 3.7: In case *x* does not fit in 16-bit unsigned integer, but does fit in a positive C int, it is silently truncated to 16-bit unsigned integer. This silent truncation feature is deprecated, and will raise an exception in future versions of Python.

socket.htonl(*x*)
Convert 32-bit positive integers from host to network byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 4-byte swap operation.

socket.htons(*x*)
Convert 16-bit positive integers from host to network byte order. On machines where the host byte order is the same as network byte order, this is a no-op; otherwise, it performs a 2-byte swap operation.

Deprecated since version 3.7: In case *x* does not fit in 16-bit unsigned integer, but does fit in a positive C int, it is silently truncated to 16-bit unsigned integer. This silent truncation feature is deprecated, and will raise an exception in future versions of Python.

socket.inet_aton(*ip_string*)
Convert an IPv4 address from dotted-quad string format (for example, '123.45.67.89') to 32-bit packed binary format, as a bytes object four characters in length. This is useful when conversing with a program that uses the standard C library and needs objects of type `struct in_addr`, which is the C type for the 32-bit packed binary this function returns.

inet_aton() also accepts strings with less than three dots; see the Unix manual page *inet(3)* for details.

If the IPv4 address string passed to this function is invalid, *OSError* will be raised. Note that exactly what is valid depends on the underlying C implementation of `inet_aton()`.

inet_aton() does not support IPv6, and *inet_pton()* should be used instead for IPv4/v6 dual stack support.

socket.inet_ntoa(*packed_ip*)
Convert a 32-bit packed IPv4 address (a *bytes-like object* four bytes in length) to its standard dotted-quad string representation (for example, '123.45.67.89'). This is useful when conversing with a program that uses the standard C library and needs objects of type `struct in_addr`, which is the C type for the 32-bit packed binary data this function takes as an argument.

If the byte sequence passed to this function is not exactly 4 bytes in length, *OSError* will be raised. *inet_ntoa()* does not support IPv6, and *inet_ntop()* should be used instead for IPv4/v6 dual stack support.

Changed in version 3.5: Writable *bytes-like object* is now accepted.

socket.inet_pton(*address_family*, *ip_string*)
Convert an IP address from its family-specific string format to a packed, binary format. *inet_pton()* is useful when a library or network protocol calls for an object of type `struct in_addr` (similar to *inet_aton()*) or `struct in6_addr`.

Supported values for *address_family* are currently *AF_INET* and *AF_INET6*. If the IP address string *ip_string* is invalid, *OSError* will be raised. Note that exactly what is valid depends on both the value of *address_family* and the underlying implementation of `inet_pton()`.

Availability: Unix (maybe not all platforms), Windows.

Changed in version 3.4: Windows support added

socket.**inet_ntop**(*address_family*, *packed_ip*)
Convert a packed IP address (a *bytes-like object* of some number of bytes) to its standard, family-specific string representation (for example, `'7.10.0.5'` or `'5aef:2b::8'`). *inet_ntop()* is useful when a library or network protocol returns an object of type `struct in_addr` (similar to *inet_ntoa()*) or `struct in6_addr`.

Supported values for *address_family* are currently *AF_INET* and *AF_INET6*. If the bytes object *packed_ip* is not the correct length for the specified address family, *ValueError* will be raised. *OSError* is raised for errors from the call to *inet_ntop()*.

Availability: Unix (maybe not all platforms), Windows.

Changed in version 3.4: Windows support added

Changed in version 3.5: Writable *bytes-like object* is now accepted.

socket.**CMSG_LEN**(*length*)
Return the total length, without trailing padding, of an ancillary data item with associated data of the given *length*. This value can often be used as the buffer size for *recvmsg()* to receive a single item of ancillary data, but **RFC 3542** requires portable applications to use *CMSG_SPACE()* and thus include space for padding, even when the item will be the last in the buffer. Raises *OverflowError* if *length* is outside the permissible range of values.

Availability: most Unix platforms, possibly others.

New in version 3.3.

socket.**CMSG_SPACE**(*length*)
Return the buffer size needed for *recvmsg()* to receive an ancillary data item with associated data of the given *length*, along with any trailing padding. The buffer space needed to receive multiple items is the sum of the *CMSG_SPACE()* values for their associated data lengths. Raises *OverflowError* if *length* is outside the permissible range of values.

Note that some systems might support ancillary data without providing this function. Also note that setting the buffer size using the results of this function may not precisely limit the amount of ancillary data that can be received, since additional data may be able to fit into the padding area.

Availability: most Unix platforms, possibly others.

New in version 3.3.

socket.**getdefaulttimeout**()
Return the default timeout in seconds (float) for new socket objects. A value of `None` indicates that new socket objects have no timeout. When the socket module is first imported, the default is `None`.

socket.**setdefaulttimeout**(*timeout*)
Set the default timeout in seconds (float) for new socket objects. When the socket module is first imported, the default is `None`. See *settimeout()* for possible values and their respective meanings.

socket.**sethostname**(*name*)
Set the machine's hostname to *name*. This will raise an *OSError* if you don't have enough rights.

Availability: Unix.

New in version 3.3.

socket.**if_nameindex**()
Return a list of network interface information (index int, name string) tuples. *OSError* if the system call fails.

Availability: Unix.

New in version 3.3.

`socket.if_nametoindex(if_name)`
Return a network interface index number corresponding to an interface name. *OSError* if no interface with the given name exists.

Availability: Unix.

New in version 3.3.

`socket.if_indextoname(if_index)`
Return a network interface name corresponding to an interface index number. *OSError* if no interface with the given index exists.

Availability: Unix.

New in version 3.3.

19.1.3 Socket Objects

Socket objects have the following methods. Except for *makefile()*, these correspond to Unix system calls applicable to sockets.

Changed in version 3.2: Support for the *context manager* protocol was added. Exiting the context manager is equivalent to calling *close()*.

`socket.accept()`
Accept a connection. The socket must be bound to an address and listening for connections. The return value is a pair `(conn, address)` where *conn* is a *new* socket object usable to send and receive data on the connection, and *address* is the address bound to the socket on the other end of the connection.

The newly created socket is *non-inheritable*.

Changed in version 3.4: The socket is now non-inheritable.

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

`socket.bind(address)`
Bind the socket to *address*. The socket must not already be bound. (The format of *address* depends on the address family — see above.)

`socket.close()`
Mark the socket closed. The underlying system resource (e.g. a file descriptor) is also closed when all file objects from *makefile()* are closed. Once that happens, all future operations on the socket object will fail. The remote end will receive no more data (after queued data is flushed).

Sockets are automatically closed when they are garbage-collected, but it is recommended to *close()* them explicitly, or to use a `with` statement around them.

Changed in version 3.6: *OSError* is now raised if an error occurs when the underlying `close()` call is made.

Note: *close()* releases the resource associated with a connection but does not necessarily close the connection immediately. If you want to close the connection in a timely fashion, call *shutdown()* before *close()*.

`socket.connect(address)`
Connect to a remote socket at *address*. (The format of *address* depends on the address family — see above.)

If the connection is interrupted by a signal, the method waits until the connection completes, or raise a *socket.timeout* on timeout, if the signal handler doesn't raise an exception and the socket is blocking or has a timeout. For non-blocking sockets, the method raises an *InterruptedError* exception if the connection is interrupted by a signal (or the exception raised by the signal handler).

Changed in version 3.5: The method now waits until the connection completes instead of raising an *InterruptedError* exception if the connection is interrupted by a signal, the signal handler doesn't raise an exception and the socket is blocking or has a timeout (see the **PEP 475** for the rationale).

`socket.connect_ex(`*address*`)`
Like `connect(address)`, but return an error indicator instead of raising an exception for errors returned by the C-level `connect()` call (other problems, such as "host not found," can still raise exceptions). The error indicator is `0` if the operation succeeded, otherwise the value of the `errno` variable. This is useful to support, for example, asynchronous connects.

`socket.detach()`
Put the socket object into closed state without actually closing the underlying file descriptor. The file descriptor is returned, and can be reused for other purposes.

New in version 3.2.

`socket.dup()`
Duplicate the socket.

The newly created socket is *non-inheritable*.

Changed in version 3.4: The socket is now non-inheritable.

`socket.fileno()`
Return the socket's file descriptor (a small integer), or -1 on failure. This is useful with *select.select()*.

Under Windows the small integer returned by this method cannot be used where a file descriptor can be used (such as *os.fdopen()*). Unix does not have this limitation.

`socket.get_inheritable()`
Get the *inheritable flag* of the socket's file descriptor or socket's handle: `True` if the socket can be inherited in child processes, `False` if it cannot.

New in version 3.4.

`socket.getpeername()`
Return the remote address to which the socket is connected. This is useful to find out the port number of a remote IPv4/v6 socket, for instance. (The format of the address returned depends on the address family — see above.) On some systems this function is not supported.

`socket.getsockname()`
Return the socket's own address. This is useful to find out the port number of an IPv4/v6 socket, for instance. (The format of the address returned depends on the address family — see above.)

`socket.getsockopt(`*level*, *optname*[, *buflen*]`)`
Return the value of the given socket option (see the Unix man page *getsockopt(2)*). The needed symbolic constants (`SO_*` etc.) are defined in this module. If *buflen* is absent, an integer option is assumed and its integer value is returned by the function. If *buflen* is present, it specifies the maximum length of the buffer used to receive the option in, and this buffer is returned as a bytes object. It is up to the caller to decode the contents of the buffer (see the optional built-in module *struct* for a way to decode C structures encoded as byte strings).

`socket.getblocking()`
Return `True` if socket is in blocking mode, `False` if in non-blocking.

This is equivalent to checking `socket.gettimeout() == 0`.

New in version 3.7.

socket.gettimeout()
Return the timeout in seconds (float) associated with socket operations, or None if no timeout is set. This reflects the last call to *setblocking()* or *settimeout()*.

socket.ioctl(*control*, *option*)

Platform Windows

The *ioctl()* method is a limited interface to the WSAIoctl system interface. Please refer to the Win32 documentation for more information.

On other platforms, the generic *fcntl.fcntl()* and *fcntl.ioctl()* functions may be used; they accept a socket object as their first argument.

Currently only the following control codes are supported: SIO_RCVALL, SIO_KEEPALIVE_VALS, and SIO_LOOPBACK_FAST_PATH.

Changed in version 3.6: SIO_LOOPBACK_FAST_PATH was added.

socket.listen([*backlog*])
Enable a server to accept connections. If *backlog* is specified, it must be at least 0 (if it is lower, it is set to 0); it specifies the number of unaccepted connections that the system will allow before refusing new connections. If not specified, a default reasonable value is chosen.

Changed in version 3.5: The *backlog* parameter is now optional.

socket.makefile(*mode='r'*, *buffering=None*, ***, *encoding=None*, *errors=None*, *newline=None*)
Return a *file object* associated with the socket. The exact returned type depends on the arguments given to *makefile()*. These arguments are interpreted the same way as by the built-in *open()* function, except the only supported *mode* values are 'r' (default), 'w' and 'b'.

The socket must be in blocking mode; it can have a timeout, but the file object's internal buffer may end up in an inconsistent state if a timeout occurs.

Closing the file object returned by *makefile()* won't close the original socket unless all other file objects have been closed and *socket.close()* has been called on the socket object.

Note: On Windows, the file-like object created by *makefile()* cannot be used where a file object with a file descriptor is expected, such as the stream arguments of *subprocess.Popen()*.

---

socket.recv(*bufsize*[, *flags*])
Receive data from the socket. The return value is a bytes object representing the data received. The maximum amount of data to be received at once is specified by *bufsize*. See the Unix manual page *recv(2)* for the meaning of the optional argument *flags*; it defaults to zero.

Note: For best match with hardware and network realities, the value of *bufsize* should be a relatively small power of 2, for example, 4096.

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

socket.recvfrom(*bufsize*[, *flags*])
Receive data from the socket. The return value is a pair (bytes, address) where *bytes* is a bytes object representing the data received and *address* is the address of the socket sending the data. See the Unix manual page *recv(2)* for the meaning of the optional argument *flags*; it defaults to zero. (The format of *address* depends on the address family — see above.)

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

Changed in version 3.7: For multicast IPv6 address, first item of *address* does not contain `%scope` part anymore. In order to get full IPv6 address use *getnameinfo()*.

`socket.recvmsg`(*bufsize*[, *ancbufsize*[, *flags*]])

Receive normal data (up to *bufsize* bytes) and ancillary data from the socket. The *ancbufsize* argument sets the size in bytes of the internal buffer used to receive the ancillary data; it defaults to 0, meaning that no ancillary data will be received. Appropriate buffer sizes for ancillary data can be calculated using *CMSG_SPACE()* or *CMSG_LEN()*, and items which do not fit into the buffer might be truncated or discarded. The *flags* argument defaults to 0 and has the same meaning as for *recv()*.

The return value is a 4-tuple: `(data, ancdata, msg_flags, address)`. The *data* item is a *bytes* object holding the non-ancillary data received. The *ancdata* item is a list of zero or more tuples `(cmsg_level, cmsg_type, cmsg_data)` representing the ancillary data (control messages) received: *cmsg_level* and *cmsg_type* are integers specifying the protocol level and protocol-specific type respectively, and *cmsg_data* is a *bytes* object holding the associated data. The *msg_flags* item is the bitwise OR of various flags indicating conditions on the received message; see your system documentation for details. If the receiving socket is unconnected, *address* is the address of the sending socket, if available; otherwise, its value is unspecified.

On some systems, *sendmsg()* and *recvmsg()* can be used to pass file descriptors between processes over an *AF_UNIX* socket. When this facility is used (it is often restricted to *SOCK_STREAM* sockets), *recvmsg()* will return, in its ancillary data, items of the form `(socket.SOL_SOCKET, socket.SCM_RIGHTS, fds)`, where *fds* is a *bytes* object representing the new file descriptors as a binary array of the native C `int` type. If *recvmsg()* raises an exception after the system call returns, it will first attempt to close any file descriptors received via this mechanism.

Some systems do not indicate the truncated length of ancillary data items which have been only partially received. If an item appears to extend beyond the end of the buffer, *recvmsg()* will issue a *RuntimeWarning*, and will return the part of it which is inside the buffer provided it has not been truncated before the start of its associated data.

On systems which support the `SCM_RIGHTS` mechanism, the following function will receive up to *maxfds* file descriptors, returning the message data and a list containing the descriptors (while ignoring unexpected conditions such as unrelated control messages being received). See also *sendmsg()*.

```
import socket, array

def recv_fds(sock, msglen, maxfds):
    fds = array.array("i")   # Array of ints
    msg, ancdata, flags, addr = sock.recvmsg(msglen, socket.CMSG_LEN(maxfds * fds.itemsize))
    for cmsg_level, cmsg_type, cmsg_data in ancdata:
        if (cmsg_level == socket.SOL_SOCKET and cmsg_type == socket.SCM_RIGHTS):
            # Append data, ignoring any truncated integers at the end.
            fds.fromstring(cmsg_data[:len(cmsg_data) - (len(cmsg_data) % fds.itemsize)])
    return msg, list(fds)
```

Availability: most Unix platforms, possibly others.

New in version 3.3.

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

`socket.recvmsg_into`(*buffers*[, *ancbufsize*[, *flags*]])

Receive normal data and ancillary data from the socket, behaving as *recvmsg()* would, but scatter

the non-ancillary data into a series of buffers instead of returning a new bytes object. The *buffers* argument must be an iterable of objects that export writable buffers (e.g. *bytearray* objects); these will be filled with successive chunks of the non-ancillary data until it has all been written or there are no more buffers. The operating system may set a limit (*sysconf()* value `SC_IOV_MAX`) on the number of buffers that can be used. The *ancbufsize* and *flags* arguments have the same meaning as for *recvmsg()*.

The return value is a 4-tuple: `(nbytes, ancdata, msg_flags, address)`, where *nbytes* is the total number of bytes of non-ancillary data written into the buffers, and *ancdata*, *msg_flags* and *address* are the same as for *recvmsg()*.

Example:

```
>>> import socket
>>> s1, s2 = socket.socketpair()
>>> b1 = bytearray(b'----')
>>> b2 = bytearray(b'0123456789')
>>> b3 = bytearray(b'--------------')
>>> s1.send(b'Mary had a little lamb')
22
>>> s2.recvmsg_into([b1, memoryview(b2)[2:9], b3])
(22, [], 0, None)
>>> [b1, b2, b3]
[bytearray(b'Mary'), bytearray(b'01 had a 9'), bytearray(b'little lamb---')]
```

Availability: most Unix platforms, possibly others.

New in version 3.3.

`socket.recvfrom_into(`*buffer*[, *nbytes*[, *flags*]]`)`

Receive data from the socket, writing it into *buffer* instead of creating a new bytestring. The return value is a pair `(nbytes, address)` where *nbytes* is the number of bytes received and *address* is the address of the socket sending the data. See the Unix manual page *recv(2)* for the meaning of the optional argument *flags*; it defaults to zero. (The format of *address* depends on the address family — see above.)

`socket.recv_into(`*buffer*[, *nbytes*[, *flags*]]`)`

Receive up to *nbytes* bytes from the socket, storing the data into a buffer rather than creating a new bytestring. If *nbytes* is not specified (or 0), receive up to the size available in the given buffer. Returns the number of bytes received. See the Unix manual page *recv(2)* for the meaning of the optional argument *flags*; it defaults to zero.

`socket.send(`*bytes*[, *flags*]`)`

Send data to the socket. The socket must be connected to a remote socket. The optional *flags* argument has the same meaning as for *recv()* above. Returns the number of bytes sent. Applications are responsible for checking that all data has been sent; if only some of the data was transmitted, the application needs to attempt delivery of the remaining data. For further information on this topic, consult the socket-howto.

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

`socket.sendall(`*bytes*[, *flags*]`)`

Send data to the socket. The socket must be connected to a remote socket. The optional *flags* argument has the same meaning as for *recv()* above. Unlike *send()*, this method continues to send data from *bytes* until either all data has been sent or an error occurs. `None` is returned on success. On error, an exception is raised, and there is no way to determine how much data, if any, was successfully sent.

Changed in version 3.5: The socket timeout is no more reset each time data is sent successfully. The socket timeout is now the maximum total duration to send all data.

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

socket.sendto(*bytes*, *address*)
socket.sendto(*bytes*, *flags*, *address*)
Send data to the socket. The socket should not be connected to a remote socket, since the destination socket is specified by *address*. The optional *flags* argument has the same meaning as for *recv()* above. Return the number of bytes sent. (The format of *address* depends on the address family — see above.)

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

socket.sendmsg(*buffers*[, *ancdata*[, *flags*[, *address*]]])
Send normal and ancillary data to the socket, gathering the non-ancillary data from a series of buffers and concatenating it into a single message. The *buffers* argument specifies the non-ancillary data as an iterable of *bytes-like objects* (e.g. *bytes* objects); the operating system may set a limit (*sysconf()* value `SC_IOV_MAX`) on the number of buffers that can be used. The *ancdata* argument specifies the ancillary data (control messages) as an iterable of zero or more tuples `(cmsg_level, cmsg_type, cmsg_data)`, where *cmsg_level* and *cmsg_type* are integers specifying the protocol level and protocol-specific type respectively, and *cmsg_data* is a bytes-like object holding the associated data. Note that some systems (in particular, systems without *CMSG_SPACE()*) might support sending only one control message per call. The *flags* argument defaults to 0 and has the same meaning as for *send()*. If *address* is supplied and not `None`, it sets a destination address for the message. The return value is the number of bytes of non-ancillary data sent.

The following function sends the list of file descriptors *fds* over an *AF_UNIX* socket, on systems which support the `SCM_RIGHTS` mechanism. See also *recvmsg()*.

```
import socket, array

def send_fds(sock, msg, fds):
    return sock.sendmsg([msg], [(socket.SOL_SOCKET, socket.SCM_RIGHTS, array.array("i",␣
↪fds))])
```

Availability: most Unix platforms, possibly others.

New in version 3.3.

Changed in version 3.5: If the system call is interrupted and the signal handler does not raise an exception, the method now retries the system call instead of raising an *InterruptedError* exception (see **PEP 475** for the rationale).

socket.sendmsg_afalg([*msg*], *, *op*[, *iv*[, *assoclen*[, *flags*]]])
Specialized version of *sendmsg()* for *AF_ALG* socket. Set mode, IV, AEAD associated data length and flags for *AF_ALG* socket.

Availability: Linux >= 2.6.38

New in version 3.6.

socket.sendfile(*file*, *offset=0*, *count=None*)
Send a file until EOF is reached by using high-performance *os.sendfile* and return the total number of bytes which were sent. *file* must be a regular file object opened in binary mode. If *os.sendfile* is not available (e.g. Windows) or *file* is not a regular file *send()* will be used instead. *offset* tells from where to start reading the file. If specified, *count* is the total number of bytes to transmit as opposed to sending the file until EOF is reached. File position is updated on return or also in case of error in

which case *file.tell()* can be used to figure out the number of bytes which were sent. The socket must be of *SOCK_STREAM* type. Non-blocking sockets are not supported.

New in version 3.5.

socket.set_inheritable(*inheritable*)
Set the *inheritable flag* of the socket's file descriptor or socket's handle.

New in version 3.4.

socket.setblocking(*flag*)
Set blocking or non-blocking mode of the socket: if *flag* is false, the socket is set to non-blocking, else to blocking mode.

This method is a shorthand for certain *settimeout()* calls:

- `sock.setblocking(True)` is equivalent to `sock.settimeout(None)`
- `sock.setblocking(False)` is equivalent to `sock.settimeout(0.0)`

Changed in version 3.7: The method no longer applies *SOCK_NONBLOCK* flag on *socket.type*.

socket.settimeout(*value*)
Set a timeout on blocking socket operations. The *value* argument can be a nonnegative floating point number expressing seconds, or `None`. If a non-zero value is given, subsequent socket operations will raise a *timeout* exception if the timeout period *value* has elapsed before the operation has completed. If zero is given, the socket is put in non-blocking mode. If `None` is given, the socket is put in blocking mode.

For further information, please consult the *notes on socket timeouts*.

Changed in version 3.7: The method no longer toggles *SOCK_NONBLOCK* flag on *socket.type*.

socket.setsockopt(*level*, *optname*, *value: int*)

socket.setsockopt(*level*, *optname*, *value: buffer*)

socket.setsockopt(*level*, *optname*, *None*, *optlen: int*)
Set the value of the given socket option (see the Unix manual page *setsockopt(2)*). The needed symbolic constants are defined in the *socket* module (`SO_*` etc.). The value can be an integer, `None` or a *bytes-like object* representing a buffer. In the later case it is up to the caller to ensure that the bytestring contains the proper bits (see the optional built-in module *struct* for a way to encode C structures as bytestrings). When value is set to `None`, optlen argument is required. It's equivalent to call setsockopt C function with optval=NULL and optlen=optlen.

Changed in version 3.5: Writable *bytes-like object* is now accepted.

Changed in version 3.6: setsockopt(level, optname, None, optlen: int) form added.

socket.shutdown(*how*)
Shut down one or both halves of the connection. If *how* is `SHUT_RD`, further receives are disallowed. If *how* is `SHUT_WR`, further sends are disallowed. If *how* is `SHUT_RDWR`, further sends and receives are disallowed.

socket.share(*process_id*)
Duplicate a socket and prepare it for sharing with a target process. The target process must be provided with *process_id*. The resulting bytes object can then be passed to the target process using some form of interprocess communication and the socket can be recreated there using *fromshare()*. Once this method has been called, it is safe to close the socket since the operating system has already duplicated it for the target process.

Availability: Windows.

New in version 3.3.

Note that there are no methods `read()` or `write()`; use *recv()* and *send()* without *flags* argument instead.

Socket objects also have these (read-only) attributes that correspond to the values given to the *socket* constructor.

`socket.family`
The socket family.

`socket.type`
The socket type.

`socket.proto`
The socket protocol.

19.1.4 Notes on socket timeouts

A socket object can be in one of three modes: blocking, non-blocking, or timeout. Sockets are by default always created in blocking mode, but this can be changed by calling *setdefaulttimeout()*.

- In *blocking mode*, operations block until complete or the system returns an error (such as connection timed out).
- In *non-blocking mode*, operations fail (with an error that is unfortunately system-dependent) if they cannot be completed immediately: functions from the *select* can be used to know when and whether a socket is available for reading or writing.
- In *timeout mode*, operations fail if they cannot be completed within the timeout specified for the socket (they raise a *timeout* exception) or if the system returns an error.

Note: At the operating system level, sockets in *timeout mode* are internally set in non-blocking mode. Also, the blocking and timeout modes are shared between file descriptors and socket objects that refer to the same network endpoint. This implementation detail can have visible consequences if e.g. you decide to use the *fileno()* of a socket.

Timeouts and the `connect` method

The *connect()* operation is also subject to the timeout setting, and in general it is recommended to call *settimeout()* before calling *connect()* or pass a timeout parameter to *create_connection()*. However, the system network stack may also return a connection timeout error of its own regardless of any Python socket timeout setting.

Timeouts and the `accept` method

If *getdefaulttimeout()* is not *None*, sockets returned by the *accept()* method inherit that timeout. Otherwise, the behaviour depends on settings of the listening socket:

- if the listening socket is in *blocking mode* or in *timeout mode*, the socket returned by *accept()* is in *blocking mode*;
- if the listening socket is in *non-blocking mode*, whether the socket returned by *accept()* is in blocking or non-blocking mode is operating system-dependent. If you want to ensure cross-platform behaviour, it is recommended you manually override this setting.

19.1.5 Example

Here are four minimal example programs using the TCP/IP protocol: a server that echoes all data that it receives back (servicing only one client), and a client using it. Note that a server must perform the sequence *socket()*, *bind()*, *listen()*, *accept()* (possibly repeating the *accept()* to service more than one client), while a client only needs the sequence *socket()*, *connect()*. Also note that the server does not *sendall()*/*recv()* on the socket it is listening on but on the new socket returned by *accept()*.

The first two examples support IPv4 only.

```
# Echo server program
import socket

HOST = ''                 # Symbolic name meaning all available interfaces
PORT = 50007              # Arbitrary non-privileged port
with socket.socket(socket.AF_INET, socket.SOCK_STREAM) as s:
    s.bind((HOST, PORT))
    s.listen(1)
    conn, addr = s.accept()
    with conn:
        print('Connected by', addr)
        while True:
            data = conn.recv(1024)
            if not data: break
            conn.sendall(data)
```

```
# Echo client program
import socket

HOST = 'daring.cwi.nl'    # The remote host
PORT = 50007              # The same port as used by the server
with socket.socket(socket.AF_INET, socket.SOCK_STREAM) as s:
    s.connect((HOST, PORT))
    s.sendall(b'Hello, world')
    data = s.recv(1024)
print('Received', repr(data))
```

The next two examples are identical to the above two, but support both IPv4 and IPv6. The server side will listen to the first address family available (it should listen to both instead). On most of IPv6-ready systems, IPv6 will take precedence and the server may not accept IPv4 traffic. The client side will try to connect to the all addresses returned as a result of the name resolution, and sends traffic to the first one connected successfully.

```
# Echo server program
import socket
import sys

HOST = None               # Symbolic name meaning all available interfaces
PORT = 50007              # Arbitrary non-privileged port
s = None
for res in socket.getaddrinfo(HOST, PORT, socket.AF_UNSPEC,
                              socket.SOCK_STREAM, 0, socket.AI_PASSIVE):
    af, socktype, proto, canonname, sa = res
    try:
        s = socket.socket(af, socktype, proto)
    except OSError as msg:
        s = None
```

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```
        continue
    try:
        s.bind(sa)
        s.listen(1)
    except OSError as msg:
        s.close()
        s = None
        continue
    break
if s is None:
    print('could not open socket')
    sys.exit(1)
conn, addr = s.accept()
with conn:
    print('Connected by', addr)
    while True:
        data = conn.recv(1024)
        if not data: break
        conn.send(data)
```

```
# Echo client program
import socket
import sys

HOST = 'daring.cwi.nl'    # The remote host
PORT = 50007              # The same port as used by the server
s = None
for res in socket.getaddrinfo(HOST, PORT, socket.AF_UNSPEC, socket.SOCK_STREAM):
    af, socktype, proto, canonname, sa = res
    try:
        s = socket.socket(af, socktype, proto)
    except OSError as msg:
        s = None
        continue
    try:
        s.connect(sa)
    except OSError as msg:
        s.close()
        s = None
        continue
    break
if s is None:
    print('could not open socket')
    sys.exit(1)
with s:
    s.sendall(b'Hello, world')
    data = s.recv(1024)
print('Received', repr(data))
```

The next example shows how to write a very simple network sniffer with raw sockets on Windows. The example requires administrator privileges to modify the interface:

```
import socket

# the public network interface
HOST = socket.gethostbyname(socket.gethostname())
```

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```
# create a raw socket and bind it to the public interface
s = socket.socket(socket.AF_INET, socket.SOCK_RAW, socket.IPPROTO_IP)
s.bind((HOST, 0))

# Include IP headers
s.setsockopt(socket.IPPROTO_IP, socket.IP_HDRINCL, 1)

# receive all packages
s.ioctl(socket.SIO_RCVALL, socket.RCVALL_ON)

# receive a package
print(s.recvfrom(65565))

# disabled promiscuous mode
s.ioctl(socket.SIO_RCVALL, socket.RCVALL_OFF)
```

The next example shows how to use the socket interface to communicate to a CAN network using the raw socket protocol. To use CAN with the broadcast manager protocol instead, open a socket with:

```
socket.socket(socket.AF_CAN, socket.SOCK_DGRAM, socket.CAN_BCM)
```

After binding (`CAN_RAW`) or connecting (*CAN_BCM*) the socket, you can use the *socket.send()*, and the *socket.recv()* operations (and their counterparts) on the socket object as usual.

This last example might require special privileges:

```
import socket
import struct


# CAN frame packing/unpacking (see 'struct can_frame' in <linux/can.h>)

can_frame_fmt = "=IB3x8s"
can_frame_size = struct.calcsize(can_frame_fmt)

def build_can_frame(can_id, data):
    can_dlc = len(data)
    data = data.ljust(8, b'\x00')
    return struct.pack(can_frame_fmt, can_id, can_dlc, data)

def dissect_can_frame(frame):
    can_id, can_dlc, data = struct.unpack(can_frame_fmt, frame)
    return (can_id, can_dlc, data[:can_dlc])


# create a raw socket and bind it to the 'vcan0' interface
s = socket.socket(socket.AF_CAN, socket.SOCK_RAW, socket.CAN_RAW)
s.bind(('vcan0',))

while True:
    cf, addr = s.recvfrom(can_frame_size)

    print('Received: can_id=%x, can_dlc=%x, data=%s' % dissect_can_frame(cf))

    try:
        s.send(cf)
```

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```
    except OSError:
        print('Error sending CAN frame')

    try:
        s.send(build_can_frame(0x01, b'\x01\x02\x03'))
    except OSError:
        print('Error sending CAN frame')
```

Running an example several times with too small delay between executions, could lead to this error:

```
OSError: [Errno 98] Address already in use
```

This is because the previous execution has left the socket in a `TIME_WAIT` state, and can't be immediately reused.

There is a *socket* flag to set, in order to prevent this, `socket.SO_REUSEADDR`:

```
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
s.bind((HOST, PORT))
```

the `SO_REUSEADDR` flag tells the kernel to reuse a local socket in `TIME_WAIT` state, without waiting for its natural timeout to expire.

See also:

For an introduction to socket programming (in C), see the following papers:

- *An Introductory 4.3BSD Interprocess Communication Tutorial*, by Stuart Sechrest
- *An Advanced 4.3BSD Interprocess Communication Tutorial*, by Samuel J. Leffler et al,

both in the UNIX Programmer's Manual, Supplementary Documents 1 (sections PS1:7 and PS1:8). The platform-specific reference material for the various socket-related system calls are also a valuable source of information on the details of socket semantics. For Unix, refer to the manual pages; for Windows, see the WinSock (or Winsock 2) specification. For IPv6-ready APIs, readers may want to refer to **RFC 3493** titled Basic Socket Interface Extensions for IPv6.

19.2 `ssl` — TLS/SSL wrapper for socket objects

Source code: Lib/ssl.py

This module provides access to Transport Layer Security (often known as "Secure Sockets Layer") encryption and peer authentication facilities for network sockets, both client-side and server-side. This module uses the OpenSSL library. It is available on all modern Unix systems, Windows, Mac OS X, and probably additional platforms, as long as OpenSSL is installed on that platform.

Note: Some behavior may be platform dependent, since calls are made to the operating system socket APIs. The installed version of OpenSSL may also cause variations in behavior. For example, TLSv1.1 and TLSv1.2 come with openssl version 1.0.1.

Warning: Don't use this module without reading the *Security considerations*. Doing so may lead to a false sense of security, as the default settings of the ssl module are not necessarily appropriate for your application.

This section documents the objects and functions in the `ssl` module; for more general information about TLS, SSL, and certificates, the reader is referred to the documents in the "See Also" section at the bottom.

This module provides a class, *ssl.SSLSocket*, which is derived from the *socket.socket* type, and provides a socket-like wrapper that also encrypts and decrypts the data going over the socket with SSL. It supports additional methods such as `getpeercert()`, which retrieves the certificate of the other side of the connection, and `cipher()`,which retrieves the cipher being used for the secure connection.

For more sophisticated applications, the *ssl.SSLContext* class helps manage settings and certificates, which can then be inherited by SSL sockets created through the *SSLContext.wrap_socket()* method.

Changed in version 3.5.3: Updated to support linking with OpenSSL 1.1.0

Changed in version 3.6: OpenSSL 0.9.8, 1.0.0 and 1.0.1 are deprecated and no longer supported. In the future the ssl module will require at least OpenSSL 1.0.2 or 1.1.0.

19.2.1 Functions, Constants, and Exceptions

Socket creation

Since Python 3.2 and 2.7.9, it is recommended to use the *SSLContext.wrap_socket()* of an *SSLContext* instance to wrap sockets as *SSLSocket* objects. The helper functions *create_default_context()* returns a new context with secure default settings. The old *wrap_socket()* function is deprecated since it is both inefficient and has no support for server name indication (SNI) and hostname matching.

Client socket example with default context and IPv4/IPv6 dual stack:

```
import socket
import ssl

hostname = 'www.python.org'
context = ssl.create_default_context()

with socket.create_connection((hostname, 443)) as sock:
    with context.wrap_socket(sock, server_hostname=hostname) as ssock:
        print(ssock.version())
```

Client socket example with custom context and IPv4:

```
hostname = 'www.python.org'
# PROTOCOL_TLS_CLIENT requires valid cert chain and hostname
context = ssl.SSLContext(ssl.PROTOCOL_TLS_CLIENT)
context.load_verify_locations('path/to/cabundle.pem')

with socket.socket(socket.AF_INET, socket.SOCK_STREAM, 0) as sock:
    with context.wrap_socket(sock, server_hostname=hostname) as ssock:
        print(ssock.version())
```

Server socket example listening on localhost IPv4:

```
context = ssl.SSLContext(ssl.PROTOCOL_TLS_SERVER)
context.load_cert_chain('/path/to/certchain.pem', '/path/to/private.key')
```

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```
with socket.socket(socket.AF_INET, socket.SOCK_STREAM, 0) as sock:
    sock.bind(('127.0.0.1', 8443))
    sock.listen(5)
    with context.wrap_socket(sock, server_side=True) as ssock:
        conn, addr = ssock.accept()
        ...
```

Context creation

A convenience function helps create *SSLContext* objects for common purposes.

ssl.create_default_context(*purpose=Purpose.SERVER_AUTH*, *cafile=None*, *capath=None*, *cadata=None*)

Return a new *SSLContext* object with default settings for the given *purpose*. The settings are chosen by the *ssl* module, and usually represent a higher security level than when calling the *SSLContext* constructor directly.

cafile, *capath*, *cadata* represent optional CA certificates to trust for certificate verification, as in *SSLContext.load_verify_locations()*. If all three are *None*, this function can choose to trust the system's default CA certificates instead.

The settings are: *PROTOCOL_TLS*, *OP_NO_SSLv2*, and *OP_NO_SSLv3* with high encryption cipher suites without RC4 and without unauthenticated cipher suites. Passing *SERVER_AUTH* as *purpose* sets *verify_mode* to *CERT_REQUIRED* and either loads CA certificates (when at least one of *cafile*, *capath* or *cadata* is given) or uses *SSLContext.load_default_certs()* to load default CA certificates.

Note: The protocol, options, cipher and other settings may change to more restrictive values anytime without prior deprecation. The values represent a fair balance between compatibility and security.

If your application needs specific settings, you should create a *SSLContext* and apply the settings yourself.

Note: If you find that when certain older clients or servers attempt to connect with a *SSLContext* created by this function that they get an error stating "Protocol or cipher suite mismatch", it may be that they only support SSL3.0 which this function excludes using the *OP_NO_SSLv3*. SSL3.0 is widely considered to be completely broken. If you still wish to continue to use this function but still allow SSL 3.0 connections you can re-enable them using:

```
ctx = ssl.create_default_context(Purpose.CLIENT_AUTH)
ctx.options &= ~ssl.OP_NO_SSLv3
```

New in version 3.4.

Changed in version 3.4.4: RC4 was dropped from the default cipher string.

Changed in version 3.6: ChaCha20/Poly1305 was added to the default cipher string.

3DES was dropped from the default cipher string.

Exceptions

exception ssl.SSLError

Raised to signal an error from the underlying SSL implementation (currently provided by the OpenSSL

library). This signifies some problem in the higher-level encryption and authentication layer that's superimposed on the underlying network connection. This error is a subtype of *OSError*. The error code and message of *SSLError* instances are provided by the OpenSSL library.

Changed in version 3.3: *SSLError* used to be a subtype of *socket.error*.

library
A string mnemonic designating the OpenSSL submodule in which the error occurred, such as `SSL`, `PEM` or `X509`. The range of possible values depends on the OpenSSL version.

New in version 3.3.

reason
A string mnemonic designating the reason this error occurred, for example `CERTIFICATE_VERIFY_FAILED`. The range of possible values depends on the OpenSSL version.

New in version 3.3.

exception ssl.SSLZeroReturnError
A subclass of *SSLError* raised when trying to read or write and the SSL connection has been closed cleanly. Note that this doesn't mean that the underlying transport (read TCP) has been closed.

New in version 3.3.

exception ssl.SSLWantReadError
A subclass of *SSLError* raised by a *non-blocking SSL socket* when trying to read or write data, but more data needs to be received on the underlying TCP transport before the request can be fulfilled.

New in version 3.3.

exception ssl.SSLWantWriteError
A subclass of *SSLError* raised by a *non-blocking SSL socket* when trying to read or write data, but more data needs to be sent on the underlying TCP transport before the request can be fulfilled.

New in version 3.3.

exception ssl.SSLSyscallError
A subclass of *SSLError* raised when a system error was encountered while trying to fulfill an operation on a SSL socket. Unfortunately, there is no easy way to inspect the original errno number.

New in version 3.3.

exception ssl.SSLEOFError
A subclass of *SSLError* raised when the SSL connection has been terminated abruptly. Generally, you shouldn't try to reuse the underlying transport when this error is encountered.

New in version 3.3.

exception ssl.SSLCertVerificationError
A subclass of *SSLError* raised when certificate validation has failed.

New in version 3.7.

verify_code
A numeric error number that denotes the verification error.

verify_message
A human readable string of the verification error.

exception ssl.CertificateError
An alias for *SSLCertVerificationError*.

Changed in version 3.7: The exception is now an alias for *SSLCertVerificationError*.

Random generation

ssl.RAND_bytes(*num*)
: Return *num* cryptographically strong pseudo-random bytes. Raises an *SSLError* if the PRNG has not been seeded with enough data or if the operation is not supported by the current RAND method. *RAND_status()* can be used to check the status of the PRNG and *RAND_add()* can be used to seed the PRNG.

  For almost all applications *os.urandom()* is preferable.

  Read the Wikipedia article, Cryptographically secure pseudorandom number generator (CSPRNG), to get the requirements of a cryptographically generator.

  New in version 3.3.

ssl.RAND_pseudo_bytes(*num*)
: Return (bytes, is_cryptographic): bytes are *num* pseudo-random bytes, is_cryptographic is `True` if the bytes generated are cryptographically strong. Raises an *SSLError* if the operation is not supported by the current RAND method.

  Generated pseudo-random byte sequences will be unique if they are of sufficient length, but are not necessarily unpredictable. They can be used for non-cryptographic purposes and for certain purposes in cryptographic protocols, but usually not for key generation etc.

  For almost all applications *os.urandom()* is preferable.

  New in version 3.3.

  Deprecated since version 3.6: OpenSSL has deprecated *ssl.RAND_pseudo_bytes()*, use *ssl.RAND_bytes()* instead.

ssl.RAND_status()
: Return `True` if the SSL pseudo-random number generator has been seeded with 'enough' randomness, and `False` otherwise. You can use *ssl.RAND_egd()* and *ssl.RAND_add()* to increase the randomness of the pseudo-random number generator.

ssl.RAND_egd(*path*)
: If you are running an entropy-gathering daemon (EGD) somewhere, and *path* is the pathname of a socket connection open to it, this will read 256 bytes of randomness from the socket, and add it to the SSL pseudo-random number generator to increase the security of generated secret keys. This is typically only necessary on systems without better sources of randomness.

  See http://egd.sourceforge.net/ or http://prngd.sourceforge.net/ for sources of entropy-gathering daemons.

  Availability: not available with LibreSSL and OpenSSL > 1.1.0

ssl.RAND_add(*bytes*, *entropy*)
: Mix the given *bytes* into the SSL pseudo-random number generator. The parameter *entropy* (a float) is a lower bound on the entropy contained in string (so you can always use `0.0`). See **RFC 1750** for more information on sources of entropy.

  Changed in version 3.5: Writable *bytes-like object* is now accepted.

Certificate handling

ssl.match_hostname(*cert*, *hostname*)
: Verify that *cert* (in decoded format as returned by *SSLSocket.getpeercert()*) matches the given *hostname*. The rules applied are those for checking the identity of HTTPS servers as outlined in **RFC 2818**, **RFC 5280** and **RFC 6125**. In addition to HTTPS, this function should be suitable for checking the identity of servers in various SSL-based protocols such as FTPS, IMAPS, POPS and others.

CertificateError is raised on failure. On success, the function returns nothing:

```
>>> cert = {'subject': ((('commonName', 'example.com'),),)}
>>> ssl.match_hostname(cert, "example.com")
>>> ssl.match_hostname(cert, "example.org")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "/home/py3k/Lib/ssl.py", line 130, in match_hostname
ssl.CertificateError: hostname 'example.org' doesn't match 'example.com'
```

New in version 3.2.

Changed in version 3.3.3: The function now follows **RFC 6125**, section 6.4.3 and does neither match multiple wildcards (e.g. `*.*.com` or `*a*.example.org`) nor a wildcard inside an internationalized domain names (IDN) fragment. IDN A-labels such as `www*.xn--pthon-kva.org` are still supported, but `x*.python.org` no longer matches `xn--tda.python.org`.

Changed in version 3.5: Matching of IP addresses, when present in the subjectAltName field of the certificate, is now supported.

Changed in version 3.7: The function is no longer used to TLS connections. Hostname matching is now performed by OpenSSL.

Allow wildcard when it is the leftmost and the only character in that segment. Partial wildcards like `www*.example.com` are no longer supported.

Deprecated since version 3.7.

ssl.cert_time_to_seconds(*cert_time*)

Return the time in seconds since the Epoch, given the `cert_time` string representing the "notBefore" or "notAfter" date from a certificate in `"%b %d %H:%M:%S %Y %Z"` strptime format (C locale).

Here's an example:

```
>>> import ssl
>>> timestamp = ssl.cert_time_to_seconds("Jan  5 09:34:43 2018 GMT")
>>> timestamp
1515144883
>>> from datetime import datetime
>>> print(datetime.utcfromtimestamp(timestamp))
2018-01-05 09:34:43
```

"notBefore" or "notAfter" dates must use GMT (**RFC 5280**).

Changed in version 3.5: Interpret the input time as a time in UTC as specified by 'GMT' timezone in the input string. Local timezone was used previously. Return an integer (no fractions of a second in the input format)

ssl.get_server_certificate(*addr*, *ssl_version=PROTOCOL_TLS*, *ca_certs=None*)

Given the address `addr` of an SSL-protected server, as a (*hostname*, *port-number*) pair, fetches the server's certificate, and returns it as a PEM-encoded string. If `ssl_version` is specified, uses that version of the SSL protocol to attempt to connect to the server. If `ca_certs` is specified, it should be a file containing a list of root certificates, the same format as used for the same parameter in *SSLContext.wrap_socket()*. The call will attempt to validate the server certificate against that set of root certificates, and will fail if the validation attempt fails.

Changed in version 3.3: This function is now IPv6-compatible.

Changed in version 3.5: The default *ssl_version* is changed from *PROTOCOL_SSLv3* to *PROTOCOL_TLS* for maximum compatibility with modern servers.

ssl.DER_cert_to_PEM_cert(*DER_cert_bytes*)
Given a certificate as a DER-encoded blob of bytes, returns a PEM-encoded string version of the same certificate.

ssl.PEM_cert_to_DER_cert(*PEM_cert_string*)
Given a certificate as an ASCII PEM string, returns a DER-encoded sequence of bytes for that same certificate.

ssl.get_default_verify_paths()
Returns a named tuple with paths to OpenSSL's default cafile and capath. The paths are the same as used by *SSLContext.set_default_verify_paths()*. The return value is a *named tuple* `DefaultVerifyPaths`:

- `cafile` - resolved path to cafile or `None` if the file doesn't exist,
- `capath` - resolved path to capath or `None` if the directory doesn't exist,
- `openssl_cafile_env` - OpenSSL's environment key that points to a cafile,
- `openssl_cafile` - hard coded path to a cafile,
- `openssl_capath_env` - OpenSSL's environment key that points to a capath,
- `openssl_capath` - hard coded path to a capath directory

Availability: LibreSSL ignores the environment vars `openssl_cafile_env` and `openssl_capath_env`

New in version 3.4.

ssl.enum_certificates(*store_name*)
Retrieve certificates from Windows' system cert store. *store_name* may be one of `CA`, `ROOT` or `MY`. Windows may provide additional cert stores, too.

The function returns a list of (cert_bytes, encoding_type, trust) tuples. The encoding_type specifies the encoding of cert_bytes. It is either `x509_asn` for X.509 ASN.1 data or `pkcs_7_asn` for PKCS#7 ASN.1 data. Trust specifies the purpose of the certificate as a set of OIDS or exactly `True` if the certificate is trustworthy for all purposes.

Example:

```
>>> ssl.enum_certificates("CA")
[(b'data...', 'x509_asn', {'1.3.6.1.5.5.7.3.1', '1.3.6.1.5.5.7.3.2'}),
 (b'data...', 'x509_asn', True)]
```

Availability: Windows.

New in version 3.4.

ssl.enum_crls(*store_name*)
Retrieve CRLs from Windows' system cert store. *store_name* may be one of `CA`, `ROOT` or `MY`. Windows may provide additional cert stores, too.

The function returns a list of (cert_bytes, encoding_type, trust) tuples. The encoding_type specifies the encoding of cert_bytes. It is either `x509_asn` for X.509 ASN.1 data or `pkcs_7_asn` for PKCS#7 ASN.1 data.

Availability: Windows.

New in version 3.4.

ssl.wrap_socket(*sock*, *keyfile=None*, *certfile=None*, *server_side=False*, *cert_reqs=CERT_NONE*, *ssl_version=PROTOCOL_TLS*, *ca_certs=None*, *do_handshake_on_connect=True*, *suppress_ragged_eofs=True*, *ciphers=None*)
Takes an instance `sock` of *socket.socket*, and returns an instance of *ssl.SSLSocket*, a subtype of *socket.socket*, which wraps the underlying socket in an SSL context. `sock` must be a *SOCK_STREAM* socket; other socket types are unsupported.

Internally, function creates a *SSLContext* with protocol *ssl_version* and *SSLContext.options* set to *cert_reqs*. If parameters *keyfile*, *certfile*, *ca_certs* or *ciphers* are set, then the values are passed to *SSLContext.load_cert_chain()*, *SSLContext.load_verify_locations()*, and *SSLContext.set_ciphers()*.

The arguments *server_side*, *do_handshake_on_connect*, and *suppress_ragged_eofs* have the same meaning as *SSLContext.wrap_socket()*.

Deprecated since version 3.7: Since Python 3.2 and 2.7.9, it is recommended to use the *SSLContext.wrap_socket()* instead of *wrap_socket()*. The top-level function is limited and creates an insecure client socket without server name indication or hostname matching.

Constants

All constants are now *enum.IntEnum* or *enum.IntFlag* collections.

New in version 3.6.

ssl.CERT_NONE

Possible value for *SSLContext.verify_mode*, or the `cert_reqs` parameter to *wrap_socket()*. Except for *PROTOCOL_TLS_CLIENT*, it is the default mode. With client-side sockets, just about any cert is accepted. Validation errors, such as untrusted or expired cert, are ignored and do not abort the TLS/SSL handshake.

In server mode, no certificate is requested from the client, so the client does not send any for client cert authentication.

See the discussion of *Security considerations* below.

ssl.CERT_OPTIONAL

Possible value for *SSLContext.verify_mode*, or the `cert_reqs` parameter to *wrap_socket()*. In client mode, *CERT_OPTIONAL* has the same meaning as *CERT_REQUIRED*. It is recommended to use *CERT_REQUIRED* for client-side sockets instead.

In server mode, a client certificate request is sent to the client. The client may either ignore the request or send a certificate in order perform TLS client cert authentication. If the client chooses to send a certificate, it is verified. Any verification error immediately aborts the TLS handshake.

Use of this setting requires a valid set of CA certificates to be passed, either to *SSLContext.load_verify_locations()* or as a value of the `ca_certs` parameter to *wrap_socket()*.

ssl.CERT_REQUIRED

Possible value for *SSLContext.verify_mode*, or the `cert_reqs` parameter to *wrap_socket()*. In this mode, certificates are required from the other side of the socket connection; an *SSLError* will be raised if no certificate is provided, or if its validation fails. This mode is **not** sufficient to verify a certificate in client mode as it does not match hostnames. *check_hostname* must be enabled as well to verify the authenticity of a cert. *PROTOCOL_TLS_CLIENT* uses *CERT_REQUIRED* and enables *check_hostname* by default.

With server socket, this mode provides mandatory TLS client cert authentication. A client certificate request is sent to the client and the client must provide a valid and trusted certificate.

Use of this setting requires a valid set of CA certificates to be passed, either to *SSLContext.load_verify_locations()* or as a value of the `ca_certs` parameter to *wrap_socket()*.

class ssl.VerifyMode

enum.IntEnum collection of CERT_* constants.

New in version 3.6.

ssl.VERIFY_DEFAULT
Possible value for *SSLContext.verify_flags*. In this mode, certificate revocation lists (CRLs) are not checked. By default OpenSSL does neither require nor verify CRLs.

New in version 3.4.

ssl.VERIFY_CRL_CHECK_LEAF
Possible value for *SSLContext.verify_flags*. In this mode, only the peer cert is check but non of the intermediate CA certificates. The mode requires a valid CRL that is signed by the peer cert's issuer (its direct ancestor CA). If no proper has been loaded *SSLContext.load_verify_locations*, validation will fail.

New in version 3.4.

ssl.VERIFY_CRL_CHECK_CHAIN
Possible value for *SSLContext.verify_flags*. In this mode, CRLs of all certificates in the peer cert chain are checked.

New in version 3.4.

ssl.VERIFY_X509_STRICT
Possible value for *SSLContext.verify_flags* to disable workarounds for broken X.509 certificates.

New in version 3.4.

ssl.VERIFY_X509_TRUSTED_FIRST
Possible value for *SSLContext.verify_flags*. It instructs OpenSSL to prefer trusted certificates when building the trust chain to validate a certificate. This flag is enabled by default.

New in version 3.4.4.

class ssl.VerifyFlags
enum.IntFlag collection of VERIFY_* constants.

New in version 3.6.

ssl.PROTOCOL_TLS
Selects the highest protocol version that both the client and server support. Despite the name, this option can select both "SSL" and "TLS" protocols.

New in version 3.6.

ssl.PROTOCOL_TLS_CLIENT
Auto-negotiate the highest protocol version like *PROTOCOL_TLS*, but only support client-side *SSLSocket* connections. The protocol enables *CERT_REQUIRED* and *check_hostname* by default.

New in version 3.6.

ssl.PROTOCOL_TLS_SERVER
Auto-negotiate the highest protocol version like *PROTOCOL_TLS*, but only support server-side *SSLSocket* connections.

New in version 3.6.

ssl.PROTOCOL_SSLv23
Alias for data:*PROTOCOL_TLS*.

Deprecated since version 3.6: Use *PROTOCOL_TLS* instead.

ssl.PROTOCOL_SSLv2
Selects SSL version 2 as the channel encryption protocol.

This protocol is not available if OpenSSL is compiled with the `OPENSSL_NO_SSL2` flag.

> **Warning:** SSL version 2 is insecure. Its use is highly discouraged.

Deprecated since version 3.6: OpenSSL has removed support for SSLv2.

`ssl.PROTOCOL_SSLv3`
Selects SSL version 3 as the channel encryption protocol.

This protocol is not be available if OpenSSL is compiled with the `OPENSSL_NO_SSLv3` flag.

> **Warning:** SSL version 3 is insecure. Its use is highly discouraged.

Deprecated since version 3.6: OpenSSL has deprecated all version specific protocols. Use the default protocol *PROTOCOL_TLS* with flags like *OP_NO_SSLv3* instead.

`ssl.PROTOCOL_TLSv1`
Selects TLS version 1.0 as the channel encryption protocol.

Deprecated since version 3.6: OpenSSL has deprecated all version specific protocols. Use the default protocol *PROTOCOL_TLS* with flags like *OP_NO_SSLv3* instead.

`ssl.PROTOCOL_TLSv1_1`
Selects TLS version 1.1 as the channel encryption protocol. Available only with openssl version 1.0.1+.

New in version 3.4.

Deprecated since version 3.6: OpenSSL has deprecated all version specific protocols. Use the default protocol *PROTOCOL_TLS* with flags like *OP_NO_SSLv3* instead.

`ssl.PROTOCOL_TLSv1_2`
Selects TLS version 1.2 as the channel encryption protocol. This is the most modern version, and probably the best choice for maximum protection, if both sides can speak it. Available only with openssl version 1.0.1+.

New in version 3.4.

Deprecated since version 3.6: OpenSSL has deprecated all version specific protocols. Use the default protocol *PROTOCOL_TLS* with flags like *OP_NO_SSLv3* instead.

`ssl.OP_ALL`
Enables workarounds for various bugs present in other SSL implementations. This option is set by default. It does not necessarily set the same flags as OpenSSL's `SSL_OP_ALL` constant.

New in version 3.2.

`ssl.OP_NO_SSLv2`
Prevents an SSLv2 connection. This option is only applicable in conjunction with *PROTOCOL_TLS*. It prevents the peers from choosing SSLv2 as the protocol version.

New in version 3.2.

Deprecated since version 3.6: SSLv2 is deprecated

`ssl.OP_NO_SSLv3`
Prevents an SSLv3 connection. This option is only applicable in conjunction with *PROTOCOL_TLS*. It prevents the peers from choosing SSLv3 as the protocol version.

New in version 3.2.

Deprecated since version 3.6: SSLv3 is deprecated

ssl.OP_NO_TLSv1
Prevents a TLSv1 connection. This option is only applicable in conjunction with *PROTOCOL_TLS*. It prevents the peers from choosing TLSv1 as the protocol version.

New in version 3.2.

Deprecated since version 3.7: The option is deprecated since OpenSSL 1.1.0, use the new *SSLContext.minimum_version* and *SSLContext.maximum_version* instead.

ssl.OP_NO_TLSv1_1
Prevents a TLSv1.1 connection. This option is only applicable in conjunction with *PROTOCOL_TLS*. It prevents the peers from choosing TLSv1.1 as the protocol version. Available only with openssl version 1.0.1+.

New in version 3.4.

Deprecated since version 3.7: The option is deprecated since OpenSSL 1.1.0.

ssl.OP_NO_TLSv1_2
Prevents a TLSv1.2 connection. This option is only applicable in conjunction with *PROTOCOL_TLS*. It prevents the peers from choosing TLSv1.2 as the protocol version. Available only with openssl version 1.0.1+.

New in version 3.4.

Deprecated since version 3.7: The option is deprecated since OpenSSL 1.1.0.

ssl.OP_NO_TLSv1_3
Prevents a TLSv1.3 connection. This option is only applicable in conjunction with *PROTOCOL_TLS*. It prevents the peers from choosing TLSv1.3 as the protocol version. TLS 1.3 is available with OpenSSL 1.1.1 or later. When Python has been compiled against an older version of OpenSSL, the flag defaults to *0*.

New in version 3.7.

Deprecated since version 3.7: The option is deprecated since OpenSSL 1.1.0. It was added to 2.7.15, 3.6.3 and 3.7.0 for backwards compatibility with OpenSSL 1.0.2.

ssl.OP_NO_RENEGOTIATION
Disable all renegotiation in TLSv1.2 and earlier. Do not send HelloRequest messages, and ignore renegotiation requests via ClientHello.

This option is only available with OpenSSL 1.1.0h and later.

New in version 3.7.

ssl.OP_CIPHER_SERVER_PREFERENCE
Use the server's cipher ordering preference, rather than the client's. This option has no effect on client sockets and SSLv2 server sockets.

New in version 3.3.

ssl.OP_SINGLE_DH_USE
Prevents re-use of the same DH key for distinct SSL sessions. This improves forward secrecy but requires more computational resources. This option only applies to server sockets.

New in version 3.3.

ssl.OP_SINGLE_ECDH_USE
Prevents re-use of the same ECDH key for distinct SSL sessions. This improves forward secrecy but requires more computational resources. This option only applies to server sockets.

New in version 3.3.

ssl.OP_ENABLE_MIDDLEBOX_COMPAT
Send dummy Change Cipher Spec (CCS) messages in TLS 1.3 handshake to make a TLS 1.3 connection look more like a TLS 1.2 connection.

This option is only available with OpenSSL 1.1.1 and later.

New in version 3.8.

ssl.OP_NO_COMPRESSION
Disable compression on the SSL channel. This is useful if the application protocol supports its own compression scheme.

This option is only available with OpenSSL 1.0.0 and later.

New in version 3.3.

class ssl.Options
enum.IntFlag collection of OP_* constants.

ssl.OP_NO_TICKET
Prevent client side from requesting a session ticket.

New in version 3.6.

ssl.HAS_ALPN
Whether the OpenSSL library has built-in support for the *Application-Layer Protocol Negotiation* TLS extension as described in **RFC 7301**.

New in version 3.5.

ssl.HAS_NEVER_CHECK_COMMON_NAME
Whether the OpenSSL library has built-in support not checking subject common name and *SSLContext.hostname_checks_common_name* is writeable.

New in version 3.7.

ssl.HAS_ECDH
Whether the OpenSSL library has built-in support for the Elliptic Curve-based Diffie-Hellman key exchange. This should be true unless the feature was explicitly disabled by the distributor.

New in version 3.3.

ssl.HAS_SNI
Whether the OpenSSL library has built-in support for the *Server Name Indication* extension (as defined in **RFC 6066**).

New in version 3.2.

ssl.HAS_NPN
Whether the OpenSSL library has built-in support for the *Next Protocol Negotiation* as described in the Application Layer Protocol Negotiation. When true, you can use the *SSLContext.set_npn_protocols()* method to advertise which protocols you want to support.

New in version 3.3.

ssl.HAS_SSLv2
Whether the OpenSSL library has built-in support for the SSL 2.0 protocol.

New in version 3.7.

ssl.HAS_SSLv3
Whether the OpenSSL library has built-in support for the SSL 3.0 protocol.

New in version 3.7.

ssl.HAS_TLSv1
Whether the OpenSSL library has built-in support for the TLS 1.0 protocol.

New in version 3.7.

ssl.HAS_TLSv1_1
Whether the OpenSSL library has built-in support for the TLS 1.1 protocol.

New in version 3.7.

ssl.HAS_TLSv1_2
Whether the OpenSSL library has built-in support for the TLS 1.2 protocol.

New in version 3.7.

ssl.HAS_TLSv1_3
Whether the OpenSSL library has built-in support for the TLS 1.3 protocol.

New in version 3.7.

ssl.CHANNEL_BINDING_TYPES
List of supported TLS channel binding types. Strings in this list can be used as arguments to *SSLSocket.get_channel_binding()*.

New in version 3.3.

ssl.OPENSSL_VERSION
The version string of the OpenSSL library loaded by the interpreter:

```
>>> ssl.OPENSSL_VERSION
'OpenSSL 1.0.2k  26 Jan 2017'
```

New in version 3.2.

ssl.OPENSSL_VERSION_INFO
A tuple of five integers representing version information about the OpenSSL library:

```
>>> ssl.OPENSSL_VERSION_INFO
(1, 0, 2, 11, 15)
```

New in version 3.2.

ssl.OPENSSL_VERSION_NUMBER
The raw version number of the OpenSSL library, as a single integer:

```
>>> ssl.OPENSSL_VERSION_NUMBER
268443839
>>> hex(ssl.OPENSSL_VERSION_NUMBER)
'0x100020bf'
```

New in version 3.2.

ssl.ALERT_DESCRIPTION_HANDSHAKE_FAILURE
ssl.ALERT_DESCRIPTION_INTERNAL_ERROR
ALERT_DESCRIPTION_*
Alert Descriptions from **RFC 5246** and others. The IANA TLS Alert Registry contains this list and references to the RFCs where their meaning is defined.

Used as the return value of the callback function in *SSLContext.set_servername_callback()*.

New in version 3.4.

class ssl.AlertDescription
enum.IntEnum collection of ALERT_DESCRIPTION_* constants.

New in version 3.6.

Purpose.**SERVER_AUTH**
Option for *create_default_context()* and *SSLContext.load_default_certs()*. This value indicates that the context may be used to authenticate Web servers (therefore, it will be used to create client-side sockets).

New in version 3.4.

Purpose.**CLIENT_AUTH**
Option for *create_default_context()* and *SSLContext.load_default_certs()*. This value indicates that the context may be used to authenticate Web clients (therefore, it will be used to create server-side sockets).

New in version 3.4.

class ssl.SSLErrorNumber
enum.IntEnum collection of SSL_ERROR_* constants.

New in version 3.6.

class ssl.TLSVersion
enum.IntEnum collection of SSL and TLS versions for *SSLContext.maximum_version* and *SSLContext.minimum_version*.

New in version 3.7.

TLSVersion.**MINIMUM_SUPPORTED**

TLSVersion.**MAXIMUM_SUPPORTED**
The minimum or maximum supported SSL or TLS version. These are magic constants. Their values don't reflect the lowest and highest available TLS/SSL versions.

TLSVersion.**SSLv3**

TLSVersion.**TLSv1**

TLSVersion.**TLSv1_1**

TLSVersion.**TLSv1_2**

TLSVersion.**TLSv1_3**
SSL 3.0 to TLS 1.3.

19.2.2 SSL Sockets

class ssl.SSLSocket(*socket.socket*)
SSL sockets provide the following methods of *Socket Objects*:

- *accept()*
- *bind()*
- *close()*
- *connect()*
- *detach()*
- *fileno()*
- *getpeername()*, *getsockname()*
- *getsockopt()*, *setsockopt()*
- *gettimeout()*, *settimeout()*, *setblocking()*
- *listen()*
- *makefile()*

- *recv()*, *recv_into()* (but passing a non-zero `flags` argument is not allowed)
- *send()*, *sendall()* (with the same limitation)
- *sendfile()* (but *os.sendfile* will be used for plain-text sockets only, else *send()* will be used)
- *shutdown()*

However, since the SSL (and TLS) protocol has its own framing atop of TCP, the SSL sockets abstraction can, in certain respects, diverge from the specification of normal, OS-level sockets. See especially the *notes on non-blocking sockets*.

Instances of *SSLSocket* must be created using the *SSLContext.wrap_socket()* method.

Changed in version 3.5: The `sendfile()` method was added.

Changed in version 3.5: The `shutdown()` does not reset the socket timeout each time bytes are received or sent. The socket timeout is now to maximum total duration of the shutdown.

Deprecated since version 3.6: It is deprecated to create a *SSLSocket* instance directly, use *SSLContext.wrap_socket()* to wrap a socket.

Changed in version 3.7: *SSLSocket* instances must to created with *wrap_socket()*. In earlier versions, it was possible to create instances directly. This was never documented or officially supported.

SSL sockets also have the following additional methods and attributes:

`SSLSocket.read`(*len=1024*, *buffer=None*)

Read up to *len* bytes of data from the SSL socket and return the result as a `bytes` instance. If *buffer* is specified, then read into the buffer instead, and return the number of bytes read.

Raise *SSLWantReadError* or *SSLWantWriteError* if the socket is *non-blocking* and the read would block.

As at any time a re-negotiation is possible, a call to *read()* can also cause write operations.

Changed in version 3.5: The socket timeout is no more reset each time bytes are received or sent. The socket timeout is now to maximum total duration to read up to *len* bytes.

Deprecated since version 3.6: Use `recv()` instead of *read()*.

`SSLSocket.write`(*buf*)

Write *buf* to the SSL socket and return the number of bytes written. The *buf* argument must be an object supporting the buffer interface.

Raise *SSLWantReadError* or *SSLWantWriteError* if the socket is *non-blocking* and the write would block.

As at any time a re-negotiation is possible, a call to *write()* can also cause read operations.

Changed in version 3.5: The socket timeout is no more reset each time bytes are received or sent. The socket timeout is now to maximum total duration to write *buf*.

Deprecated since version 3.6: Use `send()` instead of *write()*.

Note: The *read()* and *write()* methods are the low-level methods that read and write unencrypted, application-level data and decrypt/encrypt it to encrypted, wire-level data. These methods require an active SSL connection, i.e. the handshake was completed and *SSLSocket.unwrap()* was not called.

Normally you should use the socket API methods like *recv()* and *send()* instead of these methods.

`SSLSocket.do_handshake`()

Perform the SSL setup handshake.

Changed in version 3.4: The handshake method also performs *match_hostname()* when the *check_hostname* attribute of the socket's *context* is true.

Changed in version 3.5: The socket timeout is no more reset each time bytes are received or sent. The socket timeout is now to maximum total duration of the handshake.

Changed in version 3.7: Hostname or IP address is matched by OpenSSL during handshake. The function *match_hostname()* is no longer used. In case OpenSSL refuses a hostname or IP address, the handshake is aborted early and a TLS alert message is send to the peer.

SSLSocket.**getpeercert**(*binary_form=False*)

If there is no certificate for the peer on the other end of the connection, return `None`. If the SSL handshake hasn't been done yet, raise *ValueError*.

If the `binary_form` parameter is *False*, and a certificate was received from the peer, this method returns a *dict* instance. If the certificate was not validated, the dict is empty. If the certificate was validated, it returns a dict with several keys, amongst them `subject` (the principal for which the certificate was issued) and `issuer` (the principal issuing the certificate). If a certificate contains an instance of the *Subject Alternative Name* extension (see **RFC 3280**), there will also be a `subjectAltName` key in the dictionary.

The `subject` and `issuer` fields are tuples containing the sequence of relative distinguished names (RDNs) given in the certificate's data structure for the respective fields, and each RDN is a sequence of name-value pairs. Here is a real-world example:

```
{'issuer': ((('countryName', 'IL'),),
            ((('organizationName', 'StartCom Ltd.'),),
            ((('organizationalUnitName',
              'Secure Digital Certificate Signing'),),
            ((('commonName',
              'StartCom Class 2 Primary Intermediate Server CA'),)),
 'notAfter': 'Nov 22 08:15:19 2013 GMT',
 'notBefore': 'Nov 21 03:09:52 2011 GMT',
 'serialNumber': '95F0',
 'subject': ((('description', '571208-SLe257oHY9fVQ07Z'),),
             ((('countryName', 'US'),),
             ((('stateOrProvinceName', 'California'),),
             ((('localityName', 'San Francisco'),),
             ((('organizationName', 'Electronic Frontier Foundation, Inc.'),),
             ((('commonName', '*.eff.org'),),
             ((('emailAddress', 'hostmaster@eff.org'),)),
 'subjectAltName': (('DNS', '*.eff.org'), ('DNS', 'eff.org')),
 'version': 3}
```

Note: To validate a certificate for a particular service, you can use the *match_hostname()* function.

If the `binary_form` parameter is *True*, and a certificate was provided, this method returns the DER-encoded form of the entire certificate as a sequence of bytes, or *None* if the peer did not provide a certificate. Whether the peer provides a certificate depends on the SSL socket's role:

- for a client SSL socket, the server will always provide a certificate, regardless of whether validation was required;
- for a server SSL socket, the client will only provide a certificate when requested by the server; therefore *getpeercert()* will return *None* if you used *CERT_NONE* (rather than *CERT_OPTIONAL* or *CERT_REQUIRED*).

Changed in version 3.2: The returned dictionary includes additional items such as `issuer` and `notBefore`.

Changed in version 3.4: *ValueError* is raised when the handshake isn't done. The returned dictionary includes additional X509v3 extension items such as `crlDistributionPoints`, `caIssuers` and `OCSP`

URIs.

SSLSocket.cipher()
Returns a three-value tuple containing the name of the cipher being used, the version of the SSL protocol that defines its use, and the number of secret bits being used. If no connection has been established, returns None.

SSLSocket.shared_ciphers()
Return the list of ciphers shared by the client during the handshake. Each entry of the returned list is a three-value tuple containing the name of the cipher, the version of the SSL protocol that defines its use, and the number of secret bits the cipher uses. *shared_ciphers()* returns None if no connection has been established or the socket is a client socket.

New in version 3.5.

SSLSocket.compression()
Return the compression algorithm being used as a string, or None if the connection isn't compressed.

If the higher-level protocol supports its own compression mechanism, you can use *OP_NO_COMPRESSION* to disable SSL-level compression.

New in version 3.3.

SSLSocket.get_channel_binding(*cb_type="tls-unique"*)
Get channel binding data for current connection, as a bytes object. Returns None if not connected or the handshake has not been completed.

The *cb_type* parameter allow selection of the desired channel binding type. Valid channel binding types are listed in the *CHANNEL_BINDING_TYPES* list. Currently only the 'tls-unique' channel binding, defined by **RFC 5929**, is supported. *ValueError* will be raised if an unsupported channel binding type is requested.

New in version 3.3.

SSLSocket.selected_alpn_protocol()
Return the protocol that was selected during the TLS handshake. If *SSLContext.set_alpn_protocols()* was not called, if the other party does not support ALPN, if this socket does not support any of the client's proposed protocols, or if the handshake has not happened yet, None is returned.

New in version 3.5.

SSLSocket.selected_npn_protocol()
Return the higher-level protocol that was selected during the TLS/SSL handshake. If *SSLContext.set_npn_protocols()* was not called, or if the other party does not support NPN, or if the handshake has not yet happened, this will return None.

New in version 3.3.

SSLSocket.unwrap()
Performs the SSL shutdown handshake, which removes the TLS layer from the underlying socket, and returns the underlying socket object. This can be used to go from encrypted operation over a connection to unencrypted. The returned socket should always be used for further communication with the other side of the connection, rather than the original socket.

SSLSocket.version()
Return the actual SSL protocol version negotiated by the connection as a string, or None is no secure connection is established. As of this writing, possible return values include "SSLv2", "SSLv3", "TLSv1", "TLSv1.1" and "TLSv1.2". Recent OpenSSL versions may define more return values.

New in version 3.5.

SSLSocket.pending()
Returns the number of already decrypted bytes available for read, pending on the connection.

SSLSocket.context
: The *SSLContext* object this SSL socket is tied to. If the SSL socket was created using the deprecated *wrap_socket()* function (rather than *SSLContext.wrap_socket()*), this is a custom context object created for this SSL socket.

  New in version 3.2.

SSLSocket.server_side
: A boolean which is `True` for server-side sockets and `False` for client-side sockets.

  New in version 3.2.

SSLSocket.server_hostname
: Hostname of the server: *str* type, or `None` for server-side socket or if the hostname was not specified in the constructor.

  New in version 3.2.

  Changed in version 3.7: The attribute is now always ASCII text. When `server_hostname` is an internationalized domain name (IDN), this attribute now stores the A-label form (`"xn--pythn-mua.org"`), rather than the U-label form (`"pythön.org"`).

SSLSocket.session
: The *SSLSession* for this SSL connection. The session is available for client and server side sockets after the TLS handshake has been performed. For client sockets the session can be set before *do_handshake()* has been called to reuse a session.

  New in version 3.6.

SSLSocket.session_reused
: New in version 3.6.

19.2.3 SSL Contexts

New in version 3.2.

An SSL context holds various data longer-lived than single SSL connections, such as SSL configuration options, certificate(s) and private key(s). It also manages a cache of SSL sessions for server-side sockets, in order to speed up repeated connections from the same clients.

class ssl.SSLContext(*protocol=PROTOCOL_TLS*)
: Create a new SSL context. You may pass *protocol* which must be one of the `PROTOCOL_*` constants defined in this module. The parameter specifies which version of the SSL protocol to use. Typically, the server chooses a particular protocol version, and the client must adapt to the server's choice. Most of the versions are not interoperable with the other versions. If not specified, the default is *PROTOCOL_TLS*; it provides the most compatibility with other versions.

  Here's a table showing which versions in a client (down the side) can connect to which versions in a server (along the top):

client / **server**	**SSLv2**	**SSLv3**	**TLS**[3]	**TLSv1**	**TLSv1.1**	**TLSv1.2**
SSLv2	yes	no	no[1]	no	no	no
SSLv3	no	yes	no[2]	no	no	no
TLS (SSLv23)[3]	no[1]	no[2]	yes	yes	yes	yes
TLSv1	no	no	yes	yes	no	no
TLSv1.1	no	no	yes	no	yes	no
TLSv1.2	no	no	yes	no	no	yes

See also:

create_default_context() lets the *ssl* module choose security settings for a given purpose.

Changed in version 3.6: The context is created with secure default values. The options *OP_NO_COMPRESSION*, *OP_CIPHER_SERVER_PREFERENCE*, *OP_SINGLE_DH_USE*, *OP_SINGLE_ECDH_USE*, *OP_NO_SSLv2* (except for *PROTOCOL_SSLv2*), and *OP_NO_SSLv3* (except for *PROTOCOL_SSLv3*) are set by default. The initial cipher suite list contains only `HIGH` ciphers, no `NULL` ciphers and no `MD5` ciphers (except for *PROTOCOL_SSLv2*).

SSLContext objects have the following methods and attributes:

SSLContext.cert_store_stats()

Get statistics about quantities of loaded X.509 certificates, count of X.509 certificates flagged as CA certificates and certificate revocation lists as dictionary.

Example for a context with one CA cert and one other cert:

```
>>> context.cert_store_stats()
{'crl': 0, 'x509_ca': 1, 'x509': 2}
```

New in version 3.4.

SSLContext.load_cert_chain(*certfile*, *keyfile=None*, *password=None*)

Load a private key and the corresponding certificate. The *certfile* string must be the path to a single file in PEM format containing the certificate as well as any number of CA certificates needed to establish the certificate's authenticity. The *keyfile* string, if present, must point to a file containing the private key in. Otherwise the private key will be taken from *certfile* as well. See the discussion of *Certificates* for more information on how the certificate is stored in the *certfile*.

The *password* argument may be a function to call to get the password for decrypting the private key. It will only be called if the private key is encrypted and a password is necessary. It will be called with no arguments, and it should return a string, bytes, or bytearray. If the return value is a string it will be encoded as UTF-8 before using it to decrypt the key. Alternatively a string, bytes, or bytearray value may be supplied directly as the *password* argument. It will be ignored if the private key is not encrypted and no password is needed.

If the *password* argument is not specified and a password is required, OpenSSL's built-in password prompting mechanism will be used to interactively prompt the user for a password.

An *SSLError* is raised if the private key doesn't match with the certificate.

Changed in version 3.3: New optional argument *password*.

SSLContext.load_default_certs(*purpose=Purpose.SERVER_AUTH*)

Load a set of default "certification authority" (CA) certificates from default locations. On Windows it loads CA certs from the `CA` and `ROOT` system stores. On other systems it calls *SSLContext.set_default_verify_paths()*. In the future the method may load CA certificates from other locations, too.

The *purpose* flag specifies what kind of CA certificates are loaded. The default settings *Purpose.SERVER_AUTH* loads certificates, that are flagged and trusted for TLS web server authentication (client side sockets). *Purpose.CLIENT_AUTH* loads CA certificates for client certificate verification on the server side.

New in version 3.4.

[3] TLS 1.3 protocol will be available with *PROTOCOL_TLS* in OpenSSL >= 1.1.1. There is no dedicated PROTOCOL constant for just TLS 1.3.

[1] *SSLContext* disables SSLv2 with *OP_NO_SSLv2* by default.

[2] *SSLContext* disables SSLv3 with *OP_NO_SSLv3* by default.

SSLContext.load_verify_locations(*cafile=None*, *capath=None*, *cadata=None*)

Load a set of "certification authority" (CA) certificates used to validate other peers' certificates when *verify_mode* is other than *CERT_NONE*. At least one of *cafile* or *capath* must be specified.

This method can also load certification revocation lists (CRLs) in PEM or DER format. In order to make use of CRLs, *SSLContext.verify_flags* must be configured properly.

The *cafile* string, if present, is the path to a file of concatenated CA certificates in PEM format. See the discussion of *Certificates* for more information about how to arrange the certificates in this file.

The *capath* string, if present, is the path to a directory containing several CA certificates in PEM format, following an OpenSSL specific layout.

The *cadata* object, if present, is either an ASCII string of one or more PEM-encoded certificates or a *bytes-like object* of DER-encoded certificates. Like with *capath* extra lines around PEM-encoded certificates are ignored but at least one certificate must be present.

Changed in version 3.4: New optional argument *cadata*

SSLContext.get_ca_certs(*binary_form=False*)

Get a list of loaded "certification authority" (CA) certificates. If the `binary_form` parameter is *False* each list entry is a dict like the output of *SSLSocket.getpeercert()*. Otherwise the method returns a list of DER-encoded certificates. The returned list does not contain certificates from *capath* unless a certificate was requested and loaded by a SSL connection.

Note: Certificates in a capath directory aren't loaded unless they have been used at least once.

New in version 3.4.

SSLContext.get_ciphers()

Get a list of enabled ciphers. The list is in order of cipher priority. See *SSLContext.set_ciphers()*.

Example:

```
>>> ctx = ssl.SSLContext(ssl.PROTOCOL_SSLv23)
>>> ctx.set_ciphers('ECDHE+AESGCM:!ECDSA')
>>> ctx.get_ciphers()  # OpenSSL 1.0.x
[{'alg_bits': 256,
  'description': 'ECDHE-RSA-AES256-GCM-SHA384 TLSv1.2 Kx=ECDH     Au=RSA  '
                 'Enc=AESGCM(256) Mac=AEAD',
  'id': 50380848,
  'name': 'ECDHE-RSA-AES256-GCM-SHA384',
  'protocol': 'TLSv1/SSLv3',
  'strength_bits': 256},
 {'alg_bits': 128,
  'description': 'ECDHE-RSA-AES128-GCM-SHA256 TLSv1.2 Kx=ECDH     Au=RSA  '
                 'Enc=AESGCM(128) Mac=AEAD',
  'id': 50380847,
  'name': 'ECDHE-RSA-AES128-GCM-SHA256',
  'protocol': 'TLSv1/SSLv3',
  'strength_bits': 128}]
```

On OpenSSL 1.1 and newer the cipher dict contains additional fields:

```
>>> ctx.get_ciphers()  # OpenSSL 1.1+
[{'aead': True,
  'alg_bits': 256,
  'auth': 'auth-rsa',
  'description': 'ECDHE-RSA-AES256-GCM-SHA384 TLSv1.2 Kx=ECDH     Au=RSA  '
```

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```
                'Enc=AESGCM(256) Mac=AEAD',
  'digest': None,
  'id': 50380848,
  'kea': 'kx-ecdhe',
  'name': 'ECDHE-RSA-AES256-GCM-SHA384',
  'protocol': 'TLSv1.2',
  'strength_bits': 256,
  'symmetric': 'aes-256-gcm'},
 {'aead': True,
  'alg_bits': 128,
  'auth': 'auth-rsa',
  'description': 'ECDHE-RSA-AES128-GCM-SHA256 TLSv1.2 Kx=ECDH     Au=RSA  '
                'Enc=AESGCM(128) Mac=AEAD',
  'digest': None,
  'id': 50380847,
  'kea': 'kx-ecdhe',
  'name': 'ECDHE-RSA-AES128-GCM-SHA256',
  'protocol': 'TLSv1.2',
  'strength_bits': 128,
  'symmetric': 'aes-128-gcm'}]
```

Availability: OpenSSL 1.0.2+

New in version 3.6.

SSLContext.set_default_verify_paths()

Load a set of default "certification authority" (CA) certificates from a filesystem path defined when building the OpenSSL library. Unfortunately, there's no easy way to know whether this method succeeds: no error is returned if no certificates are to be found. When the OpenSSL library is provided as part of the operating system, though, it is likely to be configured properly.

SSLContext.set_ciphers(*ciphers*)

Set the available ciphers for sockets created with this context. It should be a string in the OpenSSL cipher list format. If no cipher can be selected (because compile-time options or other configuration forbids use of all the specified ciphers), an *SSLError* will be raised.

Note: when connected, the *SSLSocket.cipher()* method of SSL sockets will give the currently selected cipher.

OpenSSL 1.1.1 has TLS 1.3 cipher suites enabled by default. The suites cannot be disabled with *set_ciphers()*.

SSLContext.set_alpn_protocols(*protocols*)

Specify which protocols the socket should advertise during the SSL/TLS handshake. It should be a list of ASCII strings, like `['http/1.1', 'spdy/2']`, ordered by preference. The selection of a protocol will happen during the handshake, and will play out according to **RFC 7301**. After a successful handshake, the *SSLSocket.selected_alpn_protocol()* method will return the agreed-upon protocol.

This method will raise *NotImplementedError* if *HAS_ALPN* is False.

OpenSSL 1.1.0 to 1.1.0e will abort the handshake and raise *SSLError* when both sides support ALPN but cannot agree on a protocol. 1.1.0f+ behaves like 1.0.2, *SSLSocket.selected_alpn_protocol()* returns None.

New in version 3.5.

SSLContext.set_npn_protocols(*protocols*)

Specify which protocols the socket should advertise during the SSL/TLS handshake. It should be

a list of strings, like `['http/1.1', 'spdy/2']`, ordered by preference. The selection of a protocol will happen during the handshake, and will play out according to the Application Layer Protocol Negotiation. After a successful handshake, the *SSLSocket.selected_npn_protocol()* method will return the agreed-upon protocol.

This method will raise *NotImplementedError* if *HAS_NPN* is False.

New in version 3.3.

`SSLContext.sni_callback`
Register a callback function that will be called after the TLS Client Hello handshake message has been received by the SSL/TLS server when the TLS client specifies a server name indication. The server name indication mechanism is specified in **RFC 6066** section 3 - Server Name Indication.

Only one callback can be set per `SSLContext`. If *sni_callback* is set to `None` then the callback is disabled. Calling this function a subsequent time will disable the previously registered callback.

The callback function will be called with three arguments; the first being the *ssl.SSLSocket*, the second is a string that represents the server name that the client is intending to communicate (or *None* if the TLS Client Hello does not contain a server name) and the third argument is the original *SSLContext*. The server name argument is text. For internationalized domain name, the server name is an IDN A-label (`"xn--pythn-mua.org"`).

A typical use of this callback is to change the *ssl.SSLSocket*'s *SSLSocket.context* attribute to a new object of type *SSLContext* representing a certificate chain that matches the server name.

Due to the early negotiation phase of the TLS connection, only limited methods and attributes are usable like *SSLSocket.selected_alpn_protocol()* and *SSLSocket.context*. *SSLSocket.getpeercert()*, *SSLSocket.getpeercert()*, *SSLSocket.cipher()* and `SSLSocket.compress()` methods require that the TLS connection has progressed beyond the TLS Client Hello and therefore will not contain return meaningful values nor can they be called safely.

The *sni_callback* function must return `None` to allow the TLS negotiation to continue. If a TLS failure is required, a constant *ALERT_DESCRIPTION_** can be returned. Other return values will result in a TLS fatal error with *ALERT_DESCRIPTION_INTERNAL_ERROR*.

If an exception is raised from the *sni_callback* function the TLS connection will terminate with a fatal TLS alert message *ALERT_DESCRIPTION_HANDSHAKE_FAILURE*.

This method will raise *NotImplementedError* if the OpenSSL library had OPENSSL_NO_TLSEXT defined when it was built.

New in version 3.7.

`SSLContext.set_servername_callback`(*server_name_callback*)
This is a legacy API retained for backwards compatibility. When possible, you should use *sni_callback* instead. The given *server_name_callback* is similar to *sni_callback*, except that when the server hostname is an IDN-encoded internationalized domain name, the *server_name_callback* receives a decoded U-label (`"pythön.org"`).

If there is an decoding error on the server name, the TLS connection will terminate with an *ALERT_DESCRIPTION_INTERNAL_ERROR* fatal TLS alert message to the client.

New in version 3.4.

`SSLContext.load_dh_params`(*dhfile*)
Load the key generation parameters for Diffie-Hellman (DH) key exchange. Using DH key exchange improves forward secrecy at the expense of computational resources (both on the server and on the client). The *dhfile* parameter should be the path to a file containing DH parameters in PEM format.

This setting doesn't apply to client sockets. You can also use the *OP_SINGLE_DH_USE* option to further improve security.

New in version 3.3.

SSLContext.set_ecdh_curve(*curve_name*)
Set the curve name for Elliptic Curve-based Diffie-Hellman (ECDH) key exchange. ECDH is significantly faster than regular DH while arguably as secure. The *curve_name* parameter should be a string describing a well-known elliptic curve, for example `prime256v1` for a widely supported curve.

This setting doesn't apply to client sockets. You can also use the *OP_SINGLE_ECDH_USE* option to further improve security.

This method is not available if *HAS_ECDH* is `False`.

New in version 3.3.

See also:

SSL/TLS & Perfect Forward Secrecy Vincent Bernat.

SSLContext.wrap_socket(*sock*, *server_side=False*, *do_handshake_on_connect=True*, *suppress_ragged_eofs=True*, *server_hostname=None*, *session=None*)
Wrap an existing Python socket *sock* and return an instance of *SSLContext.sslsocket_class* (default *SSLSocket*). The returned SSL socket is tied to the context, its settings and certificates. *sock* must be a *SOCK_STREAM* socket; other socket types are unsupported.

The parameter `server_side` is a boolean which identifies whether server-side or client-side behavior is desired from this socket.

For client-side sockets, the context construction is lazy; if the underlying socket isn't connected yet, the context construction will be performed after `connect()` is called on the socket. For server-side sockets, if the socket has no remote peer, it is assumed to be a listening socket, and the server-side SSL wrapping is automatically performed on client connections accepted via the `accept()` method. The method may raise *SSLError*.

On client connections, the optional parameter *server_hostname* specifies the hostname of the service which we are connecting to. This allows a single server to host multiple SSL-based services with distinct certificates, quite similarly to HTTP virtual hosts. Specifying *server_hostname* will raise a *ValueError* if *server_side* is true.

The parameter `do_handshake_on_connect` specifies whether to do the SSL handshake automatically after doing a `socket.connect()`, or whether the application program will call it explicitly, by invoking the *SSLSocket.do_handshake()* method. Calling *SSLSocket.do_handshake()* explicitly gives the program control over the blocking behavior of the socket I/O involved in the handshake.

The parameter `suppress_ragged_eofs` specifies how the `SSLSocket.recv()` method should signal unexpected EOF from the other end of the connection. If specified as *True* (the default), it returns a normal EOF (an empty bytes object) in response to unexpected EOF errors raised from the underlying socket; if *False*, it will raise the exceptions back to the caller.

session, see *session*.

Changed in version 3.5: Always allow a server_hostname to be passed, even if OpenSSL does not have SNI.

Changed in version 3.6: *session* argument was added.

Changed in version 3.7: The method returns on instance of *SSLContext.sslsocket_class* instead of hard-coded *SSLSocket*.

SSLContext.sslsocket_class
The return type of `SSLContext.wrap_sockets()`, defaults to *SSLSocket*. The attribute can be overridden on instance of class in order to return a custom subclass of *SSLSocket*.

New in version 3.7.

SSLContext.**wrap_bio**(*incoming*, *outgoing*, *server_side=False*, *server_hostname=None*, *session=None*)

Wrap the BIO objects *incoming* and *outgoing* and return an instance of attr:*SSLContext.sslobject_class* (default *SSLObject*). The SSL routines will read input data from the incoming BIO and write data to the outgoing BIO.

The *server_side*, *server_hostname* and *session* parameters have the same meaning as in *SSLContext.wrap_socket()*.

Changed in version 3.6: *session* argument was added.

Changed in version 3.7: The method returns on instance of *SSLContext.sslobject_class* instead of hard-coded *SSLObject*.

SSLContext.**sslobject_class**

The return type of *SSLContext.wrap_bio()*, defaults to *SSLObject*. The attribute can be overridden on instance of class in order to return a custom subclass of *SSLObject*.

New in version 3.7.

SSLContext.**session_stats**()

Get statistics about the SSL sessions created or managed by this context. A dictionary is returned which maps the names of each piece of information to their numeric values. For example, here is the total number of hits and misses in the session cache since the context was created:

```
>>> stats = context.session_stats()
>>> stats['hits'], stats['misses']
(0, 0)
```

SSLContext.**check_hostname**

Whether to match the peer cert's hostname with *match_hostname()* in *SSLSocket.do_handshake()*. The context's *verify_mode* must be set to *CERT_OPTIONAL* or *CERT_REQUIRED*, and you must pass *server_hostname* to *wrap_socket()* in order to match the hostname. Enabling hostname checking automatically sets *verify_mode* from *CERT_NONE* to *CERT_REQUIRED*. It cannot be set back to *CERT_NONE* as long as hostname checking is enabled.

Example:

```
import socket, ssl

context = ssl.SSLContext()
context.verify_mode = ssl.CERT_REQUIRED
context.check_hostname = True
context.load_default_certs()

s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
ssl_sock = context.wrap_socket(s, server_hostname='www.verisign.com')
ssl_sock.connect(('www.verisign.com', 443))
```

New in version 3.4.

Changed in version 3.7: *verify_mode* is now automatically changed to *CERT_REQUIRED* when hostname checking is enabled and *verify_mode* is *CERT_NONE*. Previously the same operation would have failed with a *ValueError*.

Note: This features requires OpenSSL 0.9.8f or newer.

SSLContext.**maximum_version**

A *TLSVersion* enum member representing the highest supported TLS version. The value defaults to

TLSVersion.MAXIMUM_SUPPORTED. The attribute is read-only for protocols other than *PROTOCOL_TLS*, *PROTOCOL_TLS_CLIENT*, and *PROTOCOL_TLS_SERVER*.

The attributes *maximum_version*, *minimum_version* and *SSLContext.options* all affect the supported SSL and TLS versions of the context. The implementation does not prevent invalid combination. For example a context with *OP_NO_TLSv1_2* in *options* and *maximum_version* set to *TLSVersion.TLSv1_2* will not be able to establish a TLS 1.2 connection.

Note: This attribute is not available unless the ssl module is compiled with OpenSSL 1.1.0g or newer.

SSLContext.minimum_version

Like *SSLContext.maximum_version* except it is the lowest supported version or *TLSVersion.MINIMUM_SUPPORTED*.

Note: This attribute is not available unless the ssl module is compiled with OpenSSL 1.1.0g or newer.

SSLContext.options

An integer representing the set of SSL options enabled on this context. The default value is *OP_ALL*, but you can specify other options such as *OP_NO_SSLv2* by ORing them together.

Note: With versions of OpenSSL older than 0.9.8m, it is only possible to set options, not to clear them. Attempting to clear an option (by resetting the corresponding bits) will raise a `ValueError`.

Changed in version 3.6: *SSLContext.options* returns *Options* flags:

```
>>> ssl.create_default_context().options
<Options.OP_ALL|OP_NO_SSLv3|OP_NO_SSLv2|OP_NO_COMPRESSION: 2197947391>
```

SSLContext.protocol

The protocol version chosen when constructing the context. This attribute is read-only.

SSLContext.hostname_checks_common_name

Whether *check_hostname* falls back to verify the cert's subject common name in the absence of a subject alternative name extension (default: true).

New in version 3.7.

Note: Only writeable with OpenSSL 1.1.0 or higher.

SSLContext.verify_flags

The flags for certificate verification operations. You can set flags like *VERIFY_CRL_CHECK_LEAF* by ORing them together. By default OpenSSL does neither require nor verify certificate revocation lists (CRLs). Available only with openssl version 0.9.8+.

New in version 3.4.

Changed in version 3.6: *SSLContext.verify_flags* returns *VerifyFlags* flags:

```
>>> ssl.create_default_context().verify_flags
<VerifyFlags.VERIFY_X509_TRUSTED_FIRST: 32768>
```

SSLContext.verify_mode

Whether to try to verify other peers' certificates and how to behave if verification fails. This attribute must be one of *CERT_NONE*, *CERT_OPTIONAL* or *CERT_REQUIRED*.

Changed in version 3.6: *SSLContext.verify_mode* returns *VerifyMode* enum:

```
>>> ssl.create_default_context().verify_mode
<VerifyMode.CERT_REQUIRED: 2>
```

19.2.4 Certificates

Certificates in general are part of a public-key / private-key system. In this system, each *principal*, (which may be a machine, or a person, or an organization) is assigned a unique two-part encryption key. One part of the key is public, and is called the *public key*; the other part is kept secret, and is called the *private key*. The two parts are related, in that if you encrypt a message with one of the parts, you can decrypt it with the other part, and **only** with the other part.

A certificate contains information about two principals. It contains the name of a *subject*, and the subject's public key. It also contains a statement by a second principal, the *issuer*, that the subject is who they claim to be, and that this is indeed the subject's public key. The issuer's statement is signed with the issuer's private key, which only the issuer knows. However, anyone can verify the issuer's statement by finding the issuer's public key, decrypting the statement with it, and comparing it to the other information in the certificate. The certificate also contains information about the time period over which it is valid. This is expressed as two fields, called "notBefore" and "notAfter".

In the Python use of certificates, a client or server can use a certificate to prove who they are. The other side of a network connection can also be required to produce a certificate, and that certificate can be validated to the satisfaction of the client or server that requires such validation. The connection attempt can be set to raise an exception if the validation fails. Validation is done automatically, by the underlying OpenSSL framework; the application need not concern itself with its mechanics. But the application does usually need to provide sets of certificates to allow this process to take place.

Python uses files to contain certificates. They should be formatted as "PEM" (see **RFC 1422**), which is a base-64 encoded form wrapped with a header line and a footer line:

```
-----BEGIN CERTIFICATE-----
... (certificate in base64 PEM encoding) ...
-----END CERTIFICATE-----
```

Certificate chains

The Python files which contain certificates can contain a sequence of certificates, sometimes called a *certificate chain*. This chain should start with the specific certificate for the principal who "is" the client or server, and then the certificate for the issuer of that certificate, and then the certificate for the issuer of *that* certificate, and so on up the chain till you get to a certificate which is *self-signed*, that is, a certificate which has the same subject and issuer, sometimes called a *root certificate*. The certificates should just be concatenated together in the certificate file. For example, suppose we had a three certificate chain, from our server certificate to the certificate of the certification authority that signed our server certificate, to the root certificate of the agency which issued the certification authority's certificate:

```
-----BEGIN CERTIFICATE-----
... (certificate for your server)...
-----END CERTIFICATE-----
-----BEGIN CERTIFICATE-----
... (the certificate for the CA)...
-----END CERTIFICATE-----
-----BEGIN CERTIFICATE-----
... (the root certificate for the CA's issuer)...
-----END CERTIFICATE-----
```

CA certificates

If you are going to require validation of the other side of the connection's certificate, you need to provide a "CA certs" file, filled with the certificate chains for each issuer you are willing to trust. Again, this file just contains these chains concatenated together. For validation, Python will use the first chain it finds in the file which matches. The platform's certificates file can be used by calling *SSLContext.load_default_certs()*, this is done automatically with *create_default_context()*.

Combined key and certificate

Often the private key is stored in the same file as the certificate; in this case, only the `certfile` parameter to *SSLContext.load_cert_chain()* and *wrap_socket()* needs to be passed. If the private key is stored with the certificate, it should come before the first certificate in the certificate chain:

```
-----BEGIN RSA PRIVATE KEY-----
... (private key in base64 encoding) ...
-----END RSA PRIVATE KEY-----
-----BEGIN CERTIFICATE-----
... (certificate in base64 PEM encoding) ...
-----END CERTIFICATE-----
```

Self-signed certificates

If you are going to create a server that provides SSL-encrypted connection services, you will need to acquire a certificate for that service. There are many ways of acquiring appropriate certificates, such as buying one from a certification authority. Another common practice is to generate a self-signed certificate. The simplest way to do this is with the OpenSSL package, using something like the following:

```
% openssl req -new -x509 -days 365 -nodes -out cert.pem -keyout cert.pem
Generating a 1024 bit RSA private key
.......++++++
..............................++++++
writing new private key to 'cert.pem'
-----
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Country Name (2 letter code) [AU]:US
State or Province Name (full name) [Some-State]:MyState
Locality Name (eg, city) []:Some City
Organization Name (eg, company) [Internet Widgits Pty Ltd]:My Organization, Inc.
Organizational Unit Name (eg, section) []:My Group
Common Name (eg, YOUR name) []:myserver.mygroup.myorganization.com
Email Address []:ops@myserver.mygroup.myorganization.com
%
```

The disadvantage of a self-signed certificate is that it is its own root certificate, and no one else will have it in their cache of known (and trusted) root certificates.

19.2.5 Examples

Testing for SSL support

To test for the presence of SSL support in a Python installation, user code should use the following idiom:

```
try:
    import ssl
except ImportError:
    pass
else:
    ...  # do something that requires SSL support
```

Client-side operation

This example creates a SSL context with the recommended security settings for client sockets, including automatic certificate verification:

```
>>> context = ssl.create_default_context()
```

If you prefer to tune security settings yourself, you might create a context from scratch (but beware that you might not get the settings right):

```
>>> context = ssl.SSLContext()
>>> context.verify_mode = ssl.CERT_REQUIRED
>>> context.check_hostname = True
>>> context.load_verify_locations("/etc/ssl/certs/ca-bundle.crt")
```

(this snippet assumes your operating system places a bundle of all CA certificates in `/etc/ssl/certs/ca-bundle.crt`; if not, you'll get an error and have to adjust the location)

When you use the context to connect to a server, *CERT_REQUIRED* validates the server certificate: it ensures that the server certificate was signed with one of the CA certificates, and checks the signature for correctness:

```
>>> conn = context.wrap_socket(socket.socket(socket.AF_INET),
...                            server_hostname="www.python.org")
>>> conn.connect(("www.python.org", 443))
```

You may then fetch the certificate:

```
>>> cert = conn.getpeercert()
```

Visual inspection shows that the certificate does identify the desired service (that is, the HTTPS host `www.python.org`):

```
>>> pprint.pprint(cert)
{'OCSP': ('http://ocsp.digicert.com',),
 'caIssuers': ('http://cacerts.digicert.com/DigiCertSHA2ExtendedValidationServerCA.crt',),
 'crlDistributionPoints': ('http://crl3.digicert.com/sha2-ev-server-g1.crl',
                           'http://crl4.digicert.com/sha2-ev-server-g1.crl'),
 'issuer': ((('countryName', 'US'),),
            (('organizationName', 'DigiCert Inc'),),
            (('organizationalUnitName', 'www.digicert.com'),),
            (('commonName', 'DigiCert SHA2 Extended Validation Server CA'),)),
 'notAfter': 'Sep  9 12:00:00 2016 GMT',
 'notBefore': 'Sep  5 00:00:00 2014 GMT',
```

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```
 'serialNumber': '01BB6F00122B177F36CAB49CEA8B6B26',
 'subject': ((('businessCategory', 'Private Organization'),),
             (('1.3.6.1.4.1.311.60.2.1.3', 'US'),),
             (('1.3.6.1.4.1.311.60.2.1.2', 'Delaware'),),
             (('serialNumber', '3359300'),),
             (('streetAddress', '16 Allen Rd'),),
             (('postalCode', '03894-4801'),),
             (('countryName', 'US'),),
             (('stateOrProvinceName', 'NH'),),
             (('localityName', 'Wolfeboro,'),),
             (('organizationName', 'Python Software Foundation'),),
             (('commonName', 'www.python.org'),)),
 'subjectAltName': (('DNS', 'www.python.org'),
                    ('DNS', 'python.org'),
                    ('DNS', 'pypi.org'),
                    ('DNS', 'docs.python.org'),
                    ('DNS', 'testpypi.org'),
                    ('DNS', 'bugs.python.org'),
                    ('DNS', 'wiki.python.org'),
                    ('DNS', 'hg.python.org'),
                    ('DNS', 'mail.python.org'),
                    ('DNS', 'packaging.python.org'),
                    ('DNS', 'pythonhosted.org'),
                    ('DNS', 'www.pythonhosted.org'),
                    ('DNS', 'test.pythonhosted.org'),
                    ('DNS', 'us.pycon.org'),
                    ('DNS', 'id.python.org')),
 'version': 3}
```

Now the SSL channel is established and the certificate verified, you can proceed to talk with the server:

```
>>> conn.sendall(b"HEAD / HTTP/1.0\r\nHost: linuxfr.org\r\n\r\n")
>>> pprint.pprint(conn.recv(1024).split(b"\r\n"))
[b'HTTP/1.1 200 OK',
 b'Date: Sat, 18 Oct 2014 18:27:20 GMT',
 b'Server: nginx',
 b'Content-Type: text/html; charset=utf-8',
 b'X-Frame-Options: SAMEORIGIN',
 b'Content-Length: 45679',
 b'Accept-Ranges: bytes',
 b'Via: 1.1 varnish',
 b'Age: 2188',
 b'X-Served-By: cache-lcy1134-LCY',
 b'X-Cache: HIT',
 b'X-Cache-Hits: 11',
 b'Vary: Cookie',
 b'Strict-Transport-Security: max-age=63072000; includeSubDomains',
 b'Connection: close',
 b'',
 b'']
```

See the discussion of *Security considerations* below.

Server-side operation

For server operation, typically you'll need to have a server certificate, and private key, each in a file. You'll first create a context holding the key and the certificate, so that clients can check your authenticity. Then you'll open a socket, bind it to a port, call `listen()` on it, and start waiting for clients to connect:

```
import socket, ssl

context = ssl.create_default_context(ssl.Purpose.CLIENT_AUTH)
context.load_cert_chain(certfile="mycertfile", keyfile="mykeyfile")

bindsocket = socket.socket()
bindsocket.bind(('myaddr.mydomain.com', 10023))
bindsocket.listen(5)
```

When a client connects, you'll call `accept()` on the socket to get the new socket from the other end, and use the context's *SSLContext.wrap_socket()* method to create a server-side SSL socket for the connection:

```
while True:
    newsocket, fromaddr = bindsocket.accept()
    connstream = context.wrap_socket(newsocket, server_side=True)
    try:
        deal_with_client(connstream)
    finally:
        connstream.shutdown(socket.SHUT_RDWR)
        connstream.close()
```

Then you'll read data from the `connstream` and do something with it till you are finished with the client (or the client is finished with you):

```
def deal_with_client(connstream):
    data = connstream.recv(1024)
    # empty data means the client is finished with us
    while data:
        if not do_something(connstream, data):
            # we'll assume do_something returns False
            # when we're finished with client
            break
        data = connstream.recv(1024)
    # finished with client
```

And go back to listening for new client connections (of course, a real server would probably handle each client connection in a separate thread, or put the sockets in *non-blocking mode* and use an event loop).

19.2.6 Notes on non-blocking sockets

SSL sockets behave slightly different than regular sockets in non-blocking mode. When working with non-blocking sockets, there are thus several things you need to be aware of:

- Most *SSLSocket* methods will raise either *SSLWantWriteError* or *SSLWantReadError* instead of *BlockingIOError* if an I/O operation would block. *SSLWantReadError* will be raised if a read operation on the underlying socket is necessary, and *SSLWantWriteError* for a write operation on the underlying socket. Note that attempts to *write* to an SSL socket may require *reading* from the underlying socket first, and attempts to *read* from the SSL socket may require a prior *write* to the underlying socket.

  Changed in version 3.5: In earlier Python versions, the `SSLSocket.send()` method returned zero instead of raising *SSLWantWriteError* or *SSLWantReadError*.

- Calling *select()* tells you that the OS-level socket can be read from (or written to), but it does not imply that there is sufficient data at the upper SSL layer. For example, only part of an SSL frame might have arrived. Therefore, you must be ready to handle `SSLSocket.recv()` and `SSLSocket.send()` failures, and retry after another call to *select()*.
- Conversely, since the SSL layer has its own framing, a SSL socket may still have data available for reading without *select()* being aware of it. Therefore, you should first call `SSLSocket.recv()` to drain any potentially available data, and then only block on a *select()* call if still necessary.

  (of course, similar provisions apply when using other primitives such as *poll()*, or those in the *selectors* module)
- The SSL handshake itself will be non-blocking: the *SSLSocket.do_handshake()* method has to be retried until it returns successfully. Here is a synopsis using *select()* to wait for the socket's readiness:

```
while True:
    try:
        sock.do_handshake()
        break
    except ssl.SSLWantReadError:
        select.select([sock], [], [])
    except ssl.SSLWantWriteError:
        select.select([], [sock], [])
```

See also:

The *asyncio* module supports *non-blocking SSL sockets* and provides a higher level API. It polls for events using the *selectors* module and handles *SSLWantWriteError*, *SSLWantReadError* and *BlockingIOError* exceptions. It runs the SSL handshake asynchronously as well.

19.2.7 Memory BIO Support

New in version 3.5.

Ever since the SSL module was introduced in Python 2.6, the *SSLSocket* class has provided two related but distinct areas of functionality:

- SSL protocol handling
- Network IO

The network IO API is identical to that provided by *socket.socket*, from which *SSLSocket* also inherits. This allows an SSL socket to be used as a drop-in replacement for a regular socket, making it very easy to add SSL support to an existing application.

Combining SSL protocol handling and network IO usually works well, but there are some cases where it doesn't. An example is async IO frameworks that want to use a different IO multiplexing model than the "select/poll on a file descriptor" (readiness based) model that is assumed by *socket.socket* and by the internal OpenSSL socket IO routines. This is mostly relevant for platforms like Windows where this model is not efficient. For this purpose, a reduced scope variant of *SSLSocket* called *SSLObject* is provided.

class ssl.SSLObject

A reduced-scope variant of *SSLSocket* representing an SSL protocol instance that does not contain any network IO methods. This class is typically used by framework authors that want to implement asynchronous IO for SSL through memory buffers.

This class implements an interface on top of a low-level SSL object as implemented by OpenSSL. This object captures the state of an SSL connection but does not provide any network IO itself. IO needs to be performed through separate "BIO" objects which are OpenSSL's IO abstraction layer.

This class has no public constructor. An *SSLObject* instance must be created using the *wrap_bio()* method. This method will create the *SSLObject* instance and bind it to a pair of BIOs. The *incoming* BIO is used to pass data from Python to the SSL protocol instance, while the *outgoing* BIO is used to pass data the other way around.

The following methods are available:

- *context*
- *server_side*
- *server_hostname*
- *session*
- *session_reused*
- *read()*
- *write()*
- *getpeercert()*
- *selected_npn_protocol()*
- *cipher()*
- *shared_ciphers()*
- *compression()*
- *pending()*
- *do_handshake()*
- *unwrap()*
- *get_channel_binding()*

When compared to *SSLSocket*, this object lacks the following features:

- Any form of network IO; `recv()` and `send()` read and write only to the underlying *MemoryBIO* buffers.
- There is no *do_handshake_on_connect* machinery. You must always manually call *do_handshake()* to start the handshake.
- There is no handling of *suppress_ragged_eofs*. All end-of-file conditions that are in violation of the protocol are reported via the *SSLEOFError* exception.
- The method *unwrap()* call does not return anything, unlike for an SSL socket where it returns the underlying socket.
- The *server_name_callback* callback passed to *SSLContext.set_servername_callback()* will get an *SSLObject* instance instead of a *SSLSocket* instance as its first parameter.

Some notes related to the use of *SSLObject*:

- All IO on an *SSLObject* is *non-blocking*. This means that for example *read()* will raise an *SSLWantReadError* if it needs more data than the incoming BIO has available.
- There is no module-level `wrap_bio()` call like there is for *wrap_socket()*. An *SSLObject* is always created via an *SSLContext*.

Changed in version 3.7: *SSLObject* instances must to created with *wrap_bio()*. In earlier versions, it was possible to create instances directly. This was never documented or officially supported.

An SSLObject communicates with the outside world using memory buffers. The class *MemoryBIO* provides a memory buffer that can be used for this purpose. It wraps an OpenSSL memory BIO (Basic IO) object:

class ssl.MemoryBIO
A memory buffer that can be used to pass data between Python and an SSL protocol instance.

pending
Return the number of bytes currently in the memory buffer.

eof
A boolean indicating whether the memory BIO is current at the end-of-file position.

read(*n=-1*)
Read up to *n* bytes from the memory buffer. If *n* is not specified or negative, all bytes are returned.

write(*buf*)
Write the bytes from *buf* to the memory BIO. The *buf* argument must be an object supporting the buffer protocol.

The return value is the number of bytes written, which is always equal to the length of *buf*.

write_eof()
Write an EOF marker to the memory BIO. After this method has been called, it is illegal to call *write()*. The attribute *eof* will become true after all data currently in the buffer has been read.

19.2.8 SSL session

New in version 3.6.

class ssl.SSLSession
Session object used by *session*.

id

time

timeout

ticket_lifetime_hint

has_ticket

19.2.9 Security considerations

Best defaults

For **client use**, if you don't have any special requirements for your security policy, it is highly recommended that you use the *create_default_context()* function to create your SSL context. It will load the system's trusted CA certificates, enable certificate validation and hostname checking, and try to choose reasonably secure protocol and cipher settings.

For example, here is how you would use the *smtplib.SMTP* class to create a trusted, secure connection to a SMTP server:

```
>>> import ssl, smtplib
>>> smtp = smtplib.SMTP("mail.python.org", port=587)
>>> context = ssl.create_default_context()
>>> smtp.starttls(context=context)
(220, b'2.0.0 Ready to start TLS')
```

If a client certificate is needed for the connection, it can be added with *SSLContext.load_cert_chain()*.

By contrast, if you create the SSL context by calling the *SSLContext* constructor yourself, it will not have certificate validation nor hostname checking enabled by default. If you do so, please read the paragraphs below to achieve a good security level.

Manual settings

Verifying certificates

When calling the *SSLContext* constructor directly, *CERT_NONE* is the default. Since it does not authenticate the other peer, it can be insecure, especially in client mode where most of time you would like to ensure the authenticity of the server you're talking to. Therefore, when in client mode, it is highly recommended to use *CERT_REQUIRED*. However, it is in itself not sufficient; you also have to check that the server certificate, which can be obtained by calling *SSLSocket.getpeercert()*, matches the desired service. For many protocols and applications, the service can be identified by the hostname; in this case, the *match_hostname()* function can be used. This common check is automatically performed when *SSLContext.check_hostname* is enabled.

Changed in version 3.7: Hostname matchings is now performed by OpenSSL. Python no longer uses *match_hostname()*.

In server mode, if you want to authenticate your clients using the SSL layer (rather than using a higher-level authentication mechanism), you'll also have to specify *CERT_REQUIRED* and similarly check the client certificate.

Protocol versions

SSL versions 2 and 3 are considered insecure and are therefore dangerous to use. If you want maximum compatibility between clients and servers, it is recommended to use *PROTOCOL_TLS_CLIENT* or *PROTOCOL_TLS_SERVER* as the protocol version. SSLv2 and SSLv3 are disabled by default.

```
>>> client_context = ssl.SSLContext(ssl.PROTOCOL_TLS_CLIENT)
>>> client_context.options |= ssl.OP_NO_TLSv1
>>> client_context.options |= ssl.OP_NO_TLSv1_1
```

The SSL context created above will only allow TLSv1.2 and later (if supported by your system) connections to a server. *PROTOCOL_TLS_CLIENT* implies certificate validation and hostname checks by default. You have to load certificates into the context.

Cipher selection

If you have advanced security requirements, fine-tuning of the ciphers enabled when negotiating a SSL session is possible through the *SSLContext.set_ciphers()* method. Starting from Python 3.2.3, the ssl module disables certain weak ciphers by default, but you may want to further restrict the cipher choice. Be sure to read OpenSSL's documentation about the cipher list format. If you want to check which ciphers are enabled by a given cipher list, use *SSLContext.get_ciphers()* or the `openssl ciphers` command on your system.

Multi-processing

If using this module as part of a multi-processed application (using, for example the *multiprocessing* or *concurrent.futures* modules), be aware that OpenSSL's internal random number generator does not properly handle forked processes. Applications must change the PRNG state of the parent process if they use any SSL feature with *os.fork()*. Any successful call of *RAND_add()*, *RAND_bytes()* or *RAND_pseudo_bytes()* is sufficient.

19.2.10 TLS 1.3

New in version 3.7.

Python has provisional and experimental support for TLS 1.3 with OpenSSL 1.1.1. The new protocol behaves slightly differently than previous version of TLS/SSL. Some new TLS 1.3 features are not yet available.

- TLS 1.3 uses a disjunct set of cipher suites. All AES-GCM and ChaCha20 cipher suites are enabled by default. The method *SSLContext.set_ciphers()* cannot enable or disable any TLS 1.3 ciphers yet, but `SSLContext.get_cipers()` returns them.
- Session tickets are no longer sent as part of the initial handshake and are handled differently. *SSLSocket.session* and *SSLSession* are not compatible with TLS 1.3.
- Client-side certificates are also no longer verified during the initial handshake. A server can request a certificate at any time. Clients process certificate requests while they send or receive application data from the server.
- TLS 1.3 features like early data, deferred TLS client cert request, signature algorithm configuration, and rekeying are not supported yet.

19.2.11 LibreSSL support

LibreSSL is a fork of OpenSSL 1.0.1. The ssl module has limited support for LibreSSL. Some features are not available when the ssl module is compiled with LibreSSL.

- LibreSSL >= 2.6.1 no longer supports NPN. The methods *SSLContext.set_npn_protocols()* and *SSLSocket.selected_npn_protocol()* are not available.
- *SSLContext.set_default_verify_paths()* ignores the env vars `SSL_CERT_FILE` and `SSL_CERT_PATH` although *get_default_verify_paths()* still reports them.

See also:

Class *socket.socket* Documentation of underlying *socket* class

SSL/TLS Strong Encryption: An Introduction Intro from the Apache HTTP Server documentation

RFC 1422: Privacy Enhancement for Internet Electronic Mail: Part II: Certificate-Based Key Management Steve Kent

RFC 4086: Randomness Requirements for Security Donald E., Jeffrey I. Schiller

RFC 5280: Internet X.509 Public Key Infrastructure Certificate and Certificate Revocation List (CRL) Pro D. Cooper

RFC 5246: The Transport Layer Security (TLS) Protocol Version 1.2 T. Dierks et. al.

RFC 6066: Transport Layer Security (TLS) Extensions D. Eastlake

IANA TLS: Transport Layer Security (TLS) Parameters IANA

RFC 7525: Recommendations for Secure Use of Transport Layer Security (TLS) and Datagram Transport L IETF

Mozilla's Server Side TLS recommendations Mozilla

19.3 `select` — Waiting for I/O completion

This module provides access to the `select()` and `poll()` functions available in most operating systems, `devpoll()` available on Solaris and derivatives, `epoll()` available on Linux 2.5+ and `kqueue()` available on

most BSD. Note that on Windows, it only works for sockets; on other operating systems, it also works for other file types (in particular, on Unix, it works on pipes). It cannot be used on regular files to determine whether a file has grown since it was last read.

Note: The *selectors* module allows high-level and efficient I/O multiplexing, built upon the *select* module primitives. Users are encouraged to use the *selectors* module instead, unless they want precise control over the OS-level primitives used.

The module defines the following:

exception select.error
A deprecated alias of *OSError*.

Changed in version 3.3: Following **PEP 3151**, this class was made an alias of *OSError*.

select.devpoll()
(Only supported on Solaris and derivatives.) Returns a `/dev/poll` polling object; see section */dev/poll Polling Objects* below for the methods supported by devpoll objects.

`devpoll()` objects are linked to the number of file descriptors allowed at the time of instantiation. If your program reduces this value, `devpoll()` will fail. If your program increases this value, `devpoll()` may return an incomplete list of active file descriptors.

The new file descriptor is *non-inheritable*.

New in version 3.3.

Changed in version 3.4: The new file descriptor is now non-inheritable.

select.epoll(*sizehint=-1*, *flags=0*)
(Only supported on Linux 2.5.44 and newer.) Return an edge polling object, which can be used as Edge or Level Triggered interface for I/O events.

sizehint informs epoll about the expected number of events to be registered. It must be positive, or *-1* to use the default. It is only used on older systems where `epoll_create1()` is not available; otherwise it has no effect (though its value is still checked).

flags is deprecated and completely ignored. However, when supplied, its value must be `0` or `select.EPOLL_CLOEXEC`, otherwise `OSError` is raised.

See the *Edge and Level Trigger Polling (epoll) Objects* section below for the methods supported by epolling objects.

`epoll` objects support the context management protocol: when used in a `with` statement, the new file descriptor is automatically closed at the end of the block.

The new file descriptor is *non-inheritable*.

Changed in version 3.3: Added the *flags* parameter.

Changed in version 3.4: Support for the `with` statement was added. The new file descriptor is now non-inheritable.

Deprecated since version 3.4: The *flags* parameter. `select.EPOLL_CLOEXEC` is used by default now. Use *os.set_inheritable()* to make the file descriptor inheritable.

select.poll()
(Not supported by all operating systems.) Returns a polling object, which supports registering and unregistering file descriptors, and then polling them for I/O events; see section *Polling Objects* below for the methods supported by polling objects.

select.kqueue()
(Only supported on BSD.) Returns a kernel queue object; see section *Kqueue Objects* below for the methods supported by kqueue objects.

The new file descriptor is *non-inheritable*.

Changed in version 3.4: The new file descriptor is now non-inheritable.

`select.kevent`(*ident*, *filter=KQ_FILTER_READ*, *flags=KQ_EV_ADD*, *fflags=0*, *data=0*, *udata=0*)
(Only supported on BSD.) Returns a kernel event object; see section *Kevent Objects* below for the methods supported by kevent objects.

`select.select`(*rlist*, *wlist*, *xlist*[, *timeout*])
This is a straightforward interface to the Unix `select()` system call. The first three arguments are sequences of 'waitable objects': either integers representing file descriptors or objects with a parameterless method named *`fileno()`* returning such an integer:

- *rlist*: wait until ready for reading
- *wlist*: wait until ready for writing
- *xlist*: wait for an "exceptional condition" (see the manual page for what your system considers such a condition)

Empty sequences are allowed, but acceptance of three empty sequences is platform-dependent. (It is known to work on Unix but not on Windows.) The optional *timeout* argument specifies a time-out as a floating point number in seconds. When the *timeout* argument is omitted the function blocks until at least one file descriptor is ready. A time-out value of zero specifies a poll and never blocks.

The return value is a triple of lists of objects that are ready: subsets of the first three arguments. When the time-out is reached without a file descriptor becoming ready, three empty lists are returned.

Among the acceptable object types in the sequences are Python *file objects* (e.g. `sys.stdin`, or objects returned by *`open()`* or *`os.popen()`*), socket objects returned by *`socket.socket()`*. You may also define a *wrapper* class yourself, as long as it has an appropriate *`fileno()`* method (that really returns a file descriptor, not just a random integer).

Note: File objects on Windows are not acceptable, but sockets are. On Windows, the underlying `select()` function is provided by the WinSock library, and does not handle file descriptors that don't originate from WinSock.

Changed in version 3.5: The function is now retried with a recomputed timeout when interrupted by a signal, except if the signal handler raises an exception (see **PEP 475** for the rationale), instead of raising *`InterruptedError`*.

`select.PIPE_BUF`
The minimum number of bytes which can be written without blocking to a pipe when the pipe has been reported as ready for writing by *`select()`*, *`poll()`* or another interface in this module. This doesn't apply to other kind of file-like objects such as sockets.

This value is guaranteed by POSIX to be at least 512. Availability: Unix.

New in version 3.2.

19.3.1 `/dev/poll` Polling Objects

Solaris and derivatives have `/dev/poll`. While `select()` is O(highest file descriptor) and `poll()` is O(number of file descriptors), `/dev/poll` is O(active file descriptors).

`/dev/poll` behaviour is very close to the standard `poll()` object.

`devpoll.close()`
Close the file descriptor of the polling object.

New in version 3.4.

`devpoll.closed`
`True` if the polling object is closed.

New in version 3.4.

`devpoll.fileno()`
Return the file descriptor number of the polling object.

New in version 3.4.

`devpoll.register(`*fd*[, *eventmask*]`)`
Register a file descriptor with the polling object. Future calls to the *poll()* method will then check whether the file descriptor has any pending I/O events. *fd* can be either an integer, or an object with a *fileno()* method that returns an integer. File objects implement `fileno()`, so they can also be used as the argument.

eventmask is an optional bitmask describing the type of events you want to check for. The constants are the same that with `poll()` object. The default value is a combination of the constants `POLLIN`, `POLLPRI`, and `POLLOUT`.

> **Warning:** Registering a file descriptor that's already registered is not an error, but the result is undefined. The appropriate action is to unregister or modify it first. This is an important difference compared with `poll()`.

`devpoll.modify(`*fd*[, *eventmask*]`)`
This method does an *unregister()* followed by a *register()*. It is (a bit) more efficient that doing the same explicitly.

`devpoll.unregister(`*fd*`)`
Remove a file descriptor being tracked by a polling object. Just like the *register()* method, *fd* can be an integer or an object with a *fileno()* method that returns an integer.

Attempting to remove a file descriptor that was never registered is safely ignored.

`devpoll.poll(`[*timeout*]`)`
Polls the set of registered file descriptors, and returns a possibly-empty list containing `(fd, event)` 2-tuples for the descriptors that have events or errors to report. *fd* is the file descriptor, and *event* is a bitmask with bits set for the reported events for that descriptor — `POLLIN` for waiting input, `POLLOUT` to indicate that the descriptor can be written to, and so forth. An empty list indicates that the call timed out and no file descriptors had any events to report. If *timeout* is given, it specifies the length of time in milliseconds which the system will wait for events before returning. If *timeout* is omitted, -1, or *None*, the call will block until there is an event for this poll object.

Changed in version 3.5: The function is now retried with a recomputed timeout when interrupted by a signal, except if the signal handler raises an exception (see **PEP 475** for the rationale), instead of raising *InterruptedError*.

19.3.2 Edge and Level Trigger Polling (epoll) Objects

https://linux.die.net/man/4/epoll

eventmask

Constant	Meaning
EPOLLIN	Available for read
EPOLLOUT	Available for write
EPOLLPRI	Urgent data for read
EPOLLERR	Error condition happened on the assoc. fd
EPOLLHUP	Hang up happened on the assoc. fd
EPOLLET	Set Edge Trigger behavior, the default is Level Trigger behavior
EPOLLONESHOT	Set one-shot behavior. After one event is pulled out, the fd is internally disabled
EPOLLEXCLUSIVE	Wake only one epoll object when the associated fd has an event. The default (if this flag is not set) is to wake all epoll objects polling on a fd.
EPOLLRDHUP	Stream socket peer closed connection or shut down writing half of connection.
EPOLLRDNORM	Equivalent to EPOLLIN
EPOLLRDBAND	Priority data band can be read.
EPOLLWRNORM	Equivalent to EPOLLOUT
EPOLLWRBAND	Priority data may be written.
EPOLLMSG	Ignored.

epoll.close()
Close the control file descriptor of the epoll object.

epoll.closed
`True` if the epoll object is closed.

epoll.fileno()
Return the file descriptor number of the control fd.

epoll.fromfd(*fd*)
Create an epoll object from a given file descriptor.

epoll.register(*fd*[, *eventmask*])
Register a fd descriptor with the epoll object.

epoll.modify(*fd*, *eventmask*)
Modify a registered file descriptor.

epoll.unregister(*fd*)
Remove a registered file descriptor from the epoll object.

epoll.poll(*timeout=-1*, *maxevents=-1*)
Wait for events. timeout in seconds (float)

Changed in version 3.5: The function is now retried with a recomputed timeout when interrupted by a signal, except if the signal handler raises an exception (see **PEP 475** for the rationale), instead of raising *InterruptedError*.

19.3.3 Polling Objects

The `poll()` system call, supported on most Unix systems, provides better scalability for network servers that service many, many clients at the same time. `poll()` scales better because the system call only requires listing the file descriptors of interest, while `select()` builds a bitmap, turns on bits for the fds of interest, and then afterward the whole bitmap has to be linearly scanned again. `select()` is O(highest file descriptor), while `poll()` is O(number of file descriptors).

poll.register(*fd*[, *eventmask*])
Register a file descriptor with the polling object. Future calls to the *poll()* method will then check whether the file descriptor has any pending I/O events. *fd* can be either an integer, or an object with a

fileno() method that returns an integer. File objects implement `fileno()`, so they can also be used as the argument.

eventmask is an optional bitmask describing the type of events you want to check for, and can be a combination of the constants `POLLIN`, `POLLPRI`, and `POLLOUT`, described in the table below. If not specified, the default value used will check for all 3 types of events.

Constant	Meaning
`POLLIN`	There is data to read
`POLLPRI`	There is urgent data to read
`POLLOUT`	Ready for output: writing will not block
`POLLERR`	Error condition of some sort
`POLLHUP`	Hung up
`POLLRDHUP`	Stream socket peer closed connection, or shut down writing half of connection
`POLLNVAL`	Invalid request: descriptor not open

Registering a file descriptor that's already registered is not an error, and has the same effect as registering the descriptor exactly once.

`poll.modify(`*fd*, *eventmask*`)`
Modifies an already registered fd. This has the same effect as `register(fd, eventmask)`. Attempting to modify a file descriptor that was never registered causes an *OSError* exception with errno `ENOENT` to be raised.

`poll.unregister(`*fd*`)`
Remove a file descriptor being tracked by a polling object. Just like the *register()* method, *fd* can be an integer or an object with a *fileno()* method that returns an integer.

Attempting to remove a file descriptor that was never registered causes a *KeyError* exception to be raised.

`poll.poll(`[*timeout*]`)`
Polls the set of registered file descriptors, and returns a possibly-empty list containing `(fd, event)` 2-tuples for the descriptors that have events or errors to report. *fd* is the file descriptor, and *event* is a bitmask with bits set for the reported events for that descriptor — `POLLIN` for waiting input, `POLLOUT` to indicate that the descriptor can be written to, and so forth. An empty list indicates that the call timed out and no file descriptors had any events to report. If *timeout* is given, it specifies the length of time in milliseconds which the system will wait for events before returning. If *timeout* is omitted, negative, or *None*, the call will block until there is an event for this poll object.

Changed in version 3.5: The function is now retried with a recomputed timeout when interrupted by a signal, except if the signal handler raises an exception (see **PEP 475** for the rationale), instead of raising *InterruptedError*.

19.3.4 Kqueue Objects

`kqueue.close()`
Close the control file descriptor of the kqueue object.

`kqueue.closed`
`True` if the kqueue object is closed.

`kqueue.fileno()`
Return the file descriptor number of the control fd.

`kqueue.fromfd(`*fd*`)`
Create a kqueue object from a given file descriptor.

`kqueue.control(`*changelist*, *max_events*[, *timeout=None*]`)` → eventlist
Low level interface to kevent

- changelist must be an iterable of kevent object or `None`
- max_events must be 0 or a positive integer
- timeout in seconds (floats possible)

Changed in version 3.5: The function is now retried with a recomputed timeout when interrupted by a signal, except if the signal handler raises an exception (see **PEP 475** for the rationale), instead of raising *InterruptedError*.

19.3.5 Kevent Objects

https://www.freebsd.org/cgi/man.cgi?query=kqueue&sektion=2

`kevent.ident`
Value used to identify the event. The interpretation depends on the filter but it's usually the file descriptor. In the constructor ident can either be an int or an object with a *fileno()* method. kevent stores the integer internally.

`kevent.filter`
Name of the kernel filter.

Constant	Meaning
KQ_FILTER_READ	Takes a descriptor and returns whenever there is data available to read
KQ_FILTER_WRITE	Takes a descriptor and returns whenever there is data available to write
KQ_FILTER_AIO	AIO requests
KQ_FILTER_VNODE	Returns when one or more of the requested events watched in *fflag* occurs
KQ_FILTER_PROC	Watch for events on a process id
KQ_FILTER_NETDEV	Watch for events on a network device [not available on Mac OS X]
KQ_FILTER_SIGNAL	Returns whenever the watched signal is delivered to the process
KQ_FILTER_TIMER	Establishes an arbitrary timer

`kevent.flags`
Filter action.

Constant	Meaning
KQ_EV_ADD	Adds or modifies an event
KQ_EV_DELETE	Removes an event from the queue
KQ_EV_ENABLE	Permitscontrol() to returns the event
KQ_EV_DISABLE	Disablesevent
KQ_EV_ONESHOT	Removes event after first occurrence
KQ_EV_CLEAR	Reset the state after an event is retrieved
KQ_EV_SYSFLAGS	internal event
KQ_EV_FLAG1	internal event
KQ_EV_EOF	Filter specific EOF condition
KQ_EV_ERROR	See return values

`kevent.fflags`
Filter specific flags.

KQ_FILTER_READ and KQ_FILTER_WRITE filter flags:

Constant	Meaning
KQ_NOTE_LOWAT	low water mark of a socket buffer

KQ_FILTER_VNODE filter flags:

Constant	Meaning
KQ_NOTE_DELETE	*unlink()* was called
KQ_NOTE_WRITE	a write occurred
KQ_NOTE_EXTEND	the file was extended
KQ_NOTE_ATTRIB	an attribute was changed
KQ_NOTE_LINK	the link count has changed
KQ_NOTE_RENAME	the file was renamed
KQ_NOTE_REVOKE	access to the file was revoked

KQ_FILTER_PROC filter flags:

Constant	Meaning
KQ_NOTE_EXIT	the process has exited
KQ_NOTE_FORK	the process has called *fork()*
KQ_NOTE_EXEC	the process has executed a new process
KQ_NOTE_PCTRLMASK	internal filter flag
KQ_NOTE_PDATAMASK	internal filter flag
KQ_NOTE_TRACK	follow a process across *fork()*
KQ_NOTE_CHILD	returned on the child process for *NOTE_TRACK*
KQ_NOTE_TRACKERR	unable to attach to a child

KQ_FILTER_NETDEV filter flags (not available on Mac OS X):

Constant	Meaning
KQ_NOTE_LINKUP	link is up
KQ_NOTE_LINKDOWN	link is down
KQ_NOTE_LINKINV	link state is invalid

kevent.data
Filter specific data.

kevent.udata
User defined value.

19.4 selectors — High-level I/O multiplexing

New in version 3.4.

Source code: Lib/selectors.py

19.4.1 Introduction

This module allows high-level and efficient I/O multiplexing, built upon the *select* module primitives. Users are encouraged to use this module instead, unless they want precise control over the OS-level primitives used.

It defines a *BaseSelector* abstract base class, along with several concrete implementations (*KqueueSelector*, *EpollSelector*...), that can be used to wait for I/O readiness notification on multiple file objects. In the following, "file object" refers to any object with a `fileno()` method, or a raw file descriptor. See *file object*.

DefaultSelector is an alias to the most efficient implementation available on the current platform: this should be the default choice for most users.

Note: The type of file objects supported depends on the platform: on Windows, sockets are supported, but not pipes, whereas on Unix, both are supported (some other types may be supported as well, such as fifos or special file devices).

See also:

select Low-level I/O multiplexing module.

19.4.2 Classes

Classes hierarchy:

```
BaseSelector
+-- SelectSelector
+-- PollSelector
+-- EpollSelector
+-- DevpollSelector
+-- KqueueSelector
```

In the following, *events* is a bitwise mask indicating which I/O events should be waited for on a given file object. It can be a combination of the modules constants below:

Constant	Meaning
`EVENT_READ`	Available for read
`EVENT_WRITE`	Available for write

class selectors.SelectorKey

A *SelectorKey* is a *namedtuple* used to associate a file object to its underlying file descriptor, selected event mask and attached data. It is returned by several *BaseSelector* methods.

fileobj

File object registered.

fd

Underlying file descriptor.

events

Events that must be waited for on this file object.

data

Optional opaque data associated to this file object: for example, this could be used to store a per-client session ID.

class selectors.BaseSelector

A *BaseSelector* is used to wait for I/O event readiness on multiple file objects. It supports file stream registration, unregistration, and a method to wait for I/O events on those streams, with an optional timeout. It's an abstract base class, so cannot be instantiated. Use *DefaultSelector* instead, or one of *SelectSelector*, *KqueueSelector* etc. if you want to specifically use an implementation, and your platform supports it. *BaseSelector* and its concrete implementations support the *context manager* protocol.

abstractmethod register(*fileobj*, *events*, *data=None*)

Register a file object for selection, monitoring it for I/O events.

fileobj is the file object to monitor. It may either be an integer file descriptor or an object with a `fileno()` method. *events* is a bitwise mask of events to monitor. *data* is an opaque object.

This returns a new *SelectorKey* instance, or raises a *ValueError* in case of invalid event mask or file descriptor, or *KeyError* if the file object is already registered.

abstractmethod unregister(*fileobj*)

Unregister a file object from selection, removing it from monitoring. A file object shall be unregistered prior to being closed.

fileobj must be a file object previously registered.

This returns the associated *SelectorKey* instance, or raises a *KeyError* if *fileobj* is not registered. It will raise *ValueError* if *fileobj* is invalid (e.g. it has no `fileno()` method or its `fileno()` method has an invalid return value).

modify(*fileobj*, *events*, *data=None*)

Change a registered file object's monitored events or attached data.

This is equivalent to `BaseSelector.unregister(fileobj)()` followed by `BaseSelector.register(fileobj, events, data)()`, except that it can be implemented more efficiently.

This returns a new *SelectorKey* instance, or raises a *ValueError* in case of invalid event mask or file descriptor, or *KeyError* if the file object is not registered.

abstractmethod select(*timeout=None*)

Wait until some registered file objects become ready, or the timeout expires.

If `timeout > 0`, this specifies the maximum wait time, in seconds. If `timeout <= 0`, the call won't block, and will report the currently ready file objects. If *timeout* is `None`, the call will block until a monitored file object becomes ready.

This returns a list of `(key, events)` tuples, one for each ready file object.

key is the *SelectorKey* instance corresponding to a ready file object. *events* is a bitmask of events ready on this file object.

Note: This method can return before any file object becomes ready or the timeout has elapsed if the current process receives a signal: in this case, an empty list will be returned.

Changed in version 3.5: The selector is now retried with a recomputed timeout when interrupted by a signal if the signal handler did not raise an exception (see **PEP 475** for the rationale), instead of returning an empty list of events before the timeout.

close()

Close the selector.

This must be called to make sure that any underlying resource is freed. The selector shall not be used once it has been closed.

get_key(*fileobj*)
Return the key associated with a registered file object.

This returns the *SelectorKey* instance associated to this file object, or raises *KeyError* if the file object is not registered.

abstractmethod get_map()
Return a mapping of file objects to selector keys.

This returns a *Mapping* instance mapping registered file objects to their associated *SelectorKey* instance.

class selectors.DefaultSelector
The default selector class, using the most efficient implementation available on the current platform. This should be the default choice for most users.

class selectors.SelectSelector
select.select()-based selector.

class selectors.PollSelector
select.poll()-based selector.

class selectors.EpollSelector
select.epoll()-based selector.

fileno()
This returns the file descriptor used by the underlying *select.epoll()* object.

class selectors.DevpollSelector
select.devpoll()-based selector.

fileno()
This returns the file descriptor used by the underlying *select.devpoll()* object.

New in version 3.5.

class selectors.KqueueSelector
select.kqueue()-based selector.

fileno()
This returns the file descriptor used by the underlying *select.kqueue()* object.

19.4.3 Examples

Here is a simple echo server implementation:

```
import selectors
import socket

sel = selectors.DefaultSelector()

def accept(sock, mask):
    conn, addr = sock.accept()  # Should be ready
    print('accepted', conn, 'from', addr)
    conn.setblocking(False)
    sel.register(conn, selectors.EVENT_READ, read)

def read(conn, mask):
    data = conn.recv(1000)  # Should be ready
    if data:
        print('echoing', repr(data), 'to', conn)
```

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```
        conn.send(data)  # Hope it won't block
    else:
        print('closing', conn)
        sel.unregister(conn)
        conn.close()

sock = socket.socket()
sock.bind(('localhost', 1234))
sock.listen(100)
sock.setblocking(False)
sel.register(sock, selectors.EVENT_READ, accept)

while True:
    events = sel.select()
    for key, mask in events:
        callback = key.data
        callback(key.fileobj, mask)
```

19.5 `asyncio` — Asynchronous I/O, event loop, coroutines and tasks

New in version 3.4.

Source code: Lib/asyncio/

This module provides infrastructure for writing single-threaded concurrent code using coroutines, multiplexing I/O access over sockets and other resources, running network clients and servers, and other related primitives. Here is a more detailed list of the package contents:

- a pluggable *event loop* with various system-specific implementations;
- *transport* and *protocol* abstractions (similar to those in Twisted);
- concrete support for TCP, UDP, SSL, subprocess pipes, delayed calls, and others (some may be system-dependent);
- a *Future* class that mimics the one in the *concurrent.futures* module, but adapted for use with the event loop;
- coroutines and tasks based on `yield from` (**PEP 380**), to help write concurrent code in a sequential fashion;
- cancellation support for *Future*s and coroutines;
- *synchronization primitives* for use between coroutines in a single thread, mimicking those in the *threading* module;
- an interface for passing work off to a threadpool, for times when you absolutely, positively have to use a library that makes blocking I/O calls.

Asynchronous programming is more complex than classical "sequential" programming: see the *Develop with asyncio* page which lists common traps and explains how to avoid them. *Enable the debug mode* during development to detect common issues.

Table of contents:

19.5.1 Base Event Loop

Source code: Lib/asyncio/events.py

The event loop is the central execution device provided by *asyncio*. It provides multiple facilities, including:

- Registering, executing and cancelling delayed calls (timeouts).
- Creating client and server *transports* for various kinds of communication.
- Launching subprocesses and the associated *transports* for communication with an external program.
- Delegating costly function calls to a pool of threads.

class asyncio.BaseEventLoop
This class is an implementation detail. It is a subclass of *AbstractEventLoop* and may be a base class of concrete event loop implementations found in *asyncio*. It should not be used directly; use *AbstractEventLoop* instead. `BaseEventLoop` should not be subclassed by third-party code; the internal interface is not stable.

class asyncio.AbstractEventLoop
Abstract base class of event loops.

This class is *not thread safe*.

Run an event loop

AbstractEventLoop.run_forever()
Run until *stop()* is called. If *stop()* is called before *run_forever()* is called, this polls the I/O selector once with a timeout of zero, runs all callbacks scheduled in response to I/O events (and those that were already scheduled), and then exits. If *stop()* is called while *run_forever()* is running, this will run the current batch of callbacks and then exit. Note that callbacks scheduled by callbacks will not run in that case; they will run the next time *run_forever()* is called.

Changed in version 3.5.1.

AbstractEventLoop.run_until_complete(*future***)**
Run until the *Future* is done.

If the argument is a *coroutine object*, it is wrapped by *ensure_future()*.

Return the Future's result, or raise its exception.

AbstractEventLoop.is_running()
Returns running status of event loop.

AbstractEventLoop.stop()
Stop running the event loop.

This causes *run_forever()* to exit at the next suitable opportunity (see there for more details).

Changed in version 3.5.1.

AbstractEventLoop.is_closed()
Returns `True` if the event loop was closed.

New in version 3.4.2.

AbstractEventLoop.close()
Close the event loop. The loop must not be running. Pending callbacks will be lost.

This clears the queues and shuts down the executor, but does not wait for the executor to finish.

This is idempotent and irreversible. No other methods should be called after this one.

coroutine AbstractEventLoop.**shutdown_asyncgens**()
Schedule all currently open *asynchronous generator* objects to close with an `aclose()` call. After calling this method, the event loop will issue a warning whenever a new asynchronous generator is iterated. Should be used to finalize all scheduled asynchronous generators reliably. Example:

```
try:
    loop.run_forever()
finally:
    loop.run_until_complete(loop.shutdown_asyncgens())
    loop.close()
```

New in version 3.6.

Calls

Most *asyncio* functions don't accept keywords. If you want to pass keywords to your callback, use *functools.partial()*. For example, `loop.call_soon(functools.partial(print, "Hello", flush=True))` will call `print("Hello", flush=True)`.

Note: *functools.partial()* is better than `lambda` functions, because *asyncio* can inspect *functools.partial()* object to display parameters in debug mode, whereas `lambda` functions have a poor representation.

AbstractEventLoop.**call_soon**(*callback*, **args*, *context=None*)
Arrange for a callback to be called as soon as possible. The callback is called after *call_soon()* returns, when control returns to the event loop.

This operates as a FIFO queue, callbacks are called in the order in which they are registered. Each callback will be called exactly once.

Any positional arguments after the callback will be passed to the callback when it is called.

An optional keyword-only *context* argument allows specifying a custom *contextvars.Context* for the *callback* to run in. The current context is used when no *context* is provided.

An instance of *asyncio.Handle* is returned, which can be used to cancel the callback.

Use functools.partial to pass keywords to the callback.

Changed in version 3.7: The *context* keyword-only parameter was added. See **PEP 567** for more details.

AbstractEventLoop.**call_soon_threadsafe**(*callback*, **args*, *context=None*)
Like *call_soon()*, but thread safe.

See the *concurrency and multithreading* section of the documentation.

Changed in version 3.7: The *context* keyword-only parameter was added. See **PEP 567** for more details.

Delayed calls

The event loop has its own internal clock for computing timeouts. Which clock is used depends on the (platform-specific) event loop implementation; ideally it is a monotonic clock. This will generally be a different clock than *time.time()*.

Note: Timeouts (relative *delay* or absolute *when*) should not exceed one day.

`AbstractEventLoop.call_later(`*delay*, *callback*, **args*, *context=None*`)`
Arrange for the *callback* to be called after the given *delay* seconds (either an int or float).

An instance of *asyncio.TimerHandle* is returned, which can be used to cancel the callback.

callback will be called exactly once per call to *call_later()*. If two callbacks are scheduled for exactly the same time, it is undefined which will be called first.

The optional positional *args* will be passed to the callback when it is called. If you want the callback to be called with some named arguments, use a closure or *functools.partial()*.

An optional keyword-only *context* argument allows specifying a custom *contextvars.Context* for the *callback* to run in. The current context is used when no *context* is provided.

Use functools.partial to pass keywords to the callback.

Changed in version 3.7: The *context* keyword-only parameter was added. See **PEP 567** for more details.

`AbstractEventLoop.call_at(`*when*, *callback*, **args*, *context=None*`)`
Arrange for the *callback* to be called at the given absolute timestamp *when* (an int or float), using the same time reference as *AbstractEventLoop.time()*.

This method's behavior is the same as *call_later()*.

An instance of *asyncio.TimerHandle* is returned, which can be used to cancel the callback.

Use functools.partial to pass keywords to the callback.

Changed in version 3.7: The *context* keyword-only parameter was added. See **PEP 567** for more details.

`AbstractEventLoop.time()`
Return the current time, as a *float* value, according to the event loop's internal clock.

See also:

The *asyncio.sleep()* function.

Futures

`AbstractEventLoop.create_future()`
Create an *asyncio.Future* object attached to the loop.

This is a preferred way to create futures in asyncio, as event loop implementations can provide alternative implementations of the Future class (with better performance or instrumentation).

New in version 3.5.2.

Tasks

`AbstractEventLoop.create_task(`*coro*`)`
Schedule the execution of a *coroutine object*: wrap it in a future. Return a *Task* object.

Third-party event loops can use their own subclass of *Task* for interoperability. In this case, the result type is a subclass of *Task*.

New in version 3.4.2.

`AbstractEventLoop.set_task_factory(`*factory*`)`
Set a task factory that will be used by *AbstractEventLoop.create_task()*.

If *factory* is `None` the default task factory will be set.

If *factory* is a *callable*, it should have a signature matching `(loop, coro)`, where *loop* will be a reference to the active event loop, *coro* will be a coroutine object. The callable must return an *asyncio.Future* compatible object.

New in version 3.4.4.

`AbstractEventLoop.get_task_factory()`
Return a task factory, or `None` if the default one is in use.

New in version 3.4.4.

Creating connections

`coroutine AbstractEventLoop.create_connection(`*protocol_factory*, *host=None*, *port=None*, ***, *ssl=None*, *family=0*, *proto=0*, *flags=0*, *sock=None*, *local_addr=None*, *server_hostname=None*, *ssl_handshake_timeout=None*`)`

Create a streaming transport connection to a given Internet *host* and *port*: socket family *AF_INET* or *AF_INET6* depending on *host* (or *family* if specified), socket type *SOCK_STREAM*. *protocol_factory* must be a callable returning a *protocol* instance.

This method will try to establish the connection in the background. When successful, it returns a `(transport, protocol)` pair.

The chronological synopsis of the underlying operation is as follows:

1. The connection is established, and a *transport* is created to represent it.
2. *protocol_factory* is called without arguments and must return a *protocol* instance.
3. The protocol instance is tied to the transport, and its `connection_made()` method is called.
4. The coroutine returns successfully with the `(transport, protocol)` pair.

The created transport is an implementation-dependent bidirectional stream.

Note: *protocol_factory* can be any kind of callable, not necessarily a class. For example, if you want to use a pre-created protocol instance, you can pass `lambda: my_protocol`.

Options that change how the connection is created:

- *ssl*: if given and not false, a SSL/TLS transport is created (by default a plain TCP transport is created). If *ssl* is a *ssl.SSLContext* object, this context is used to create the transport; if *ssl* is *True*, a context with some unspecified default settings is used.

  See also:

  SSL/TLS security considerations

- *server_hostname*, is only for use together with *ssl*, and sets or overrides the hostname that the target server's certificate will be matched against. By default the value of the *host* argument is used. If *host* is empty, there is no default and you must pass a value for *server_hostname*. If *server_hostname* is an empty string, hostname matching is disabled (which is a serious security risk, allowing for man-in-the-middle-attacks).
- *family*, *proto*, *flags* are the optional address family, protocol and flags to be passed through to getaddrinfo() for *host* resolution. If given, these should all be integers from the corresponding *socket* module constants.

- *sock*, if given, should be an existing, already connected *socket.socket* object to be used by the transport. If *sock* is given, none of *host*, *port*, *family*, *proto*, *flags* and *local_addr* should be specified.
- *local_addr*, if given, is a `(local_host, local_port)` tuple used to bind the socket to locally. The *local_host* and *local_port* are looked up using getaddrinfo(), similarly to *host* and *port*.
- *ssl_handshake_timeout* is (for an SSL connection) the time in seconds to wait for the SSL handshake to complete before aborting the connection. `60.0` seconds if `None` (default).

New in version 3.7: The *ssl_handshake_timeout* parameter.

Changed in version 3.5: On Windows with *ProactorEventLoop*, SSL/TLS is now supported.

See also:

The *open_connection()* function can be used to get a pair of (*StreamReader*, *StreamWriter*) instead of a protocol.

`coroutine AbstractEventLoop.create_datagram_endpoint(`*protocol_factory*, *local_addr=None*, *remote_addr=None*, ***, *family=0*, *proto=0*, *flags=0*, *reuse_address=None*, *reuse_port=None*, *allow_broadcast=None*, *sock=None*`)`

Create datagram connection: socket family *AF_INET*, *AF_INET6* or *AF_UNIX* depending on *host* (or *family* if specified), socket type *SOCK_DGRAM*. *protocol_factory* must be a callable returning a *protocol* instance.

This method will try to establish the connection in the background. When successful, it returns a `(transport, protocol)` pair.

Options changing how the connection is created:

- *local_addr*, if given, is a `(local_host, local_port)` tuple used to bind the socket to locally. The *local_host* and *local_port* are looked up using *getaddrinfo()*.
- *remote_addr*, if given, is a `(remote_host, remote_port)` tuple used to connect the socket to a remote address. The *remote_host* and *remote_port* are looked up using *getaddrinfo()*.
- *family*, *proto*, *flags* are the optional address family, protocol and flags to be passed through to *getaddrinfo()* for *host* resolution. If given, these should all be integers from the corresponding *socket* module constants.
- *reuse_address* tells the kernel to reuse a local socket in TIME_WAIT state, without waiting for its natural timeout to expire. If not specified will automatically be set to `True` on UNIX.
- *reuse_port* tells the kernel to allow this endpoint to be bound to the same port as other existing endpoints are bound to, so long as they all set this flag when being created. This option is not supported on Windows and some UNIX's. If the `SO_REUSEPORT` constant is not defined then this capability is unsupported.
- *allow_broadcast* tells the kernel to allow this endpoint to send messages to the broadcast address.
- *sock* can optionally be specified in order to use a preexisting, already connected, *socket.socket* object to be used by the transport. If specified, *local_addr* and *remote_addr* should be omitted (must be *None*).

On Windows with *ProactorEventLoop*, this method is not supported.

See *UDP echo client protocol* and *UDP echo server protocol* examples.

Changed in version 3.4.4: The *family*, *proto*, *flags*, *reuse_address*, *reuse_port, *allow_broadcast*, and *sock* parameters were added.

coroutine AbstractEventLoop.create_unix_connection(*protocol_factory*, *path=None*, ***, *ssl=None*, *sock=None*, *server_hostname=None*, *ssl_handshake_timeout=None*)

Create UNIX connection: socket family *AF_UNIX*, socket type *SOCK_STREAM*. The *AF_UNIX* socket family is used to communicate between processes on the same machine efficiently.

This method will try to establish the connection in the background. When successful, it returns a `(transport, protocol)` pair.

path is the name of a UNIX domain socket, and is required unless a *sock* parameter is specified. Abstract UNIX sockets, *str*, *bytes*, and *Path* paths are supported.

See the *AbstractEventLoop.create_connection()* method for parameters.

Availability: UNIX.

New in version 3.7: The *ssl_handshake_timeout* parameter.

Changed in version 3.7: The *path* parameter can now be a *path-like object*.

Creating listening connections

coroutine AbstractEventLoop.create_server(*protocol_factory*, *host=None*, *port=None*, ***, *family=socket.AF_UNSPEC*, *flags=socket.AI_PASSIVE*, *sock=None*, *backlog=100*, *ssl=None*, *reuse_address=None*, *reuse_port=None*, *ssl_handshake_timeout=None*, *start_serving=True*)

Create a TCP server (socket type *SOCK_STREAM*) bound to *host* and *port*.

Return a *Server* object, its *sockets* attribute contains created sockets. Use the *Server.close()* method to stop the server: close listening sockets.

Parameters:

- The *host* parameter can be a string, in that case the TCP server is bound to *host* and *port*. The *host* parameter can also be a sequence of strings and in that case the TCP server is bound to all hosts of the sequence. If *host* is an empty string or `None`, all interfaces are assumed and a list of multiple sockets will be returned (most likely one for IPv4 and another one for IPv6).
- *family* can be set to either *socket.AF_INET* or *AF_INET6* to force the socket to use IPv4 or IPv6. If not set it will be determined from host (defaults to `socket.AF_UNSPEC`).
- *flags* is a bitmask for *getaddrinfo()*.
- *sock* can optionally be specified in order to use a preexisting socket object. If specified, *host* and *port* should be omitted (must be *None*).
- *backlog* is the maximum number of queued connections passed to *listen()* (defaults to 100).
- *ssl* can be set to an *SSLContext* to enable SSL over the accepted connections.
- *reuse_address* tells the kernel to reuse a local socket in TIME_WAIT state, without waiting for its natural timeout to expire. If not specified will automatically be set to `True` on UNIX.
- *reuse_port* tells the kernel to allow this endpoint to be bound to the same port as other existing endpoints are bound to, so long as they all set this flag when being created. This option is not supported on Windows.
- *ssl_handshake_timeout* is (for an SSL server) the time in seconds to wait for the SSL handshake to complete before aborting the connection. `60.0` seconds if `None` (default).

- *start_serving* set to `True` (the default) causes the created server to start accepting connections immediately. When set to `False`, the user should await on *Server.start_serving()* or *Server.serve_forever()* to make the server to start accepting connections.

New in version 3.7: *ssl_handshake_timeout* and *start_serving* parameters.

Changed in version 3.5: On Windows with *ProactorEventLoop*, SSL/TLS is now supported.

See also:

The function *start_server()* creates a (*StreamReader*, *StreamWriter*) pair and calls back a function with this pair.

Changed in version 3.5.1: The *host* parameter can now be a sequence of strings.

coroutine AbstractEventLoop.**create_unix_server**(*protocol_factory*, *path=None*, ***, *sock=None*, *backlog=100*, *ssl=None*, *ssl_handshake_timeout=None*, *start_serving=True*)

Similar to *AbstractEventLoop.create_server()*, but specific to the socket family *AF_UNIX*.

path is the name of a UNIX domain socket, and is required unless a *sock* parameter is specified. Abstract UNIX sockets, *str*, *bytes*, and *Path* paths are supported.

Availability: UNIX.

New in version 3.7: The *ssl_handshake_timeout* and *start_serving* parameters.

Changed in version 3.7: The *path* parameter can now be a *Path* object.

coroutine BaseEventLoop.**connect_accepted_socket**(*protocol_factory*, *sock*, ***, *ssl=None*, *ssl_handshake_timeout=None*)

Handle an accepted connection.

This is used by servers that accept connections outside of asyncio but that use asyncio to handle them.

Parameters:

- *sock* is a preexisting socket object returned from an `accept` call.
- *ssl* can be set to an *SSLContext* to enable SSL over the accepted connections.
- *ssl_handshake_timeout* is (for an SSL connection) the time in seconds to wait for the SSL handshake to complete before aborting the connection. `60.0` seconds if `None` (default).

When completed it returns a `(transport, protocol)` pair.

New in version 3.7: The *ssl_handshake_timeout* parameter.

New in version 3.5.3.

File Transferring

coroutine AbstractEventLoop.**sendfile**(*transport*, *file*, *offset=0*, *count=None*, ***, *fallback=True*)

Send a *file* to *transport*, return the total number of bytes which were sent.

The method uses high-performance *os.sendfile()* if available.

file must be a regular file object opened in binary mode.

offset tells from where to start reading the file. If specified, *count* is the total number of bytes to transmit as opposed to sending the file until EOF is reached. File position is updated on return or also in case of error in which case *file.tell()* can be used to figure out the number of bytes which were sent.

fallback set to `True` makes asyncio to manually read and send the file when the platform does not support the sendfile syscall (e.g. Windows or SSL socket on Unix).

Raise *SendfileNotAvailableError* if the system does not support *sendfile* syscall and *fallback* is `False`.

New in version 3.7.

TLS Upgrade

coroutine AbstractEventLoop.**start_tls**(*transport*, *protocol*, *sslcontext*, ***, *server_side=False*, *server_hostname=None*, *ssl_handshake_timeout=None*)

Upgrades an existing connection to TLS.

Returns a new transport instance, that the *protocol* must start using immediately after the *await*. The *transport* instance passed to the *start_tls* method should never be used again.

Parameters:

- *transport* and *protocol* instances that methods like *create_server()* and *create_connection()* return.
- *sslcontext*: a configured instance of *SSLContext*.
- *server_side* pass `True` when a server-side connection is being upgraded (like the one created by *create_server()*).
- *server_hostname*: sets or overrides the host name that the target server's certificate will be matched against.
- *ssl_handshake_timeout* is (for an SSL connection) the time in seconds to wait for the SSL handshake to complete before aborting the connection. `60.0` seconds if `None` (default).

New in version 3.7.

Watch file descriptors

On Windows with *SelectorEventLoop*, only socket handles are supported (ex: pipe file descriptors are not supported).

On Windows with *ProactorEventLoop*, these methods are not supported.

AbstractEventLoop.**add_reader**(*fd*, *callback*, **args*)

Start watching the file descriptor for read availability and then call the *callback* with specified arguments.

Use functools.partial to pass keywords to the callback.

AbstractEventLoop.**remove_reader**(*fd*)

Stop watching the file descriptor for read availability.

AbstractEventLoop.**add_writer**(*fd*, *callback*, **args*)

Start watching the file descriptor for write availability and then call the *callback* with specified arguments.

Use functools.partial to pass keywords to the callback.

AbstractEventLoop.**remove_writer**(*fd*)

Stop watching the file descriptor for write availability.

The *watch a file descriptor for read events* example uses the low-level *AbstractEventLoop.add_reader()* method to register the file descriptor of a socket.

Low-level socket operations

coroutine AbstractEventLoop.**sock_recv**(*sock*, *nbytes*)
Receive data from the socket. Modeled after blocking *socket.socket.recv()* method.

The return value is a bytes object representing the data received. The maximum amount of data to be received at once is specified by *nbytes*.

With *SelectorEventLoop* event loop, the socket *sock* must be non-blocking.

Changed in version 3.7: Even though the method was always documented as a coroutine method, before Python 3.7 it returned a *Future*. Since Python 3.7, this is an `async def` method.

coroutine AbstractEventLoop.**sock_recv_into**(*sock*, *buf*)
Receive data from the socket. Modeled after blocking *socket.socket.recv_into()* method.

The received data is written into *buf* (a writable buffer). The return value is the number of bytes written.

With *SelectorEventLoop* event loop, the socket *sock* must be non-blocking.

New in version 3.7.

coroutine AbstractEventLoop.**sock_sendall**(*sock*, *data*)
Send data to the socket. Modeled after blocking *socket.socket.sendall()* method.

The socket must be connected to a remote socket. This method continues to send data from *data* until either all data has been sent or an error occurs. `None` is returned on success. On error, an exception is raised, and there is no way to determine how much data, if any, was successfully processed by the receiving end of the connection.

With *SelectorEventLoop* event loop, the socket *sock* must be non-blocking.

Changed in version 3.7: Even though the method was always documented as a coroutine method, before Python 3.7 it returned an *Future*. Since Python 3.7, this is an `async def` method.

coroutine AbstractEventLoop.**sock_connect**(*sock*, *address*)
Connect to a remote socket at *address*. Modeled after blocking *socket.socket.connect()* method.

With *SelectorEventLoop* event loop, the socket *sock* must be non-blocking.

Changed in version 3.5.2: `address` no longer needs to be resolved. `sock_connect` will try to check if the *address* is already resolved by calling *socket.inet_pton()*. If not, *AbstractEventLoop.getaddrinfo()* will be used to resolve the *address*.

See also:

AbstractEventLoop.create_connection() and *asyncio.open_connection()*.

coroutine AbstractEventLoop.**sock_accept**(*sock*)
Accept a connection. Modeled after blocking *socket.socket.accept()*.

The socket must be bound to an address and listening for connections. The return value is a pair `(conn, address)` where *conn* is a *new* socket object usable to send and receive data on the connection, and *address* is the address bound to the socket on the other end of the connection.

The socket *sock* must be non-blocking.

Changed in version 3.7: Even though the method was always documented as a coroutine method, before Python 3.7 it returned a *Future*. Since Python 3.7, this is an `async def` method.

See also:

AbstractEventLoop.create_server() and *start_server()*.

coroutine AbstractEventLoop.**sock_sendfile**(*sock*, *file*, *offset=0*, *count=None*, ***, *fallback=True*)
Send a file using high-performance *os.sendfile* if possible and return the total number of bytes which were sent.

Asynchronous version of *socket.socket.sendfile()*.

sock must be non-blocking *socket* of *socket.SOCK_STREAM* type.

file must be a regular file object opened in binary mode.

offset tells from where to start reading the file. If specified, *count* is the total number of bytes to transmit as opposed to sending the file until EOF is reached. File position is updated on return or also in case of error in which case *file.tell()* can be used to figure out the number of bytes which were sent.

fallback set to `True` makes asyncio to manually read and send the file when the platform does not support the sendfile syscall (e.g. Windows or SSL socket on Unix).

Raise *SendfileNotAvailableError* if the system does not support *sendfile* syscall and *fallback* is `False`.

New in version 3.7.

Resolve host name

coroutine AbstractEventLoop.**getaddrinfo**(*host*, *port*, ***, *family=0*, *type=0*, *proto=0*, *flags=0*)
This method is a *coroutine*, similar to *socket.getaddrinfo()* function but non-blocking.

coroutine AbstractEventLoop.**getnameinfo**(*sockaddr*, *flags=0*)
This method is a *coroutine*, similar to *socket.getnameinfo()* function but non-blocking.

Changed in version 3.7: Both *getaddrinfo* and *getnameinfo* methods were always documented to return a coroutine, but prior to Python 3.7 they were, in fact, returning *asyncio.Future* objects. Starting with Python 3.7 both methods are coroutines.

Connect pipes

On Windows with *SelectorEventLoop*, these methods are not supported. Use *ProactorEventLoop* to support pipes on Windows.

coroutine AbstractEventLoop.**connect_read_pipe**(*protocol_factory*, *pipe*)
Register read pipe in eventloop.

protocol_factory should instantiate object with *Protocol* interface. *pipe* is a *file-like object*. Return pair `(transport, protocol)`, where *transport* supports the *ReadTransport* interface.

With *SelectorEventLoop* event loop, the *pipe* is set to non-blocking mode.

coroutine AbstractEventLoop.**connect_write_pipe**(*protocol_factory*, *pipe*)
Register write pipe in eventloop.

protocol_factory should instantiate object with `BaseProtocol` interface. *pipe* is *file-like object*. Return pair `(transport, protocol)`, where *transport* supports *WriteTransport* interface.

With *SelectorEventLoop* event loop, the *pipe* is set to non-blocking mode.

See also:

The *AbstractEventLoop.subprocess_exec()* and *AbstractEventLoop.subprocess_shell()* methods.

UNIX signals

Availability: UNIX only.

`AbstractEventLoop.add_signal_handler(signum, callback, *args)`
Add a handler for a signal.

Raise *ValueError* if the signal number is invalid or uncatchable. Raise *RuntimeError* if there is a problem setting up the handler.

Use functools.partial to pass keywords to the callback.

`AbstractEventLoop.remove_signal_handler(sig)`
Remove a handler for a signal.

Return `True` if a signal handler was removed, `False` if not.

See also:

The *signal* module.

Executor

Call a function in an *Executor* (pool of threads or pool of processes). By default, an event loop uses a thread pool executor (*ThreadPoolExecutor*).

`AbstractEventLoop.run_in_executor(executor, func, *args)`
Arrange for a *func* to be called in the specified executor.

The *executor* argument should be an *Executor* instance. The default executor is used if *executor* is `None`.

*Use functools.partial to pass keywords to the *func*.*

This method returns a *asyncio.Future* object.

Changed in version 3.5.3: `BaseEventLoop.run_in_executor()` no longer configures the `max_workers` of the thread pool executor it creates, instead leaving it up to the thread pool executor (*ThreadPoolExecutor*) to set the default.

`AbstractEventLoop.set_default_executor(executor)`
Set the default executor used by *run_in_executor()*.

Error Handling API

Allows customizing how exceptions are handled in the event loop.

`AbstractEventLoop.set_exception_handler(handler)`
Set *handler* as the new event loop exception handler.

If *handler* is `None`, the default exception handler will be set.

If *handler* is a callable object, it should have a matching signature to `(loop, context)`, where `loop` will be a reference to the active event loop, `context` will be a `dict` object (see *call_exception_handler()* documentation for details about context).

`AbstractEventLoop.get_exception_handler()`
Return the exception handler, or `None` if the default one is in use.

New in version 3.5.2.

`AbstractEventLoop.default_exception_handler(context)`
Default exception handler.

This is called when an exception occurs and no exception handler is set, and can be called by a custom exception handler that wants to defer to the default behavior.

context parameter has the same meaning as in *call_exception_handler()*.

`AbstractEventLoop.call_exception_handler(context)`
Call the current event loop exception handler.

context is a `dict` object containing the following keys (new keys may be introduced later):

- 'message': Error message;
- 'exception' (optional): Exception object;
- 'future' (optional): *asyncio.Future* instance;
- 'handle' (optional): *asyncio.Handle* instance;
- 'protocol' (optional): *Protocol* instance;
- 'transport' (optional): *Transport* instance;
- 'socket' (optional): *socket.socket* instance.

Note: Note: this method should not be overloaded in subclassed event loops. For any custom exception handling, use *set_exception_handler()* method.

Debug mode

`AbstractEventLoop.get_debug()`
Get the debug mode (*bool*) of the event loop.

The default value is `True` if the environment variable `PYTHONASYNCIODEBUG` is set to a non-empty string, `False` otherwise.

New in version 3.4.2.

`AbstractEventLoop.set_debug(enabled: bool)`
Set the debug mode of the event loop.

New in version 3.4.2.

See also:

The *debug mode of asyncio*.

Server

`class asyncio.Server`
Server listening on sockets.

Object created by *AbstractEventLoop.create_server()*, *AbstractEventLoop.create_unix_server()*, *start_server()*, and *start_unix_server()* functions. Don't instantiate the class directly.

Server objects are asynchronous context managers. When used in an `async with` statement, it's guaranteed that the Server object is closed and not accepting new connections when the `async with` statement is completed:

```
srv = await loop.create_server(...)

async with srv:
    # some code

# At this point, srv is closed and no longer accepts new connections.
```

Changed in version 3.7: Server object is an asynchronous context manager since Python 3.7.

close()
Stop serving: close listening sockets and set the *sockets* attribute to `None`.

The sockets that represent existing incoming client connections are left open.

The server is closed asynchronously, use the *wait_closed()* coroutine to wait until the server is closed.

get_loop()
Gives the event loop associated with the server object.

New in version 3.7.

coroutine start_serving()
Start accepting connections.

This method is idempotent, so it can be called when the server is already being serving.

The new *start_serving* keyword-only parameter to *AbstractEventLoop.create_server()* and *asyncio.start_server()* allows to create a Server object that is not accepting connections right away. In which case this method, or *Server.serve_forever()* can be used to make the Server object to start accepting connections.

New in version 3.7.

coroutine serve_forever()
Start accepting connections until the coroutine is cancelled. Cancellation of `serve_forever` task causes the server to be closed.

This method can be called if the server is already accepting connections. Only one `serve_forever` task can exist per one *Server* object.

Example:

```
async def client_connected(reader, writer):
    # Communicate with the client with
    # reader/writer streams.  For example:
    await reader.readline()

async def main(host, port):
    srv = await asyncio.start_server(
        client_connected, host, port)
    await srv.serve_forever()

asyncio.run(main('127.0.0.1', 0))
```

New in version 3.7.

is_serving()
Return `True` if the server is accepting new connections.

New in version 3.7.

coroutine wait_closed()
Wait until the *close()* method completes.

sockets
List of *socket.socket* objects the server is listening to, or `None` if the server is closed.

Changed in version 3.7: Prior to Python 3.7 `Server.sockets` used to return the internal list of server's sockets directly. In 3.7 a copy of that list is returned.

Handle

class asyncio.Handle
A callback wrapper object returned by *AbstractEventLoop.call_soon()*, *AbstractEventLoop.call_soon_threadsafe()*.

cancel()
Cancel the call. If the callback is already canceled or executed, this method has no effect.

cancelled()
Return `True` if the call was cancelled.

New in version 3.7.

class asyncio.TimerHandle
A callback wrapper object returned by *AbstractEventLoop.call_later()*, and *AbstractEventLoop.call_at()*.

The class is inherited from *Handle*.

when()
Return a scheduled callback time as *float* seconds.

The time is an absolute timestamp, using the same time reference as *AbstractEventLoop.time()*.

New in version 3.7.

SendfileNotAvailableError

exception asyncio.SendfileNotAvailableError
Sendfile syscall is not available, subclass of *RuntimeError*.

Raised if the OS does not support sendfile syscall for given socket or file type.

Event loop examples

Hello World with call_soon()

Example using the *AbstractEventLoop.call_soon()* method to schedule a callback. The callback displays `"Hello World"` and then stops the event loop:

```
import asyncio

def hello_world(loop):
    print('Hello World')
    loop.stop()

loop = asyncio.get_event_loop()

# Schedule a call to hello_world()
loop.call_soon(hello_world, loop)
```

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```
# Blocking call interrupted by loop.stop()
loop.run_forever()
loop.close()
```

See also:

The *Hello World coroutine* example uses a *coroutine*.

Display the current date with call_later()

Example of callback displaying the current date every second. The callback uses the *AbstractEventLoop.call_later()* method to reschedule itself during 5 seconds, and then stops the event loop:

```
import asyncio
import datetime

def display_date(end_time, loop):
    print(datetime.datetime.now())
    if (loop.time() + 1.0) < end_time:
        loop.call_later(1, display_date, end_time, loop)
    else:
        loop.stop()

loop = asyncio.get_event_loop()

# Schedule the first call to display_date()
end_time = loop.time() + 5.0
loop.call_soon(display_date, end_time, loop)

# Blocking call interrupted by loop.stop()
loop.run_forever()
loop.close()
```

See also:

The *coroutine displaying the current date* example uses a *coroutine*.

Watch a file descriptor for read events

Wait until a file descriptor received some data using the *AbstractEventLoop.add_reader()* method and then close the event loop:

```
import asyncio
from socket import socketpair

# Create a pair of connected file descriptors
rsock, wsock = socketpair()
loop = asyncio.get_event_loop()

def reader():
    data = rsock.recv(100)
    print("Received:", data.decode())
    # We are done: unregister the file descriptor
    loop.remove_reader(rsock)
    # Stop the event loop
```

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```
    loop.stop()

# Register the file descriptor for read event
loop.add_reader(rsock, reader)

# Simulate the reception of data from the network
loop.call_soon(wsock.send, 'abc'.encode())

# Run the event loop
loop.run_forever()

# We are done, close sockets and the event loop
rsock.close()
wsock.close()
loop.close()
```

See also:

The *register an open socket to wait for data using a protocol* example uses a low-level protocol created by the *AbstractEventLoop.create_connection()* method.

The *register an open socket to wait for data using streams* example uses high-level streams created by the *open_connection()* function in a coroutine.

Set signal handlers for SIGINT and SIGTERM

Register handlers for signals `SIGINT` and `SIGTERM` using the *AbstractEventLoop.add_signal_handler()* method:

```
import asyncio
import functools
import os
import signal

def ask_exit(signame):
    print("got signal %s: exit" % signame)
    loop.stop()

loop = asyncio.get_event_loop()
for signame in ('SIGINT', 'SIGTERM'):
    loop.add_signal_handler(getattr(signal, signame),
                            functools.partial(ask_exit, signame))

print("Event loop running forever, press Ctrl+C to interrupt.")
print("pid %s: send SIGINT or SIGTERM to exit." % os.getpid())
try:
    loop.run_forever()
finally:
    loop.close()
```

This example only works on UNIX.

19.5.2 Event loops

Source code: Lib/asyncio/events.py

Event loop functions

The following functions are convenient shortcuts to accessing the methods of the global policy. Note that this provides access to the default policy, unless an alternative policy was set by calling *set_event_loop_policy()* earlier in the execution of the process.

asyncio.get_event_loop()
Equivalent to calling `get_event_loop_policy().get_event_loop()`.

asyncio.set_event_loop(*loop*)
Equivalent to calling `get_event_loop_policy().set_event_loop(loop)`.

asyncio.new_event_loop()
Equivalent to calling `get_event_loop_policy().new_event_loop()`.

asyncio.get_running_loop()
Return the running event loop in the current OS thread. If there is no running event loop a *RuntimeError* is raised.

New in version 3.7.

Available event loops

asyncio currently provides two implementations of event loops: *SelectorEventLoop* and *ProactorEventLoop*.

class asyncio.SelectorEventLoop
Event loop based on the *selectors* module. Subclass of *AbstractEventLoop*.

Use the most efficient selector available on the platform.

On Windows, only sockets are supported (ex: pipes are not supported): see the MSDN documentation of select.

class asyncio.ProactorEventLoop
Proactor event loop for Windows using "I/O Completion Ports" aka IOCP. Subclass of *AbstractEventLoop*.

Availability: Windows.

See also:

MSDN documentation on I/O Completion Ports.

Example to use a *ProactorEventLoop* on Windows:

```
import asyncio, sys

if sys.platform == 'win32':
    loop = asyncio.ProactorEventLoop()
    asyncio.set_event_loop(loop)
```

Platform support

The *asyncio* module has been designed to be portable, but each platform still has subtle differences and may not support all *asyncio* features.

Windows

Common limits of Windows event loops:

- *create_unix_connection()* and *create_unix_server()* are not supported: the socket family *socket.AF_UNIX* is specific to UNIX
- *add_signal_handler()* and *remove_signal_handler()* are not supported
- `EventLoopPolicy.set_child_watcher()` is not supported. *ProactorEventLoop* supports subprocesses. It has only one implementation to watch child processes, there is no need to configure it.

SelectorEventLoop specific limits:

- *SelectSelector* is used which only supports sockets and is limited to 512 sockets.
- *add_reader()* and *add_writer()* only accept file descriptors of sockets
- Pipes are not supported (ex: *connect_read_pipe()*, *connect_write_pipe()*)
- *Subprocesses* are not supported (ex: *subprocess_exec()*, *subprocess_shell()*)

ProactorEventLoop specific limits:

- *create_datagram_endpoint()* (UDP) is not supported
- *add_reader()* and *add_writer()* are not supported

The resolution of the monotonic clock on Windows is usually around 15.6 msec. The best resolution is 0.5 msec. The resolution depends on the hardware (availability of HPET) and on the Windows configuration. See *asyncio delayed calls*.

Changed in version 3.5: *ProactorEventLoop* now supports SSL.

Mac OS X

Character devices like PTY are only well supported since Mavericks (Mac OS 10.9). They are not supported at all on Mac OS 10.5 and older.

On Mac OS 10.6, 10.7 and 10.8, the default event loop is *SelectorEventLoop* which uses *selectors.KqueueSelector*. *selectors.KqueueSelector* does not support character devices on these versions. The *SelectorEventLoop* can be used with *SelectSelector* or *PollSelector* to support character devices on these versions of Mac OS X. Example:

```
import asyncio
import selectors

selector = selectors.SelectSelector()
loop = asyncio.SelectorEventLoop(selector)
asyncio.set_event_loop(loop)
```

Event loop policies and the default policy

Event loop management is abstracted with a *policy* pattern, to provide maximal flexibility for custom platforms and frameworks. Throughout the execution of a process, a single global policy object manages the event loops available to the process based on the calling context. A policy is an object implementing the *AbstractEventLoopPolicy* interface.

For most users of *asyncio*, policies never have to be dealt with explicitly, since the default global policy is sufficient (see below).

The module-level functions *get_event_loop()* and *set_event_loop()* provide convenient access to event loops managed by the default policy.

Event loop policy interface

An event loop policy must implement the following interface:

class asyncio.AbstractEventLoopPolicy
Event loop policy.

get_event_loop()
Get the event loop for the current context.

Returns an event loop object implementing the *AbstractEventLoop* interface. In case called from coroutine, it returns the currently running event loop.

Raises an exception in case no event loop has been set for the current context and the current policy does not specify to create one. It must never return `None`.

Changed in version 3.6.

set_event_loop(*loop*)
Set the event loop for the current context to *loop*.

new_event_loop()
Create and return a new event loop object according to this policy's rules.

If there's need to set this loop as the event loop for the current context, *set_event_loop()* must be called explicitly.

The default policy defines context as the current thread, and manages an event loop per thread that interacts with *asyncio*. An exception to this rule happens when *get_event_loop()* is called from a running future/coroutine, in which case it will return the current loop running that future/coroutine.

If the current thread doesn't already have an event loop associated with it, the default policy's *get_event_loop()* method creates one when called from the main thread, but raises *RuntimeError* otherwise.

Access to the global loop policy

asyncio.get_event_loop_policy()
Get the current event loop policy.

asyncio.set_event_loop_policy(*policy*)
Set the current event loop policy. If *policy* is `None`, the default policy is restored.

Customizing the event loop policy

To implement a new event loop policy, it is recommended you subclass the concrete default event loop policy `DefaultEventLoopPolicy` and override the methods for which you want to change behavior, for example:

```
class MyEventLoopPolicy(asyncio.DefaultEventLoopPolicy):

    def get_event_loop(self):
        """Get the event loop.

        This may be None or an instance of EventLoop.
        """
        loop = super().get_event_loop()
```

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```
        # Do something with loop ...
        return loop

asyncio.set_event_loop_policy(MyEventLoopPolicy())
```

19.5.3 Tasks and coroutines

Source code: Lib/asyncio/tasks.py

Source code: Lib/asyncio/coroutines.py

Coroutines

Coroutines used with *asyncio* may be implemented using the `async def` statement, or by using *generators*. The `async def` type of coroutine was added in Python 3.5, and is recommended if there is no need to support older Python versions.

Generator-based coroutines should be decorated with *@asyncio.coroutine*, although this is not strictly enforced. The decorator enables compatibility with `async def` coroutines, and also serves as documentation. Generator-based coroutines use the `yield from` syntax introduced in **PEP 380**, instead of the original `yield` syntax.

The word "coroutine", like the word "generator", is used for two different (though related) concepts:

- The function that defines a coroutine (a function definition using `async def` or decorated with `@asyncio.coroutine`). If disambiguation is needed we will call this a *coroutine function* (*iscoroutinefunction()* returns `True`).
- The object obtained by calling a coroutine function. This object represents a computation or an I/O operation (usually a combination) that will complete eventually. If disambiguation is needed we will call it a *coroutine object* (*iscoroutine()* returns `True`).

Things a coroutine can do:

- `result = await future` or `result = yield from future` – suspends the coroutine until the future is done, then returns the future's result, or raises an exception, which will be propagated. (If the future is cancelled, it will raise a `CancelledError` exception.) Note that tasks are futures, and everything said about futures also applies to tasks.
- `result = await coroutine` or `result = yield from coroutine` – wait for another coroutine to produce a result (or raise an exception, which will be propagated). The `coroutine` expression must be a *call* to another coroutine.
- `return expression` – produce a result to the coroutine that is waiting for this one using `await` or `yield from`.
- `raise exception` – raise an exception in the coroutine that is waiting for this one using `await` or `yield from`.

Calling a coroutine does not start its code running – the coroutine object returned by the call doesn't do anything until you schedule its execution. There are two basic ways to start it running: call `await coroutine` or `yield from coroutine` from another coroutine (assuming the other coroutine is already running!), or schedule its execution using the *ensure_future()* function or the *AbstractEventLoop.create_task()* method.

Coroutines (and tasks) can only run when the event loop is running.

`@asyncio.coroutine`
Decorator to mark generator-based coroutines. This enables the generator use `yield from` to call `async def` coroutines, and also enables the generator to be called by `async def` coroutines, for instance using an `await` expression.

There is no need to decorate `async def` coroutines themselves.

If the generator is not yielded from before it is destroyed, an error message is logged. See *Detect coroutines never scheduled*.

Note: In this documentation, some methods are documented as coroutines, even if they are plain Python functions returning a *Future*. This is intentional to have a freedom of tweaking the implementation of these functions in the future. If such a function is needed to be used in a callback-style code, wrap its result with *ensure_future()*.

`asyncio.run(`*coro*, ***, *debug=False*`)`
This function runs the passed coroutine, taking care of managing the asyncio event loop and finalizing asynchronous generators.

This function cannot be called when another asyncio event loop is running in the same thread.

If debug is True, the event loop will be run in debug mode.

This function always creates a new event loop and closes it at the end. It should be used as a main entry point for asyncio programs, and should ideally only be called once.

New in version 3.7: **Important:** this has been been added to asyncio in Python 3.7 on a *provisional basis*.

Example: Hello World coroutine

Example of coroutine displaying `"Hello World"`:

```
import asyncio

async def hello_world():
    print("Hello World!")

asyncio.run(hello_world())
```

See also:

The *Hello World with call_soon()* example uses the *AbstractEventLoop.call_soon()* method to schedule a callback.

Example: Coroutine displaying the current date

Example of coroutine displaying the current date every second during 5 seconds using the *sleep()* function:

```
import asyncio
import datetime

async def display_date():
    loop = asyncio.get_running_loop()
    end_time = loop.time() + 5.0
    while True:
```

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```
        print(datetime.datetime.now())
        if (loop.time() + 1.0) >= end_time:
            break
        await asyncio.sleep(1)

asyncio.run(display_date())
```

See also:

The *display the current date with call_later()* example uses a callback with the *AbstractEventLoop.call_later()* method.

Example: Chain coroutines

Example chaining coroutines:

```
import asyncio

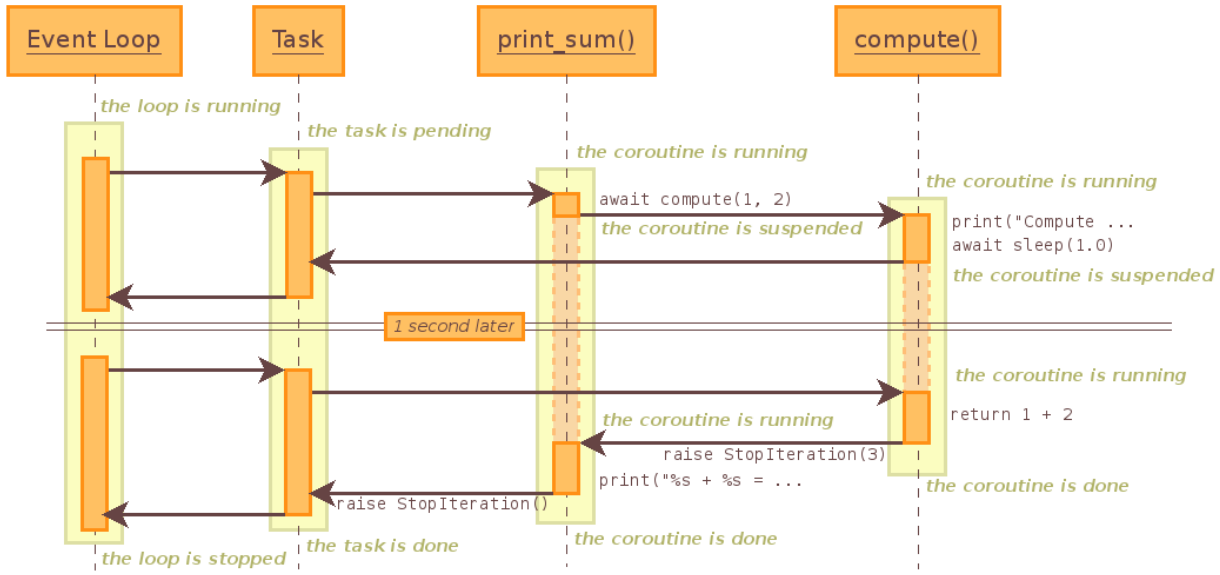
async def compute(x, y):
    print("Compute %s + %s ..." % (x, y))
    await asyncio.sleep(1.0)
    return x + y

async def print_sum(x, y):
    result = await compute(x, y)
    print("%s + %s = %s" % (x, y, result))

loop = asyncio.get_event_loop()
loop.run_until_complete(print_sum(1, 2))
loop.close()
```

`compute()` is chained to `print_sum()`: `print_sum()` coroutine waits until `compute()` is completed before returning its result.

Sequence diagram of the example:



The "Task" is created by the *AbstractEventLoop.run_until_complete()* method when it gets a coroutine object instead of a task.

The diagram shows the control flow, it does not describe exactly how things work internally. For example, the sleep coroutine creates an internal future which uses *AbstractEventLoop.call_later()* to wake up the task in 1 second.

InvalidStateError

exception asyncio.InvalidStateError
The operation is not allowed in this state.

TimeoutError

exception asyncio.TimeoutError
The operation exceeded the given deadline.

Note: This exception is different from the builtin *TimeoutError* exception!

Future

class asyncio.Future(*, *loop=None*)
This class is *almost* compatible with *concurrent.futures.Future*.

Differences:

- *result()* and *exception()* do not take a timeout argument and raise an exception when the future isn't done yet.
- Callbacks registered with *add_done_callback()* are always called via the event loop's *call_soon()*.
- This class is not compatible with the *wait()* and *as_completed()* functions in the *concurrent.futures* package.

This class is *not thread safe*.

cancel()
Cancel the future and schedule callbacks.

If the future is already done or cancelled, return `False`. Otherwise, change the future's state to cancelled, schedule the callbacks and return `True`.

cancelled()
Return `True` if the future was cancelled.

done()
Return `True` if the future is done.

Done means either that a result / exception are available, or that the future was cancelled.

result()
Return the result this future represents.

If the future has been cancelled, raises `CancelledError`. If the future's result isn't yet available, raises *InvalidStateError*. If the future is done and has an exception set, this exception is raised.

`exception()`
Return the exception that was set on this future.

The exception (or `None` if no exception was set) is returned only if the future is done. If the future has been cancelled, raises `CancelledError`. If the future isn't done yet, raises *InvalidStateError*.

`add_done_callback(`*callback*, *, *context=None*`)`
Add a callback to be run when the future becomes done.

The *callback* is called with a single argument - the future object. If the future is already done when this is called, the callback is scheduled with *call_soon()*.

An optional keyword-only *context* argument allows specifying a custom *contextvars.Context* for the *callback* to run in. The current context is used when no *context* is provided.

Use functools.partial to pass parameters to the callback. For example, `fut.add_done_callback(functools.partial(print, "Future:", flush=True))` will call `print("Future:", fut, flush=True)`.

Changed in version 3.7: The *context* keyword-only parameter was added. See **PEP 567** for more details.

`remove_done_callback(`*fn*`)`
Remove all instances of a callback from the "call when done" list.

Returns the number of callbacks removed.

`set_result(`*result*`)`
Mark the future done and set its result.

If the future is already done when this method is called, raises *InvalidStateError*.

`set_exception(`*exception*`)`
Mark the future done and set an exception.

If the future is already done when this method is called, raises *InvalidStateError*.

`get_loop()`
Return the event loop the future object is bound to.

New in version 3.7.

Example: Future with run_until_complete()

Example combining a *Future* and a *coroutine function*:

```
import asyncio

async def slow_operation(future):
    await asyncio.sleep(1)
    future.set_result('Future is done!')

loop = asyncio.get_event_loop()
future = asyncio.Future()
asyncio.ensure_future(slow_operation(future))
loop.run_until_complete(future)
print(future.result())
loop.close()
```

The coroutine function is responsible for the computation (which takes 1 second) and it stores the result into the future. The *run_until_complete()* method waits for the completion of the future.

Note: The *run_until_complete()* method uses internally the *add_done_callback()* method to be notified when the future is done.

Example: Future with run_forever()

The previous example can be written differently using the *Future.add_done_callback()* method to describe explicitly the control flow:

```
import asyncio

async def slow_operation(future):
    await asyncio.sleep(1)
    future.set_result('Future is done!')

def got_result(future):
    print(future.result())
    loop.stop()

loop = asyncio.get_event_loop()
future = asyncio.Future()
asyncio.ensure_future(slow_operation(future))
future.add_done_callback(got_result)
try:
    loop.run_forever()
finally:
    loop.close()
```

In this example, the future is used to link `slow_operation()` to `got_result()`: when `slow_operation()` is done, `got_result()` is called with the result.

Task

`asyncio.create_task(`*coro*`)`
Wrap a *coroutine* *coro* into a task and schedule its execution. Return the task object.

The task is executed in *get_running_loop()* context, *RuntimeError* is raised if there is no running loop in current thread.

New in version 3.7.

`class asyncio.Task(`*coro*, ***, *loop=None*`)`
A unit for concurrent running of *coroutines*, subclass of *Future*.

A task is responsible for executing a coroutine object in an event loop. If the wrapped coroutine yields from a future, the task suspends the execution of the wrapped coroutine and waits for the completion of the future. When the future is done, the execution of the wrapped coroutine restarts with the result or the exception of the future.

Event loops use cooperative scheduling: an event loop only runs one task at a time. Other tasks may run in parallel if other event loops are running in different threads. While a task waits for the completion of a future, the event loop executes a new task.

The cancellation of a task is different from the cancellation of a future. Calling *cancel()* will throw a *CancelledError* to the wrapped coroutine. *cancelled()* only returns `True` if the wrapped coroutine did not catch the *CancelledError* exception, or raised a *CancelledError* exception.

If a pending task is destroyed, the execution of its wrapped *coroutine* did not complete. It is probably a bug and a warning is logged: see *Pending task destroyed*.

Don't directly create *Task* instances: use the *create_task()* function or the *AbstractEventLoop.create_task()* method.

Tasks support the *contextvars* module. When a Task is created it copies the current context and later runs its coroutine in the copied context. See **PEP 567** for more details.

This class is *not thread safe*.

Changed in version 3.7: Added support for the *contextvars* module.

classmethod all_tasks(*loop=None*)
Return a set of all tasks for an event loop.

By default all tasks for the current event loop are returned. If *loop* is `None`, *get_event_loop()* function is used to get the current loop.

classmethod current_task(*loop=None*)
Return the currently running task in an event loop or `None`.

By default the current task for the current event loop is returned.

`None` is returned when called not in the context of a *Task*.

cancel()
Request that this task cancel itself.

This arranges for a *CancelledError* to be thrown into the wrapped coroutine on the next cycle through the event loop. The coroutine then has a chance to clean up or even deny the request using try/except/finally.

Unlike *Future.cancel()*, this does not guarantee that the task will be cancelled: the exception might be caught and acted upon, delaying cancellation of the task or preventing cancellation completely. The task may also return a value or raise a different exception.

Immediately after this method is called, *cancelled()* will not return `True` (unless the task was already cancelled). A task will be marked as cancelled when the wrapped coroutine terminates with a *CancelledError* exception (even if *cancel()* was not called).

get_stack(***, *limit=None*)
Return the list of stack frames for this task's coroutine.

If the coroutine is not done, this returns the stack where it is suspended. If the coroutine has completed successfully or was cancelled, this returns an empty list. If the coroutine was terminated by an exception, this returns the list of traceback frames.

The frames are always ordered from oldest to newest.

The optional limit gives the maximum number of frames to return; by default all available frames are returned. Its meaning differs depending on whether a stack or a traceback is returned: the newest frames of a stack are returned, but the oldest frames of a traceback are returned. (This matches the behavior of the traceback module.)

For reasons beyond our control, only one stack frame is returned for a suspended coroutine.

print_stack(***, *limit=None*, *file=None*)
Print the stack or traceback for this task's coroutine.

This produces output similar to that of the traceback module, for the frames retrieved by get_stack(). The limit argument is passed to get_stack(). The file argument is an I/O stream to which the output is written; by default output is written to sys.stderr.

Example: Parallel execution of tasks

Example executing 3 tasks (A, B, C) in parallel:

```
import asyncio

async def factorial(name, number):
    f = 1
    for i in range(2, number+1):
        print("Task %s: Compute factorial(%s)..." % (name, i))
        await asyncio.sleep(1)
        f *= i
    print("Task %s: factorial(%s) = %s" % (name, number, f))

loop = asyncio.get_event_loop()
loop.run_until_complete(asyncio.gather(
    factorial("A", 2),
    factorial("B", 3),
    factorial("C", 4),
))
loop.close()
```

Output:

```
Task A: Compute factorial(2)...
Task B: Compute factorial(2)...
Task C: Compute factorial(2)...
Task A: factorial(2) = 2
Task B: Compute factorial(3)...
Task C: Compute factorial(3)...
Task B: factorial(3) = 6
Task C: Compute factorial(4)...
Task C: factorial(4) = 24
```

A task is automatically scheduled for execution when it is created. The event loop stops when all tasks are done.

Task functions

Note: In the functions below, the optional *loop* argument allows explicitly setting the event loop object used by the underlying task or coroutine. If it's not provided, the default event loop is used.

`asyncio.current_task`(*loop=None*)

Return the current running *Task* instance or `None`, if no task is running.

If *loop* is `None` *get_running_loop()* is used to get the current loop.

New in version 3.7.

`asyncio.all_tasks`(*loop=None*)

Return a set of *Task* objects created for the loop.

If *loop* is `None`, *get_running_loop()* is used for getting current loop (contrary to the deprecated *Task.all_tasks()* method that uses *get_event_loop()*.)

New in version 3.7.

asyncio.**as_completed**(*fs*, ***, *loop=None*, *timeout=None*)
Return an iterator whose values, when waited for, are *Future* instances.

Raises *asyncio.TimeoutError* if the timeout occurs before all Futures are done.

Example:

```
for f in as_completed(fs):
    result = await f  # The 'await' may raise
    # Use result
```

Note: The futures `f` are not necessarily members of fs.

asyncio.**ensure_future**(*coro_or_future*, ***, *loop=None*)
Schedule the execution of a *coroutine object*: wrap it in a future. Return a *Task* object.

If the argument is a *Future*, it is returned directly.

New in version 3.4.4.

Changed in version 3.5.1: The function accepts any *awaitable* object.

Note: *create_task()* (added in Python 3.7) is the preferable way for spawning new tasks.

See also:

The *create_task()* function and *AbstractEventLoop.create_task()* method.

asyncio.**wrap_future**(*future*, ***, *loop=None*)
Wrap a *concurrent.futures.Future* object in a *Future* object.

asyncio.**gather**(**coros_or_futures*, *loop=None*, *return_exceptions=False*)
Return a future aggregating results from the given coroutine objects or futures.

All futures must share the same event loop. If all the tasks are done successfully, the returned future's result is the list of results (in the order of the original sequence, not necessarily the order of results arrival). If *return_exceptions* is true, exceptions in the tasks are treated the same as successful results, and gathered in the result list; otherwise, the first raised exception will be immediately propagated to the returned future.

Cancellation: if the outer Future is cancelled, all children (that have not completed yet) are also cancelled. If any child is cancelled, this is treated as if it raised *CancelledError* – the outer Future is *not* cancelled in this case. (This is to prevent the cancellation of one child to cause other children to be cancelled.)

Changed in version 3.7.0: If the *gather* itself is cancelled, the cancellation is propagated regardless of *return_exceptions*.

asyncio.**iscoroutine**(*obj*)
Return `True` if *obj* is a *coroutine object*, which may be based on a generator or an `async def` coroutine.

asyncio.**iscoroutinefunction**(*func*)
Return `True` if *func* is determined to be a *coroutine function*, which may be a decorated generator function or an `async def` function.

asyncio.**run_coroutine_threadsafe**(*coro*, *loop*)
Submit a *coroutine object* to a given event loop.

Return a *concurrent.futures.Future* to access the result.

This function is meant to be called from a different thread than the one where the event loop is running. Usage:

```
# Create a coroutine
coro = asyncio.sleep(1, result=3)
# Submit the coroutine to a given loop
future = asyncio.run_coroutine_threadsafe(coro, loop)
# Wait for the result with an optional timeout argument
assert future.result(timeout) == 3
```

If an exception is raised in the coroutine, the returned future will be notified. It can also be used to cancel the task in the event loop:

```
try:
    result = future.result(timeout)
except asyncio.TimeoutError:
    print('The coroutine took too long, cancelling the task...')
    future.cancel()
except Exception as exc:
    print('The coroutine raised an exception: {!r}'.format(exc))
else:
    print('The coroutine returned: {!r}'.format(result))
```

See the *concurrency and multithreading* section of the documentation.

Note: Unlike other functions from the module, *run_coroutine_threadsafe()* requires the *loop* argument to be passed explicitly.

New in version 3.5.1.

coroutine asyncio.sleep(*delay*, *result=None*, ***, *loop=None*)

Create a *coroutine* that completes after a given time (in seconds). If *result* is provided, it is produced to the caller when the coroutine completes.

The resolution of the sleep depends on the *granularity of the event loop*.

This function is a *coroutine*.

coroutine asyncio.shield(*arg*, ***, *loop=None*)

Wait for a future, shielding it from cancellation.

The statement:

```
res = await shield(something())
```

is exactly equivalent to the statement:

```
res = await something()
```

except that if the coroutine containing it is cancelled, the task running in `something()` is not cancelled. From the point of view of `something()`, the cancellation did not happen. But its caller is still cancelled, so the yield-from expression still raises *CancelledError*. Note: If `something()` is cancelled by other means this will still cancel `shield()`.

If you want to completely ignore cancellation (not recommended) you can combine `shield()` with a try/except clause, as follows:

```
try:
    res = await shield(something())
except CancelledError:
    res = None
```

coroutine asyncio.wait(*futures*, ***, *loop=None*, *timeout=None*, *return_when=ALL_COMPLETED*)

Wait for the Futures and coroutine objects given by the sequence *futures* to complete. Coroutines will be wrapped in Tasks. Returns two sets of *Future*: (done, pending).

The sequence *futures* must not be empty.

timeout can be used to control the maximum number of seconds to wait before returning. *timeout* can be an int or float. If *timeout* is not specified or `None`, there is no limit to the wait time.

return_when indicates when this function should return. It must be one of the following constants of the *concurrent.futures* module:

Constant	Description
`FIRST_COMPLETED`	The function will return when any future finishes or is cancelled.
`FIRST_EXCEPTION`	The function will return when any future finishes by raising an exception. If no future raises an exception then it is equivalent to `ALL_COMPLETED`.
`ALL_COMPLETED`	The function will return when all futures finish or are cancelled.

Unlike *wait_for()*, `wait()` will not cancel the futures when a timeout occurs.

This function is a *coroutine*.

Usage:

```
done, pending = await asyncio.wait(fs)
```

Note: This does not raise *asyncio.TimeoutError*! Futures that aren't done when the timeout occurs are returned in the second set.

coroutine asyncio.wait_for(*fut*, *timeout*, ***, *loop=None*)

Wait for the single *Future* or *coroutine object* to complete with timeout. If *timeout* is `None`, block until the future completes.

Coroutine will be wrapped in *Task*.

Returns result of the Future or coroutine. When a timeout occurs, it cancels the task and raises *asyncio.TimeoutError*. To avoid the task cancellation, wrap it in *shield()*. The function will wait until the future is actually cancelled, so the total wait time may exceed the *timeout*.

If the wait is cancelled, the future *fut* is also cancelled.

This function is a *coroutine*, usage:

```
result = await asyncio.wait_for(fut, 60.0)
```

Changed in version 3.4.3: If the wait is cancelled, the future *fut* is now also cancelled.

Changed in version 3.7: When *fut* is cancelled due to a timeout, `wait_for` now waits for *fut* to be cancelled. Previously, it raised *TimeoutError* immediately.

19.5.4 Transports and protocols (callback based API)

Source code: Lib/asyncio/transports.py

Source code: Lib/asyncio/protocols.py

Transports

Transports are classes provided by *asyncio* in order to abstract various kinds of communication channels. You generally won't instantiate a transport yourself; instead, you will call an *AbstractEventLoop* method which will create the transport and try to initiate the underlying communication channel, calling you back when it succeeds.

Once the communication channel is established, a transport is always paired with a *protocol* instance. The protocol can then call the transport's methods for various purposes.

asyncio currently implements transports for TCP, UDP, SSL, and subprocess pipes. The methods available on a transport depend on the transport's kind.

The transport classes are *not thread safe*.

Changed in version 3.6: The socket option `TCP_NODELAY` is now set by default.

BaseTransport

class asyncio.BaseTransport

Base class for transports.

close()

Close the transport. If the transport has a buffer for outgoing data, buffered data will be flushed asynchronously. No more data will be received. After all buffered data is flushed, the protocol's `connection_lost()` method will be called with *None* as its argument.

is_closing()

Return `True` if the transport is closing or is closed.

New in version 3.5.1.

get_extra_info(*name*, *default=None*)

Return optional transport information. *name* is a string representing the piece of transport-specific information to get, *default* is the value to return if the information doesn't exist.

This method allows transport implementations to easily expose channel-specific information.

- socket:
  - `'peername'`: the remote address to which the socket is connected, result of *socket.socket.getpeername()* (`None` on error)
  - `'socket'`: *socket.socket* instance
  - `'sockname'`: the socket's own address, result of *socket.socket.getsockname()*
- SSL socket:
  - `'compression'`: the compression algorithm being used as a string, or `None` if the connection isn't compressed; result of *ssl.SSLSocket.compression()*
  - `'cipher'`: a three-value tuple containing the name of the cipher being used, the version of the SSL protocol that defines its use, and the number of secret bits being used; result of *ssl.SSLSocket.cipher()*
  - `'peercert'`: peer certificate; result of *ssl.SSLSocket.getpeercert()*
  - `'sslcontext'`: *ssl.SSLContext* instance
  - `'ssl_object'`: *ssl.SSLObject* or *ssl.SSLSocket* instance
- pipe:
  - `'pipe'`: pipe object

- subprocess:
  - `'subprocess'`: *subprocess.Popen* instance

`set_protocol`(*protocol*)
Set a new protocol. Switching protocol should only be done when both protocols are documented to support the switch.

New in version 3.5.3.

`get_protocol`()
Return the current protocol.

New in version 3.5.3.

Changed in version 3.5.1: `'ssl_object'` info was added to SSL sockets.

ReadTransport

`class asyncio.ReadTransport`
Interface for read-only transports.

`is_reading`()
Return `True` if the transport is receiving new data.

New in version 3.7.

`pause_reading`()
Pause the receiving end of the transport. No data will be passed to the protocol's `data_received()` method until *resume_reading()* is called.

Changed in version 3.7: The method is idempotent, i.e. it can be called when the transport is already paused or closed.

`resume_reading`()
Resume the receiving end. The protocol's `data_received()` method will be called once again if some data is available for reading.

Changed in version 3.7: The method is idempotent, i.e. it can be called when the transport is already reading.

WriteTransport

`class asyncio.WriteTransport`
Interface for write-only transports.

`abort`()
Close the transport immediately, without waiting for pending operations to complete. Buffered data will be lost. No more data will be received. The protocol's `connection_lost()` method will eventually be called with *None* as its argument.

`can_write_eof`()
Return *True* if the transport supports *write_eof()*, *False* if not.

`get_write_buffer_size`()
Return the current size of the output buffer used by the transport.

`get_write_buffer_limits`()
Get the *high*- and *low*-water limits for write flow control. Return a tuple `(low, high)` where *low* and *high* are positive number of bytes.

Use *set_write_buffer_limits()* to set the limits.

New in version 3.4.2.

set_write_buffer_limits(*high=None*, *low=None*)
Set the *high*- and *low*-water limits for write flow control.

These two values (measured in number of bytes) control when the protocol's `pause_writing()` and `resume_writing()` methods are called. If specified, the low-water limit must be less than or equal to the high-water limit. Neither *high* nor *low* can be negative.

`pause_writing()` is called when the buffer size becomes greater than or equal to the *high* value. If writing has been paused, `resume_writing()` is called when the buffer size becomes less than or equal to the *low* value.

The defaults are implementation-specific. If only the high-water limit is given, the low-water limit defaults to an implementation-specific value less than or equal to the high-water limit. Setting *high* to zero forces *low* to zero as well, and causes `pause_writing()` to be called whenever the buffer becomes non-empty. Setting *low* to zero causes `resume_writing()` to be called only once the buffer is empty. Use of zero for either limit is generally sub-optimal as it reduces opportunities for doing I/O and computation concurrently.

Use *get_write_buffer_limits()* to get the limits.

write(*data*)
Write some *data* bytes to the transport.

This method does not block; it buffers the data and arranges for it to be sent out asynchronously.

writelines(*list_of_data*)
Write a list (or any iterable) of data bytes to the transport. This is functionally equivalent to calling *write()* on each element yielded by the iterable, but may be implemented more efficiently.

write_eof()
Close the write end of the transport after flushing buffered data. Data may still be received.

This method can raise *NotImplementedError* if the transport (e.g. SSL) doesn't support half-closes.

DatagramTransport

DatagramTransport.**sendto**(*data*, *addr=None*)
Send the *data* bytes to the remote peer given by *addr* (a transport-dependent target address). If *addr* is *None*, the data is sent to the target address given on transport creation.

This method does not block; it buffers the data and arranges for it to be sent out asynchronously.

DatagramTransport.**abort**()
Close the transport immediately, without waiting for pending operations to complete. Buffered data will be lost. No more data will be received. The protocol's `connection_lost()` method will eventually be called with *None* as its argument.

BaseSubprocessTransport

class asyncio.**BaseSubprocessTransport**

get_pid()
Return the subprocess process id as an integer.

get_pipe_transport(*fd*)
Return the transport for the communication pipe corresponding to the integer file descriptor *fd*:

- 0: readable streaming transport of the standard input (*stdin*), or *None* if the subprocess was not created with `stdin=PIPE`
- 1: writable streaming transport of the standard output (*stdout*), or *None* if the subprocess was not created with `stdout=PIPE`
- 2: writable streaming transport of the standard error (*stderr*), or *None* if the subprocess was not created with `stderr=PIPE`
- other *fd*: *None*

`get_returncode()`
Return the subprocess returncode as an integer or *None* if it hasn't returned, similarly to the *subprocess.Popen.returncode* attribute.

`kill()`
Kill the subprocess, as in *subprocess.Popen.kill()*.

On POSIX systems, the function sends SIGKILL to the subprocess. On Windows, this method is an alias for *terminate()*.

`send_signal(`*signal*`)`
Send the *signal* number to the subprocess, as in *subprocess.Popen.send_signal()*.

`terminate()`
Ask the subprocess to stop, as in *subprocess.Popen.terminate()*. This method is an alias for the *close()* method.

On POSIX systems, this method sends SIGTERM to the subprocess. On Windows, the Windows API function TerminateProcess() is called to stop the subprocess.

`close()`
Ask the subprocess to stop by calling the *terminate()* method if the subprocess hasn't returned yet, and close transports of all pipes (*stdin*, *stdout* and *stderr*).

Protocols

asyncio provides base classes that you can subclass to implement your network protocols. Those classes are used in conjunction with *transports* (see below): the protocol parses incoming data and asks for the writing of outgoing data, while the transport is responsible for the actual I/O and buffering.

When subclassing a protocol class, it is recommended you override certain methods. Those methods are callbacks: they will be called by the transport on certain events (for example when some data is received); you shouldn't call them yourself, unless you are implementing a transport.

Note: All callbacks have default implementations, which are empty. Therefore, you only need to implement the callbacks for the events in which you are interested.

Protocol classes

`class asyncio.Protocol`
The base class for implementing streaming protocols (for use with e.g. TCP and SSL transports).

`class asyncio.BufferedProtocol`
A base class for implementing streaming protocols with manual control of the receive buffer.

New in version 3.7: **Important:** this has been added to asyncio in Python 3.7 *on a provisional basis*! Treat it as an experimental API that might be changed or removed in Python 3.8.

class asyncio.DatagramProtocol
The base class for implementing datagram protocols (for use with e.g. UDP transports).

class asyncio.SubprocessProtocol
The base class for implementing protocols communicating with child processes (through a set of unidirectional pipes).

Connection callbacks

These callbacks may be called on *Protocol*, *DatagramProtocol* and *SubprocessProtocol* instances:

BaseProtocol.connection_made(*transport*)
Called when a connection is made.

The *transport* argument is the transport representing the connection. You are responsible for storing it somewhere (e.g. as an attribute) if you need to.

BaseProtocol.connection_lost(*exc*)
Called when the connection is lost or closed.

The argument is either an exception object or *None*. The latter means a regular EOF is received, or the connection was aborted or closed by this side of the connection.

connection_made() and *connection_lost()* are called exactly once per successful connection. All other callbacks will be called between those two methods, which allows for easier resource management in your protocol implementation.

The following callbacks may be called only on *SubprocessProtocol* instances:

SubprocessProtocol.pipe_data_received(*fd*, *data*)
Called when the child process writes data into its stdout or stderr pipe. *fd* is the integer file descriptor of the pipe. *data* is a non-empty bytes object containing the data.

SubprocessProtocol.pipe_connection_lost(*fd*, *exc*)
Called when one of the pipes communicating with the child process is closed. *fd* is the integer file descriptor that was closed.

SubprocessProtocol.process_exited()
Called when the child process has exited.

Streaming protocols

The following callbacks are called on *Protocol* instances:

Protocol.data_received(*data*)
Called when some data is received. *data* is a non-empty bytes object containing the incoming data.

Note: Whether the data is buffered, chunked or reassembled depends on the transport. In general, you shouldn't rely on specific semantics and instead make your parsing generic and flexible enough. However, data is always received in the correct order.

Protocol.eof_received()
Called when the other end signals it won't send any more data (for example by calling `write_eof()`, if the other end also uses asyncio).

This method may return a false value (including `None`), in which case the transport will close itself. Conversely, if this method returns a true value, closing the transport is up to the protocol. Since the default implementation returns `None`, it implicitly closes the connection.

Note: Some transports such as SSL don't support half-closed connections, in which case returning true from this method will not prevent closing the connection.

`data_received()` can be called an arbitrary number of times during a connection. However, `eof_received()` is called at most once and, if called, `data_received()` won't be called after it.

State machine:

```
start -> connection_made
    [-> data_received]*
    [-> eof_received]?
-> connection_lost -> end
```

Streaming protocols with manual receive buffer control

New in version 3.7: **Important:** *BufferedProtocol* has been added to asyncio in Python 3.7 *on a provisional basis*! Consider it as an experimental API that might be changed or removed in Python 3.8.

Event methods, such as *AbstractEventLoop.create_server()* and *AbstractEventLoop.create_connection()*, accept factories that return protocols that implement this interface.

The idea of BufferedProtocol is that it allows to manually allocate and control the receive buffer. Event loops can then use the buffer provided by the protocol to avoid unnecessary data copies. This can result in noticeable performance improvement for protocols that receive big amounts of data. Sophisticated protocols implementations can allocate the buffer only once at creation time.

The following callbacks are called on *BufferedProtocol* instances:

`BufferedProtocol.get_buffer(`*sizehint*`)`
Called to allocate a new receive buffer.

sizehint is a recommended minimal size for the returned buffer. It is acceptable to return smaller or bigger buffers than what *sizehint* suggests. When set to -1, the buffer size can be arbitrary. It is an error to return a zero-sized buffer.

Must return an object that implements the buffer protocol.

`BufferedProtocol.buffer_updated(`*nbytes*`)`
Called when the buffer was updated with the received data.

nbytes is the total number of bytes that were written to the buffer.

`BufferedProtocol.eof_received()`
See the documentation of the *Protocol.eof_received()* method.

`get_buffer()` can be called an arbitrary number of times during a connection. However, `eof_received()` is called at most once and, if called, `get_buffer()` and `buffer_updated()` won't be called after it.

State machine:

```
start -> connection_made
    [-> get_buffer
        [-> buffer_updated]?
    ]*
    [-> eof_received]?
-> connection_lost -> end
```

Datagram protocols

The following callbacks are called on *DatagramProtocol* instances.

DatagramProtocol.**datagram_received**(*data*, *addr*)
Called when a datagram is received. *data* is a bytes object containing the incoming data. *addr* is the address of the peer sending the data; the exact format depends on the transport.

DatagramProtocol.**error_received**(*exc*)
Called when a previous send or receive operation raises an *OSError*. *exc* is the *OSError* instance.

This method is called in rare conditions, when the transport (e.g. UDP) detects that a datagram couldn't be delivered to its recipient. In many conditions though, undeliverable datagrams will be silently dropped.

Flow control callbacks

These callbacks may be called on *Protocol*, *DatagramProtocol* and *SubprocessProtocol* instances:

BaseProtocol.**pause_writing**()
Called when the transport's buffer goes over the high-water mark.

BaseProtocol.**resume_writing**()
Called when the transport's buffer drains below the low-water mark.

`pause_writing()` and `resume_writing()` calls are paired – `pause_writing()` is called once when the buffer goes strictly over the high-water mark (even if subsequent writes increases the buffer size even more), and eventually `resume_writing()` is called once when the buffer size reaches the low-water mark.

Note: If the buffer size equals the high-water mark, `pause_writing()` is not called – it must go strictly over. Conversely, `resume_writing()` is called when the buffer size is equal or lower than the low-water mark. These end conditions are important to ensure that things go as expected when either mark is zero.

Note: On BSD systems (OS X, FreeBSD, etc.) flow control is not supported for *DatagramProtocol*, because send failures caused by writing too many packets cannot be detected easily. The socket always appears 'ready' and excess packets are dropped; an *OSError* with errno set to *errno.ENOBUFS* may or may not be raised; if it is raised, it will be reported to *DatagramProtocol.error_received()* but otherwise ignored.

Coroutines and protocols

Coroutines can be scheduled in a protocol method using *ensure_future()*, but there is no guarantee made about the execution order. Protocols are not aware of coroutines created in protocol methods and so will not wait for them.

To have a reliable execution order, use *stream objects* in a coroutine with `await`. For example, the *StreamWriter.drain()* coroutine can be used to wait until the write buffer is flushed.

Protocol examples

TCP echo client protocol

TCP echo client using the *AbstractEventLoop.create_connection()* method, send data and wait until the connection is closed:

```
import asyncio

class EchoClientProtocol(asyncio.Protocol):
    def __init__(self, message, loop):
        self.message = message
        self.loop = loop

    def connection_made(self, transport):
        transport.write(self.message.encode())
        print('Data sent: {!r}'.format(self.message))

    def data_received(self, data):
        print('Data received: {!r}'.format(data.decode()))

    def connection_lost(self, exc):
        print('The server closed the connection')
        print('Stop the event loop')
        self.loop.stop()

loop = asyncio.get_event_loop()
message = 'Hello World!'
coro = loop.create_connection(lambda: EchoClientProtocol(message, loop),
                              '127.0.0.1', 8888)
loop.run_until_complete(coro)
loop.run_forever()
loop.close()
```

The event loop is running twice. The *run_until_complete()* method is preferred in this short example to raise an exception if the server is not listening, instead of having to write a short coroutine to handle the exception and stop the running loop. At *run_until_complete()* exit, the loop is no longer running, so there is no need to stop the loop in case of an error.

See also:

The *TCP echo client using streams* example uses the *asyncio.open_connection()* function.

TCP echo server protocol

TCP echo server using the *AbstractEventLoop.create_server()* method, send back received data and close the connection:

```
import asyncio

class EchoServerClientProtocol(asyncio.Protocol):
    def connection_made(self, transport):
        peername = transport.get_extra_info('peername')
        print('Connection from {}'.format(peername))
        self.transport = transport

    def data_received(self, data):
```

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```
        message = data.decode()
        print('Data received: {!r}'.format(message))

        print('Send: {!r}'.format(message))
        self.transport.write(data)

        print('Close the client socket')
        self.transport.close()

loop = asyncio.get_event_loop()
# Each client connection will create a new protocol instance
coro = loop.create_server(EchoServerClientProtocol, '127.0.0.1', 8888)
server = loop.run_until_complete(coro)

# Serve requests until Ctrl+C is pressed
print('Serving on {}'.format(server.sockets[0].getsockname()))
try:
    loop.run_forever()
except KeyboardInterrupt:
    pass

# Close the server
server.close()
loop.run_until_complete(server.wait_closed())
loop.close()
```

`Transport.close()` can be called immediately after *`WriteTransport.write()`* even if data are not sent yet on the socket: both methods are asynchronous. `await` is not needed because these transport methods are not coroutines.

See also:

The *TCP echo server using streams* example uses the *`asyncio.start_server()`* function.

UDP echo client protocol

UDP echo client using the *`AbstractEventLoop.create_datagram_endpoint()`* method, send data and close the transport when we received the answer:

```
import asyncio

class EchoClientProtocol:
    def __init__(self, message, loop):
        self.message = message
        self.loop = loop
        self.transport = None

    def connection_made(self, transport):
        self.transport = transport
        print('Send:', self.message)
        self.transport.sendto(self.message.encode())

    def datagram_received(self, data, addr):
        print("Received:", data.decode())

        print("Close the socket")
```

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```
        self.transport.close()

    def error_received(self, exc):
        print('Error received:', exc)

    def connection_lost(self, exc):
        print("Socket closed, stop the event loop")
        loop = asyncio.get_event_loop()
        loop.stop()

loop = asyncio.get_event_loop()
message = "Hello World!"
connect = loop.create_datagram_endpoint(
    lambda: EchoClientProtocol(message, loop),
    remote_addr=('127.0.0.1', 9999))
transport, protocol = loop.run_until_complete(connect)
loop.run_forever()
transport.close()
loop.close()
```

UDP echo server protocol

UDP echo server using the *AbstractEventLoop.create_datagram_endpoint()* method, send back received data:

```
import asyncio

class EchoServerProtocol:
    def connection_made(self, transport):
        self.transport = transport

    def datagram_received(self, data, addr):
        message = data.decode()
        print('Received %r from %s' % (message, addr))
        print('Send %r to %s' % (message, addr))
        self.transport.sendto(data, addr)

loop = asyncio.get_event_loop()
print("Starting UDP server")
# One protocol instance will be created to serve all client requests
listen = loop.create_datagram_endpoint(
    EchoServerProtocol, local_addr=('127.0.0.1', 9999))
transport, protocol = loop.run_until_complete(listen)

try:
    loop.run_forever()
except KeyboardInterrupt:
    pass

transport.close()
loop.close()
```

Register an open socket to wait for data using a protocol

Wait until a socket receives data using the *AbstractEventLoop.create_connection()* method with a protocol, and then close the event loop

```
import asyncio
from socket import socketpair

# Create a pair of connected sockets
rsock, wsock = socketpair()
loop = asyncio.get_event_loop()

class MyProtocol(asyncio.Protocol):
    transport = None

    def connection_made(self, transport):
        self.transport = transport

    def data_received(self, data):
        print("Received:", data.decode())

        # We are done: close the transport (it will call connection_lost())
        self.transport.close()

    def connection_lost(self, exc):
        # The socket has been closed, stop the event loop
        loop.stop()

# Register the socket to wait for data
connect_coro = loop.create_connection(MyProtocol, sock=rsock)
transport, protocol = loop.run_until_complete(connect_coro)

# Simulate the reception of data from the network
loop.call_soon(wsock.send, 'abc'.encode())

# Run the event loop
loop.run_forever()

# We are done, close sockets and the event loop
rsock.close()
wsock.close()
loop.close()
```

See also:

The *watch a file descriptor for read events* example uses the low-level *AbstractEventLoop.add_reader()* method to register the file descriptor of a socket.

The *register an open socket to wait for data using streams* example uses high-level streams created by the *open_connection()* function in a coroutine.

19.5.5 Streams (coroutine based API)

Source code: Lib/asyncio/streams.py

Stream functions

Note: The top-level functions in this module are meant as convenience wrappers only; there's really nothing special there, and if they don't do exactly what you want, feel free to copy their code.

coroutine asyncio.open_connection(*host=None*, *port=None*, ***, *loop=None*, *limit=None*, *ssl=None*, *family=0*, *proto=0*, *flags=0*, *sock=None*, *local_addr=None*, *server_hostname=None*, *ssl_handshake_timeout=None*)

A wrapper for *create_connection()* returning a (reader, writer) pair.

The reader returned is a *StreamReader* instance; the writer is a *StreamWriter* instance.

When specified, the *loop* argument determines which event loop to use, and the *limit* argument determines the buffer size limit used by the returned *StreamReader* instance.

The rest of the arguments are passed directly to *AbstractEventLoop.create_connection()*.

This function is a *coroutine*.

New in version 3.7: The *ssl_handshake_timeout* parameter.

coroutine asyncio.start_server(*client_connected_cb*, *host=None*, *port=None*, ***, *loop=None*, *limit=None*, *family=socket.AF_UNSPEC*, *flags=socket.AI_PASSIVE*, *sock=None*, *backlog=100*, *ssl=None*, *reuse_address=None*, *reuse_port=None*, *ssl_handshake_timeout=None*, *start_serving=True*)

Start a socket server, with a callback for each client connected. The return value is the same as *create_server()*.

The *client_connected_cb* callback is called whenever a new client connection is established. It receives a reader/writer pair as two arguments, the first is a *StreamReader* instance, and the second is a *StreamWriter* instance.

client_connected_cb accepts a plain callable or a *coroutine function*; if it is a coroutine function, it will be automatically converted into a *Task*.

When specified, the *loop* argument determines which event loop to use, and the *limit* argument determines the buffer size limit used by the *StreamReader* instance passed to *client_connected_cb*.

The rest of the arguments are passed directly to *create_server()*.

This function is a *coroutine*.

New in version 3.7: The *ssl_handshake_timeout* and *start_serving* parameters.

coroutine asyncio.open_unix_connection(*path=None*, ***, *loop=None*, *limit=None*, *ssl=None*, *sock=None*, *server_hostname=None*, *ssl_handshake_timeout=None*)

A wrapper for *create_unix_connection()* returning a (reader, writer) pair.

When specified, the *loop* argument determines which event loop to use, and the *limit* argument determines the buffer size limit used by the returned *StreamReader* instance.

The rest of the arguments are passed directly to *create_unix_connection()*.

This function is a *coroutine*.

Availability: UNIX.

New in version 3.7: The *ssl_handshake_timeout* parameter.

Changed in version 3.7: The *path* parameter can now be a *path-like object*

coroutine asyncio.start_unix_server(*client_connected_cb*, *path=None*, ***, *loop=None*, *limit=None*, *sock=None*, *backlog=100*, *ssl=None*, *ssl_handshake_timeout=None*, *start_serving=True*)

Start a UNIX Domain Socket server, with a callback for each client connected.

The *client_connected_cb* callback is called whenever a new client connection is established. It receives a reader/writer pair as two arguments, the first is a *StreamReader* instance, and the second is a *StreamWriter* instance.

client_connected_cb accepts a plain callable or a *coroutine function*; if it is a coroutine function, it will be automatically converted into a *Task*.

When specified, the *loop* argument determines which event loop to use, and the *limit* argument determines the buffer size limit used by the *StreamReader* instance passed to *client_connected_cb*.

The rest of the arguments are passed directly to *create_unix_server()*.

This function is a *coroutine*.

Availability: UNIX.

New in version 3.7: The *ssl_handshake_timeout* and *start_serving* parameters.

Changed in version 3.7: The *path* parameter can now be a *path-like object*.

StreamReader

class asyncio.StreamReader(*limit=None*, *loop=None*)

This class is *not thread safe*.

exception()
Get the exception.

feed_eof()
Acknowledge the EOF.

feed_data(*data*)
Feed *data* bytes in the internal buffer. Any operations waiting for the data will be resumed.

set_exception(*exc*)
Set the exception.

set_transport(*transport*)
Set the transport.

coroutine read(*n=-1*)
Read up to *n* bytes. If *n* is not provided, or set to `-1`, read until EOF and return all read bytes.

If the EOF was received and the internal buffer is empty, return an empty `bytes` object.

This method is a *coroutine*.

coroutine readline()
Read one line, where "line" is a sequence of bytes ending with `\n`.

If EOF is received, and `\n` was not found, the method will return the partial read bytes.

If the EOF was received and the internal buffer is empty, return an empty `bytes` object.

This method is a *coroutine*.

coroutine readexactly(*n*)
Read exactly *n* bytes. Raise an *IncompleteReadError* if the end of the stream is reached before *n* can be read, the *IncompleteReadError.partial* attribute of the exception contains the partial read bytes.

This method is a *coroutine*.

coroutine readuntil(*separator=b'\n'*)
Read data from the stream until `separator` is found.

On success, the data and separator will be removed from the internal buffer (consumed). Returned data will include the separator at the end.

Configured stream limit is used to check result. Limit sets the maximal length of data that can be returned, not counting the separator.

If an EOF occurs and the complete separator is still not found, an *IncompleteReadError* exception will be raised, and the internal buffer will be reset. The *IncompleteReadError.partial* attribute may contain the separator partially.

If the data cannot be read because of over limit, a *LimitOverrunError* exception will be raised, and the data will be left in the internal buffer, so it can be read again.

New in version 3.5.2.

at_eof()
Return `True` if the buffer is empty and *feed_eof()* was called.

StreamWriter

class asyncio.StreamWriter(*transport*, *protocol*, *reader*, *loop*)
Wraps a Transport.

This exposes *write()*, *writelines()*, *can_write_eof()*, *write_eof()*, *get_extra_info()* and *close()*. It adds *drain()* which returns an optional *Future* on which you can wait for flow control. It also adds a transport attribute which references the `Transport` directly.

This class is *not thread safe*.

transport
Transport.

can_write_eof()
Return *True* if the transport supports *write_eof()*, *False* if not. See *WriteTransport.can_write_eof()*.

close()
Close the transport: see *BaseTransport.close()*.

is_closing()
Return `True` if the writer is closing or is closed.

New in version 3.7.

coroutine wait_closed()
Wait until the writer is closed.

Should be called after *close()* to wait until the underlying connection (and the associated transport/protocol pair) is closed.

New in version 3.7.

coroutine drain()
Let the write buffer of the underlying transport a chance to be flushed.

The intended use is to write:

```
w.write(data)
await w.drain()
```

When the size of the transport buffer reaches the high-water limit (the protocol is paused), block until the size of the buffer is drained down to the low-water limit and the protocol is resumed. When there is nothing to wait for, the yield-from continues immediately.

Yielding from *drain()* gives the opportunity for the loop to schedule the write operation and flush the buffer. It should especially be used when a possibly large amount of data is written to the transport, and the coroutine does not yield-from between calls to *write()*.

This method is a *coroutine*.

get_extra_info(*name*, *default=None*)
Return optional transport information: see *BaseTransport.get_extra_info()*.

write(*data*)
Write some *data* bytes to the transport: see *WriteTransport.write()*.

writelines(*data*)
Write a list (or any iterable) of data bytes to the transport: see *WriteTransport.writelines()*.

write_eof()
Close the write end of the transport after flushing buffered data: see *WriteTransport.write_eof()*.

StreamReaderProtocol

class asyncio.StreamReaderProtocol(*stream_reader*, *client_connected_cb=None*, *loop=None*)
Trivial helper class to adapt between *Protocol* and *StreamReader*. Subclass of *Protocol*.

stream_reader is a *StreamReader* instance, *client_connected_cb* is an optional function called with (stream_reader, stream_writer) when a connection is made, *loop* is the event loop instance to use.

(This is a helper class instead of making *StreamReader* itself a *Protocol* subclass, because the *StreamReader* has other potential uses, and to prevent the user of the *StreamReader* from accidentally calling inappropriate methods of the protocol.)

IncompleteReadError

exception asyncio.IncompleteReadError

Incomplete read error, subclass of *EOFError*.

expected
Total number of expected bytes (*int*).

partial
Read bytes string before the end of stream was reached (*bytes*).

LimitOverrunError

exception asyncio.LimitOverrunError
Reached the buffer limit while looking for a separator.

consumed
Total number of to be consumed bytes.

Stream examples

TCP echo client using streams

TCP echo client using the *asyncio.open_connection()* function:

```
import asyncio

async def tcp_echo_client(message, loop):
    reader, writer = await asyncio.open_connection('127.0.0.1', 8888,
                                                   loop=loop)

    print('Send: %r' % message)
    writer.write(message.encode())

    data = await reader.read(100)
    print('Received: %r' % data.decode())

    print('Close the socket')
    writer.close()

message = 'Hello World!'
loop = asyncio.get_event_loop()
loop.run_until_complete(tcp_echo_client(message, loop))
loop.close()
```

See also:

The *TCP echo client protocol* example uses the *AbstractEventLoop.create_connection()* method.

TCP echo server using streams

TCP echo server using the *asyncio.start_server()* function:

```
import asyncio

async def handle_echo(reader, writer):
    data = await reader.read(100)
    message = data.decode()
    addr = writer.get_extra_info('peername')
    print("Received %r from %r" % (message, addr))

    print("Send: %r" % message)
    writer.write(data)
    await writer.drain()

    print("Close the client socket")
    writer.close()

loop = asyncio.get_event_loop()
coro = asyncio.start_server(handle_echo, '127.0.0.1', 8888, loop=loop)
server = loop.run_until_complete(coro)

# Serve requests until Ctrl+C is pressed
print('Serving on {}'.format(server.sockets[0].getsockname()))
try:
    loop.run_forever()
```

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```
except KeyboardInterrupt:
    pass

# Close the server
server.close()
loop.run_until_complete(server.wait_closed())
loop.close()
```

See also:

The *TCP echo server protocol* example uses the *AbstractEventLoop.create_server()* method.

Get HTTP headers

Simple example querying HTTP headers of the URL passed on the command line:

```
import asyncio
import urllib.parse
import sys

@asyncio.coroutine
def print_http_headers(url):
    url = urllib.parse.urlsplit(url)
    if url.scheme == 'https':
        connect = asyncio.open_connection(url.hostname, 443, ssl=True)
    else:
        connect = asyncio.open_connection(url.hostname, 80)
    reader, writer = await connect
    query = ('HEAD {path} HTTP/1.0\r\n'
             'Host: {hostname}\r\n'
             '\r\n').format(path=url.path or '/', hostname=url.hostname)
    writer.write(query.encode('latin-1'))
    while True:
        line = await reader.readline()
        if not line:
            break
        line = line.decode('latin1').rstrip()
        if line:
            print('HTTP header> %s' % line)

    # Ignore the body, close the socket
    writer.close()

url = sys.argv[1]
loop = asyncio.get_event_loop()
task = asyncio.ensure_future(print_http_headers(url))
loop.run_until_complete(task)
loop.close()
```

Usage:

```
python example.py http://example.com/path/page.html
```

or with HTTPS:

```
python example.py https://example.com/path/page.html
```

Register an open socket to wait for data using streams

Coroutine waiting until a socket receives data using the *open_connection()* function:

```
import asyncio
from socket import socketpair

async def wait_for_data(loop):
    # Create a pair of connected sockets
    rsock, wsock = socketpair()

    # Register the open socket to wait for data
    reader, writer = await asyncio.open_connection(sock=rsock, loop=loop)

    # Simulate the reception of data from the network
    loop.call_soon(wsock.send, 'abc'.encode())

    # Wait for data
    data = await reader.read(100)

    # Got data, we are done: close the socket
    print("Received:", data.decode())
    writer.close()

    # Close the second socket
    wsock.close()

loop = asyncio.get_event_loop()
loop.run_until_complete(wait_for_data(loop))
loop.close()
```

See also:

The *register an open socket to wait for data using a protocol* example uses a low-level protocol created by the *AbstractEventLoop.create_connection()* method.

The *watch a file descriptor for read events* example uses the low-level *AbstractEventLoop.add_reader()* method to register the file descriptor of a socket.

19.5.6 Subprocess

Source code: Lib/asyncio/subprocess.py

Windows event loop

On Windows, the default event loop is *SelectorEventLoop* which does not support subprocesses. *ProactorEventLoop* should be used instead. Example to use it on Windows:

```
import asyncio, sys

if sys.platform == 'win32':
    loop = asyncio.ProactorEventLoop()
    asyncio.set_event_loop(loop)
```

See also:

Available event loops and *Platform support*.

Create a subprocess: high-level API using Process

coroutine asyncio.create_subprocess_exec(**args*, *stdin=None*, *stdout=None*, *stderr=None*, *loop=None*, *limit=None*, ***kwds*)

Create a subprocess.

The *limit* parameter sets the buffer limit passed to the *StreamReader*. See *AbstractEventLoop.subprocess_exec()* for other parameters.

Return a *Process* instance.

This function is a *coroutine*.

coroutine asyncio.create_subprocess_shell(*cmd*, *stdin=None*, *stdout=None*, *stderr=None*, *loop=None*, *limit=None*, ***kwds*)

Run the shell command *cmd*.

The *limit* parameter sets the buffer limit passed to the *StreamReader*. See *AbstractEventLoop.subprocess_shell()* for other parameters.

Return a *Process* instance.

It is the application's responsibility to ensure that all whitespace and metacharacters are quoted appropriately to avoid shell injection vulnerabilities. The *shlex.quote()* function can be used to properly escape whitespace and shell metacharacters in strings that are going to be used to construct shell commands.

This function is a *coroutine*.

Use the *AbstractEventLoop.connect_read_pipe()* and *AbstractEventLoop.connect_write_pipe()* methods to connect pipes.

Create a subprocess: low-level API using subprocess.Popen

Run subprocesses asynchronously using the *subprocess* module.

coroutine AbstractEventLoop.subprocess_exec(*protocol_factory*, **args*, *stdin=subprocess.PIPE*, *stdout=subprocess.PIPE*, *stderr=subprocess.PIPE*, ***kwargs*)

Create a subprocess from one or more string arguments (character strings or bytes strings encoded to the *filesystem encoding*), where the first string specifies the program to execute, and the remaining strings specify the program's arguments. (Thus, together the string arguments form the `sys.argv` value of the program, assuming it is a Python script.) This is similar to the standard library *subprocess.Popen* class called with shell=False and the list of strings passed as the first argument; however, where *Popen* takes a single argument which is list of strings, *subprocess_exec()* takes multiple string arguments.

The *protocol_factory* must instantiate a subclass of the *asyncio.SubprocessProtocol* class.

Other parameters:

- *stdin*: Either a file-like object representing the pipe to be connected to the subprocess's standard input stream using *connect_write_pipe()*, or the constant *subprocess.PIPE* (the default). By default a new pipe will be created and connected.
- *stdout*: Either a file-like object representing the pipe to be connected to the subprocess's standard output stream using *connect_read_pipe()*, or the constant *subprocess.PIPE* (the default). By default a new pipe will be created and connected.
- *stderr*: Either a file-like object representing the pipe to be connected to the subprocess's standard error stream using *connect_read_pipe()*, or one of the constants *subprocess.PIPE* (the default) or *subprocess.STDOUT*. By default a new pipe will be created and connected. When *subprocess.STDOUT* is specified, the subprocess's standard error stream will be connected to the same pipe as the standard output stream.

- All other keyword arguments are passed to *subprocess.Popen* without interpretation, except for *bufsize*, *universal_newlines* and *shell*, which should not be specified at all.

Returns a pair of `(transport, protocol)`, where *transport* is an instance of *BaseSubprocessTransport*.

This method is a *coroutine*.

See the constructor of the *subprocess.Popen* class for parameters.

coroutine AbstractEventLoop.**subprocess_shell**(*protocol_factory*, *cmd*, ***, *stdin=subprocess.PIPE*, *stdout=subprocess.PIPE*, *stderr=subprocess.PIPE*, ***kwargs*)

Create a subprocess from *cmd*, which is a character string or a bytes string encoded to the *filesystem encoding*, using the platform's "shell" syntax. This is similar to the standard library *subprocess.Popen* class called with `shell=True`.

The *protocol_factory* must instantiate a subclass of the *asyncio.SubprocessProtocol* class.

See *subprocess_exec()* for more details about the remaining arguments.

Returns a pair of `(transport, protocol)`, where *transport* is an instance of *BaseSubprocessTransport*.

It is the application's responsibility to ensure that all whitespace and metacharacters are quoted appropriately to avoid shell injection vulnerabilities. The *shlex.quote()* function can be used to properly escape whitespace and shell metacharacters in strings that are going to be used to construct shell commands.

This method is a *coroutine*.

See also:

The *AbstractEventLoop.connect_read_pipe()* and *AbstractEventLoop.connect_write_pipe()* methods.

Constants

asyncio.subprocess.**PIPE**
Special value that can be used as the *stdin*, *stdout* or *stderr* argument to *create_subprocess_shell()* and *create_subprocess_exec()* and indicates that a pipe to the standard stream should be opened.

asyncio.subprocess.**STDOUT**
Special value that can be used as the *stderr* argument to *create_subprocess_shell()* and *create_subprocess_exec()* and indicates that standard error should go into the same handle as standard output.

asyncio.subprocess.**DEVNULL**
Special value that can be used as the *stdin*, *stdout* or *stderr* argument to *create_subprocess_shell()* and *create_subprocess_exec()* and indicates that the special file *os.devnull* will be used.

Process

class asyncio.subprocess.**Process**
A subprocess created by the *create_subprocess_exec()* or the *create_subprocess_shell()* function.

The API of the *Process* class was designed to be close to the API of the *subprocess.Popen* class, but there are some differences:

- There is no explicit *poll()* method

- The *communicate()* and *wait()* methods don't take a *timeout* parameter: use the *wait_for()* function
- The *universal_newlines* parameter is not supported (only bytes strings are supported)
- The *wait()* method of the *Process* class is asynchronous whereas the *wait()* method of the *Popen* class is implemented as a busy loop.

This class is *not thread safe*. See also the *Subprocess and threads* section.

coroutine wait()
Wait for child process to terminate. Set and return *returncode* attribute.

This method is a *coroutine*.

Note: This will deadlock when using `stdout=PIPE` or `stderr=PIPE` and the child process generates enough output to a pipe such that it blocks waiting for the OS pipe buffer to accept more data. Use the *communicate()* method when using pipes to avoid that.

---

coroutine communicate(*input=None*)
Interact with process: Send data to stdin. Read data from stdout and stderr, until end-of-file is reached. Wait for process to terminate. The optional *input* argument should be data to be sent to the child process, or `None`, if no data should be sent to the child. The type of *input* must be bytes.

communicate() returns a tuple `(stdout_data, stderr_data)`.

If a *BrokenPipeError* or *ConnectionResetError* exception is raised when writing *input* into stdin, the exception is ignored. It occurs when the process exits before all data are written into stdin.

Note that if you want to send data to the process's stdin, you need to create the Process object with `stdin=PIPE`. Similarly, to get anything other than `None` in the result tuple, you need to give `stdout=PIPE` and/or `stderr=PIPE` too.

This method is a *coroutine*.

Note: The data read is buffered in memory, so do not use this method if the data size is large or unlimited.

Changed in version 3.4.2: The method now ignores *BrokenPipeError* and *ConnectionResetError*.

send_signal(*signal*)
Sends the signal *signal* to the child process.

Note: On Windows, `SIGTERM` is an alias for *terminate()*. `CTRL_C_EVENT` and `CTRL_BREAK_EVENT` can be sent to processes started with a *creationflags* parameter which includes `CREATE_NEW_PROCESS_GROUP`.

---

terminate()
Stop the child. On Posix OSs the method sends `signal.SIGTERM` to the child. On Windows the Win32 API function `TerminateProcess()` is called to stop the child.

kill()
Kills the child. On Posix OSs the function sends `SIGKILL` to the child. On Windows *kill()* is an alias for *terminate()*.

stdin
Standard input stream (*StreamWriter*), `None` if the process was created with `stdin=None`.

stdout
Standard output stream (*StreamReader*), `None` if the process was created with `stdout=None`.

stderr
Standard error stream (*StreamReader*), `None` if the process was created with `stderr=None`.

> **Warning:** Use the *communicate()* method rather than *.stdin.write*, *.stdout.read* or *.stderr.read* to avoid deadlocks due to streams pausing reading or writing and blocking the child process.

pid
The identifier of the process.

Note that for processes created by the *create_subprocess_shell()* function, this attribute is the process identifier of the spawned shell.

returncode
Return code of the process when it exited. A `None` value indicates that the process has not terminated yet.

A negative value `-N` indicates that the child was terminated by signal `N` (Unix only).

Subprocess and threads

asyncio supports running subprocesses from different threads, but there are limits:

- An event loop must run in the main thread
- The child watcher must be instantiated in the main thread, before executing subprocesses from other threads. Call the `get_child_watcher()` function in the main thread to instantiate the child watcher.

The *asyncio.subprocess.Process* class is not thread safe.

See also:

The *Concurrency and multithreading in asyncio* section.

Subprocess examples

Subprocess using transport and protocol

Example of a subprocess protocol using to get the output of a subprocess and to wait for the subprocess exit. The subprocess is created by the *AbstractEventLoop.subprocess_exec()* method:

```
import asyncio
import sys

class DateProtocol(asyncio.SubprocessProtocol):
    def __init__(self, exit_future):
        self.exit_future = exit_future
        self.output = bytearray()

    def pipe_data_received(self, fd, data):
        self.output.extend(data)
```

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```
    def process_exited(self):
        self.exit_future.set_result(True)

async def get_date(loop):
    code = 'import datetime; print(datetime.datetime.now())'
    exit_future = asyncio.Future(loop=loop)

    # Create the subprocess controlled by the protocol DateProtocol,
    # redirect the standard output into a pipe
    transport, protocol = await loop.subprocess_exec(
        lambda: DateProtocol(exit_future),
        sys.executable, '-c', code,
        stdin=None, stderr=None)

    # Wait for the subprocess exit using the process_exited() method
    # of the protocol
    await exit_future

    # Close the stdout pipe
    transport.close()

    # Read the output which was collected by the pipe_data_received()
    # method of the protocol
    data = bytes(protocol.output)
    return data.decode('ascii').rstrip()

if sys.platform == "win32":
    loop = asyncio.ProactorEventLoop()
    asyncio.set_event_loop(loop)
else:
    loop = asyncio.get_event_loop()

date = loop.run_until_complete(get_date(loop))
print("Current date: %s" % date)
loop.close()
```

Subprocess using streams

Example using the *Process* class to control the subprocess and the *StreamReader* class to read from the standard output. The subprocess is created by the *create_subprocess_exec()* function:

```
import asyncio.subprocess
import sys

@asyncio.coroutine
def get_date():
    code = 'import datetime; print(datetime.datetime.now())'

    # Create the subprocess, redirect the standard output into a pipe
    proc = await asyncio.create_subprocess_exec(
        sys.executable, '-c', code,
        stdout=asyncio.subprocess.PIPE)

    # Read one line of output
```

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```
    data = await proc.stdout.readline()
    line = data.decode('ascii').rstrip()

    # Wait for the subprocess exit
    await proc.wait()
    return line

if sys.platform == "win32":
    loop = asyncio.ProactorEventLoop()
    asyncio.set_event_loop(loop)
else:
    loop = asyncio.get_event_loop()

date = loop.run_until_complete(get_date())
print("Current date: %s" % date)
loop.close()
```

19.5.7 Synchronization primitives

Source code: Lib/asyncio/locks.py

Locks:

- *Lock*
- *Event*
- *Condition*

Semaphores:

- *Semaphore*
- *BoundedSemaphore*

asyncio lock API was designed to be close to classes of the *threading* module (*Lock*, *Event*, *Condition*, *Semaphore*, *BoundedSemaphore*), but it has no *timeout* parameter. The *asyncio.wait_for()* function can be used to cancel a task after a timeout.

Lock

class asyncio.Lock(*, *loop=None*)

Primitive lock objects.

A primitive lock is a synchronization primitive that is not owned by a particular coroutine when locked. A primitive lock is in one of two states, 'locked' or 'unlocked'.

The lock is created in the unlocked state. It has two basic methods, *acquire()* and *release()*. When the state is unlocked, acquire() changes the state to locked and returns immediately. When the state is locked, acquire() blocks until a call to release() in another coroutine changes it to unlocked, then the acquire() call resets it to locked and returns. The release() method should only be called in the locked state; it changes the state to unlocked and returns immediately. If an attempt is made to release an unlocked lock, a *RuntimeError* will be raised.

When more than one coroutine is blocked in acquire() waiting for the state to turn to unlocked, only one coroutine proceeds when a release() call resets the state to unlocked; first coroutine which is blocked in acquire() is being processed.

acquire() is a coroutine and should be called with `await`.

Locks support the *context management protocol*.

This class is *not thread safe*.

locked()
Return **True** if the lock is acquired.

coroutine acquire()
Acquire a lock.

This method blocks until the lock is unlocked, then sets it to locked and returns **True**.

This method is a *coroutine*.

release()
Release a lock.

When the lock is locked, reset it to unlocked, and return. If any other coroutines are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed.

When invoked on an unlocked lock, a *RuntimeError* is raised.

There is no return value.

Event

class asyncio.Event(**, loop=None*)
An Event implementation, asynchronous equivalent to *threading.Event*.

Class implementing event objects. An event manages a flag that can be set to true with the *set()* method and reset to false with the *clear()* method. The *wait()* method blocks until the flag is true. The flag is initially false.

This class is *not thread safe*.

clear()
Reset the internal flag to false. Subsequently, coroutines calling *wait()* will block until *set()* is called to set the internal flag to true again.

is_set()
Return **True** if and only if the internal flag is true.

set()
Set the internal flag to true. All coroutines waiting for it to become true are awakened. Coroutine that call *wait()* once the flag is true will not block at all.

coroutine wait()
Block until the internal flag is true.

If the internal flag is true on entry, return **True** immediately. Otherwise, block until another coroutine calls *set()* to set the flag to true, then return **True**.

This method is a *coroutine*.

Condition

class asyncio.Condition(*lock=None*, ***, *loop=None*)
A Condition implementation, asynchronous equivalent to *threading.Condition*.

This class implements condition variable objects. A condition variable allows one or more coroutines to wait until they are notified by another coroutine.

If the *lock* argument is given and not **None**, it must be a *Lock* object, and it is used as the underlying lock. Otherwise, a new *Lock* object is created and used as the underlying lock.

Conditions support the *context management protocol*.

This class is *not thread safe*.

coroutine acquire()
Acquire the underlying lock.

This method blocks until the lock is unlocked, then sets it to locked and returns `True`.

This method is a *coroutine*.

notify(*n=1*)
By default, wake up one coroutine waiting on this condition, if any. If the calling coroutine has not acquired the lock when this method is called, a *RuntimeError* is raised.

This method wakes up at most *n* of the coroutines waiting for the condition variable; it is a no-op if no coroutines are waiting.

Note: An awakened coroutine does not actually return from its *wait()* call until it can reacquire the lock. Since *notify()* does not release the lock, its caller should.

---

locked()
Return `True` if the underlying lock is acquired.

notify_all()
Wake up all coroutines waiting on this condition. This method acts like *notify()*, but wakes up all waiting coroutines instead of one. If the calling coroutine has not acquired the lock when this method is called, a *RuntimeError* is raised.

release()
Release the underlying lock.

When the lock is locked, reset it to unlocked, and return. If any other coroutines are blocked waiting for the lock to become unlocked, allow exactly one of them to proceed.

When invoked on an unlocked lock, a *RuntimeError* is raised.

There is no return value.

coroutine wait()
Wait until notified.

If the calling coroutine has not acquired the lock when this method is called, a *RuntimeError* is raised.

This method releases the underlying lock, and then blocks until it is awakened by a *notify()* or *notify_all()* call for the same condition variable in another coroutine. Once awakened, it re-acquires the lock and returns `True`.

This method is a *coroutine*.

coroutine wait_for(*predicate*)
Wait until a predicate becomes true.

The predicate should be a callable which result will be interpreted as a boolean value. The final predicate value is the return value.

This method is a *coroutine*.

Semaphore

class asyncio.Semaphore(*value=1*, ***, *loop=None*)
A Semaphore implementation.

A semaphore manages an internal counter which is decremented by each *acquire()* call and incremented by each *release()* call. The counter can never go below zero; when *acquire()* finds that it is zero, it blocks, waiting until some other coroutine calls *release()*.

The optional argument gives the initial value for the internal counter; it defaults to `1`. If the value given is less than `0`, *ValueError* is raised.

Semaphores support the *context management protocol*.

This class is *not thread safe*.

coroutine acquire()
Acquire a semaphore.

If the internal counter is larger than zero on entry, decrement it by one and return `True` immediately. If it is zero on entry, block, waiting until some other coroutine has called *release()* to make it larger than `0`, and then return `True`.

This method is a *coroutine*.

locked()
Returns `True` if semaphore can not be acquired immediately.

release()
Release a semaphore, incrementing the internal counter by one. When it was zero on entry and another coroutine is waiting for it to become larger than zero again, wake up that coroutine.

BoundedSemaphore

class asyncio.BoundedSemaphore(*value=1*, ***, *loop=None*)
A bounded semaphore implementation. Inherit from *Semaphore*.

This raises *ValueError* in *release()* if it would increase the value above the initial value.

Bounded semapthores support the *context management protocol*.

This class is *not thread safe*.

Using locks, conditions and semaphores in the `async with` statement

Lock, *Condition*, *Semaphore*, and *BoundedSemaphore* objects can be used in `async with` statements.

The `acquire()` method will be called when the block is entered, and `release()` will be called when the block is exited. Hence, the following snippet:

```
async with lock:
    # do something...
```

is equivalent to:

```
await lock.acquire()
try:
    # do something...
finally:
    lock.release()
```

Deprecated since version 3.7: Lock acquiring using `await lock` or `yield from lock` and `with` statement (`with await lock`, `with (yield from lock)`) are deprecated.

19.5.8 Queues

Source code: Lib/asyncio/queues.py

Queues:

- *Queue*
- *PriorityQueue*
- *LifoQueue*

asyncio queue API was designed to be close to classes of the *queue* module (*Queue*, *PriorityQueue*, *LifoQueue*), but it has no *timeout* parameter. The *asyncio.wait_for()* function can be used to cancel a task after a timeout.

Queue

class asyncio.Queue(*maxsize=0*, ***, *loop=None*)

A queue, useful for coordinating producer and consumer coroutines.

If *maxsize* is less than or equal to zero, the queue size is infinite. If it is an integer greater than `0`, then `await put()` will block when the queue reaches *maxsize*, until an item is removed by *get()*.

Unlike the standard library *queue*, you can reliably know this Queue's size with *qsize()*, since your single-threaded asyncio application won't be interrupted between calling *qsize()* and doing an operation on the Queue.

This class is *not thread safe*.

Changed in version 3.4.4: New *join()* and *task_done()* methods.

empty()

Return `True` if the queue is empty, `False` otherwise.

full()

Return `True` if there are *maxsize* items in the queue.

> **Note:** If the Queue was initialized with `maxsize=0` (the default), then *full()* is never `True`.

coroutine get()

Remove and return an item from the queue. If queue is empty, wait until an item is available.

This method is a *coroutine*.

See also:

The *empty()* method.

get_nowait()

Remove and return an item from the queue.

Return an item if one is immediately available, else raise *QueueEmpty*.

coroutine join()

Block until all items in the queue have been gotten and processed.

The count of unfinished tasks goes up whenever an item is added to the queue. The count goes down whenever a consumer thread calls *task_done()* to indicate that the item was retrieved and all work on it is complete. When the count of unfinished tasks drops to zero, *join()* unblocks.

This method is a *coroutine*.

New in version 3.4.4.

coroutine put(*item*)
Put an item into the queue. If the queue is full, wait until a free slot is available before adding item.

This method is a *coroutine*.

See also:

The *full()* method.

put_nowait(*item*)
Put an item into the queue without blocking.

If no free slot is immediately available, raise *QueueFull*.

qsize()
Number of items in the queue.

task_done()
Indicate that a formerly enqueued task is complete.

Used by queue consumers. For each *get()* used to fetch a task, a subsequent call to *task_done()* tells the queue that the processing on the task is complete.

If a *join()* is currently blocking, it will resume when all items have been processed (meaning that a *task_done()* call was received for every item that had been *put()* into the queue).

Raises *ValueError* if called more times than there were items placed in the queue.

New in version 3.4.4.

maxsize
Number of items allowed in the queue.

PriorityQueue

class asyncio.PriorityQueue
A subclass of *Queue*; retrieves entries in priority order (lowest first).

Entries are typically tuples of the form: (priority number, data).

LifoQueue

class asyncio.LifoQueue
A subclass of *Queue* that retrieves most recently added entries first.

Exceptions

exception asyncio.QueueEmpty
Exception raised when the *get_nowait()* method is called on a *Queue* object which is empty.

exception asyncio.QueueFull
Exception raised when the *put_nowait()* method is called on a *Queue* object which is full.

19.5.9 Develop with asyncio

Asynchronous programming is different than classical "sequential" programming. This page lists common traps and explains how to avoid them.

Debug mode of asyncio

The implementation of *asyncio* has been written for performance. In order to ease the development of asynchronous code, you may wish to enable *debug mode*.

To enable all debug checks for an application:

- Enable the asyncio debug mode globally by setting the environment variable `PYTHONASYNCIODEBUG` to `1`, using `-X dev` command line option (see the `-X` option), or by calling *AbstractEventLoop.set_debug()*.
- Set the log level of the *asyncio logger* to `logging.DEBUG`. For example, call `logging.basicConfig(level=logging.DEBUG)` at startup.
- Configure the *warnings* module to display *ResourceWarning* warnings. For example, use the `-Wdefault` command line option of Python to display them.

Examples debug checks:

- Log *coroutines defined but never "yielded from"*
- *call_soon()* and *call_at()* methods raise an exception if they are called from the wrong thread.
- Log the execution time of the selector
- Log callbacks taking more than 100 ms to be executed. The `AbstractEventLoop.slow_callback_duration` attribute is the minimum duration in seconds of "slow" callbacks.
- *ResourceWarning* warnings are emitted when transports and event loops are *not closed explicitly*.

Changed in version 3.7: The new `-X dev` command line option can now also be used to enable the debug mode.

See also:

The *AbstractEventLoop.set_debug()* method and the *asyncio logger*.

Cancellation

Cancellation of tasks is not common in classic programming. In asynchronous programming, not only is it something common, but you have to prepare your code to handle it.

Futures and tasks can be cancelled explicitly with their *Future.cancel()* method. The *wait_for()* function cancels the waited task when the timeout occurs. There are many other cases where a task can be cancelled indirectly.

Don't call *set_result()* or *set_exception()* method of *Future* if the future is cancelled: it would fail with an exception. For example, write:

```
if not fut.cancelled():
    fut.set_result('done')
```

Don't schedule directly a call to the *set_result()* or the *set_exception()* method of a future with *AbstractEventLoop.call_soon()*: the future can be cancelled before its method is called.

If you wait for a future, you should check early if the future was cancelled to avoid useless operations. Example:

```
async def slow_operation(fut):
    if fut.cancelled():
        return
    # ... slow computation ...
    await fut
    # ...
```

The *shield()* function can also be used to ignore cancellation.

Concurrency and multithreading

An event loop runs in a thread and executes all callbacks and tasks in the same thread. While a task is running in the event loop, no other task is running in the same thread. But when the task uses `await`, the task is suspended and the event loop executes the next task.

To schedule a callback from a different thread, the *AbstractEventLoop.call_soon_threadsafe()* method should be used. Example:

```
loop.call_soon_threadsafe(callback, *args)
```

Most asyncio objects are not thread safe. You should only worry if you access objects outside the event loop. For example, to cancel a future, don't call directly its *Future.cancel()* method, but:

```
loop.call_soon_threadsafe(fut.cancel)
```

To handle signals and to execute subprocesses, the event loop must be run in the main thread.

To schedule a coroutine object from a different thread, the *run_coroutine_threadsafe()* function should be used. It returns a *concurrent.futures.Future* to access the result:

```
future = asyncio.run_coroutine_threadsafe(coro_func(), loop)
result = future.result(timeout)  # Wait for the result with a timeout
```

The *AbstractEventLoop.run_in_executor()* method can be used with a thread pool executor to execute a callback in different thread to not block the thread of the event loop.

See also:

The *Synchronization primitives* section describes ways to synchronize tasks.

The *Subprocess and threads* section lists asyncio limitations to run subprocesses from different threads.

Handle blocking functions correctly

Blocking functions should not be called directly. For example, if a function blocks for 1 second, other tasks are delayed by 1 second which can have an important impact on reactivity.

For networking and subprocesses, the *asyncio* module provides high-level APIs like *protocols*.

An executor can be used to run a task in a different thread or even in a different process, to not block the thread of the event loop. See the *AbstractEventLoop.run_in_executor()* method.

See also:

The *Delayed calls* section details how the event loop handles time.

Logging

The *asyncio* module logs information with the *logging* module in the logger `'asyncio'`.

The default log level for the *asyncio* module is `logging.INFO`. For those not wanting such verbosity from *asyncio* the log level can be changed. For example, to change the level to `logging.WARNING`:

```
logging.getLogger('asyncio').setLevel(logging.WARNING)
```

Detect coroutine objects never scheduled

When a coroutine function is called and its result is not passed to *ensure_future()* or to the *AbstractEventLoop.create_task()* method, the execution of the coroutine object will never be scheduled which is probably a bug. *Enable the debug mode of asyncio* to *log a warning* to detect it.

Example with the bug:

```
import asyncio

async def test():
    print("never scheduled")

test()
```

Output in debug mode:

```
Coroutine test() at test.py:3 was never yielded from
Coroutine object created at (most recent call last):
  File "test.py", line 7, in <module>
    test()
```

The fix is to call the *ensure_future()* function or the *AbstractEventLoop.create_task()* method with the coroutine object.

See also:

Pending task destroyed.

Detect exceptions never consumed

Python usually calls *sys.excepthook()* on unhandled exceptions. If *Future.set_exception()* is called, but the exception is never consumed, *sys.excepthook()* is not called. Instead, *a log is emitted* when the future is deleted by the garbage collector, with the traceback where the exception was raised.

Example of unhandled exception:

```
import asyncio

@asyncio.coroutine
def bug():
    raise Exception("not consumed")

loop = asyncio.get_event_loop()
asyncio.ensure_future(bug())
loop.run_forever()
loop.close()
```

Output:

```
Task exception was never retrieved
future: <Task finished coro=<coro() done, defined at asyncio/coroutines.py:139>␣
↪exception=Exception('not consumed',)>
Traceback (most recent call last):
  File "asyncio/tasks.py", line 237, in _step
    result = next(coro)
  File "asyncio/coroutines.py", line 141, in coro
    res = func(*args, **kw)
```

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```
  File "test.py", line 5, in bug
    raise Exception("not consumed")
Exception: not consumed
```

Enable the debug mode of asyncio to get the traceback where the task was created. Output in debug mode:

```
Task exception was never retrieved
future: <Task finished coro=<bug() done, defined at test.py:3> exception=Exception('not consumed',
↪) created at test.py:8>
source_traceback: Object created at (most recent call last):
  File "test.py", line 8, in <module>
    asyncio.ensure_future(bug())
Traceback (most recent call last):
  File "asyncio/tasks.py", line 237, in _step
    result = next(coro)
  File "asyncio/coroutines.py", line 79, in __next__
    return next(self.gen)
  File "asyncio/coroutines.py", line 141, in coro
    res = func(*args, **kw)
  File "test.py", line 5, in bug
    raise Exception("not consumed")
Exception: not consumed
```

There are different options to fix this issue. The first option is to chain the coroutine in another coroutine and use classic try/except:

```
async def handle_exception():
    try:
        await bug()
    except Exception:
        print("exception consumed")

loop = asyncio.get_event_loop()
asyncio.ensure_future(handle_exception())
loop.run_forever()
loop.close()
```

Another option is to use the *AbstractEventLoop.run_until_complete()* function:

```
task = asyncio.ensure_future(bug())
try:
    loop.run_until_complete(task)
except Exception:
    print("exception consumed")
```

See also:

The *Future.exception()* method.

Chain coroutines correctly

When a coroutine function calls other coroutine functions and tasks, they should be chained explicitly with `await`. Otherwise, the execution is not guaranteed to be sequential.

Example with different bugs using *asyncio.sleep()* to simulate slow operations:

```
import asyncio

async def create():
    await asyncio.sleep(3.0)
    print("(1) create file")

async def write():
    await asyncio.sleep(1.0)
    print("(2) write into file")

async def close():
    print("(3) close file")

async def test():
    asyncio.ensure_future(create())
    asyncio.ensure_future(write())
    asyncio.ensure_future(close())
    await asyncio.sleep(2.0)
    loop.stop()

loop = asyncio.get_event_loop()
asyncio.ensure_future(test())
loop.run_forever()
print("Pending tasks at exit: %s" % asyncio.Task.all_tasks(loop))
loop.close()
```

Expected output:

```
(1) create file
(2) write into file
(3) close file
Pending tasks at exit: set()
```

Actual output:

```
(3) close file
(2) write into file
Pending tasks at exit: {<Task pending create() at test.py:7 wait_for=<Future pending cb=[Task._
↪wakeup()]>>}
Task was destroyed but it is pending!
task: <Task pending create() done at test.py:5 wait_for=<Future pending cb=[Task._wakeup()]>>
```

The loop stopped before the `create()` finished, `close()` has been called before `write()`, whereas coroutine functions were called in this order: `create()`, `write()`, `close()`.

To fix the example, tasks must be marked with `await`:

```
async def test():
    await asyncio.ensure_future(create())
    await asyncio.ensure_future(write())
    await asyncio.ensure_future(close())
    await asyncio.sleep(2.0)
    loop.stop()
```

Or without `asyncio.ensure_future()`:

```
async def test():
    await create()
```

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```
    await write()
    await close()
    await asyncio.sleep(2.0)
    loop.stop()
```

Pending task destroyed

If a pending task is destroyed, the execution of its wrapped *coroutine* did not complete. It is probably a bug and so a warning is logged.

Example of log:

```
Task was destroyed but it is pending!
task: <Task pending coro=<kill_me() done, defined at test.py:5> wait_for=<Future pending cb=[Task._
↪wakeup()]>>
```

Enable the debug mode of asyncio to get the traceback where the task was created. Example of log in debug mode:

```
Task was destroyed but it is pending!
source_traceback: Object created at (most recent call last):
  File "test.py", line 15, in <module>
    task = asyncio.ensure_future(coro, loop=loop)
task: <Task pending coro=<kill_me() done, defined at test.py:5> wait_for=<Future pending cb=[Task._
↪wakeup()] created at test.py:7> created at test.py:15>
```

See also:

Detect coroutine objects never scheduled.

Close transports and event loops

When a transport is no more needed, call its `close()` method to release resources. Event loops must also be closed explicitly.

If a transport or an event loop is not closed explicitly, a *ResourceWarning* warning will be emitted in its destructor. By default, *ResourceWarning* warnings are ignored. The *Debug mode of asyncio* section explains how to display them.

See also:

The *asyncio* module was designed in **PEP 3156**. For a motivational primer on transports and protocols, see **PEP 3153**.

19.6 asyncore — Asynchronous socket handler

Source code: Lib/asyncore.py

Deprecated since version 3.6: Please use *asyncio* instead.

Note: This module exists for backwards compatibility only. For new code we recommend using *asyncio*.

This module provides the basic infrastructure for writing asynchronous socket service clients and servers.

There are only two ways to have a program on a single processor do "more than one thing at a time." Multi-threaded programming is the simplest and most popular way to do it, but there is another very different technique, that lets you have nearly all the advantages of multi-threading, without actually using multiple threads. It's really only practical if your program is largely I/O bound. If your program is processor bound, then pre-emptive scheduled threads are probably what you really need. Network servers are rarely processor bound, however.

If your operating system supports the `select()` system call in its I/O library (and nearly all do), then you can use it to juggle multiple communication channels at once; doing other work while your I/O is taking place in the "background." Although this strategy can seem strange and complex, especially at first, it is in many ways easier to understand and control than multi-threaded programming. The *asyncore* module solves many of the difficult problems for you, making the task of building sophisticated high-performance network servers and clients a snap. For "conversational" applications and protocols the companion *asynchat* module is invaluable.

The basic idea behind both modules is to create one or more network *channels*, instances of class *asyncore.dispatcher* and *asynchat.async_chat*. Creating the channels adds them to a global map, used by the *loop()* function if you do not provide it with your own *map*.

Once the initial channel(s) is(are) created, calling the *loop()* function activates channel service, which continues until the last channel (including any that have been added to the map during asynchronous service) is closed.

`asyncore.loop`([*timeout*[, *use_poll*[, *map*[, *count*]]]])

Enter a polling loop that terminates after count passes or all open channels have been closed. All arguments are optional. The *count* parameter defaults to `None`, resulting in the loop terminating only when all channels have been closed. The *timeout* argument sets the timeout parameter for the appropriate *select()* or *poll()* call, measured in seconds; the default is 30 seconds. The *use_poll* parameter, if true, indicates that *poll()* should be used in preference to *select()* (the default is `False`).

The *map* parameter is a dictionary whose items are the channels to watch. As channels are closed they are deleted from their map. If *map* is omitted, a global map is used. Channels (instances of *asyncore.dispatcher*, *asynchat.async_chat* and subclasses thereof) can freely be mixed in the map.

`class asyncore.dispatcher`

The *dispatcher* class is a thin wrapper around a low-level socket object. To make it more useful, it has a few methods for event-handling which are called from the asynchronous loop. Otherwise, it can be treated as a normal non-blocking socket object.

The firing of low-level events at certain times or in certain connection states tells the asynchronous loop that certain higher-level events have taken place. For example, if we have asked for a socket to connect to another host, we know that the connection has been made when the socket becomes writable for the first time (at this point you know that you may write to it with the expectation of success). The implied higher-level events are:

Event	Description
`handle_connect()`	Implied by the first read or write event
`handle_close()`	Implied by a read event with no data available
`handle_accepted()`	Implied by a read event on a listening socket

During asynchronous processing, each mapped channel's *readable()* and *writable()* methods are used to determine whether the channel's socket should be added to the list of channels `select()`ed or `poll()`ed for read and write events.

Thus, the set of channel events is larger than the basic socket events. The full set of methods that can be overridden in your subclass follows:

handle_read()
Called when the asynchronous loop detects that a `read()` call on the channel's socket will succeed.

handle_write()
Called when the asynchronous loop detects that a writable socket can be written. Often this method will implement the necessary buffering for performance. For example:

```
def handle_write(self):
    sent = self.send(self.buffer)
    self.buffer = self.buffer[sent:]
```

handle_expt()
Called when there is out of band (OOB) data for a socket connection. This will almost never happen, as OOB is tenuously supported and rarely used.

handle_connect()
Called when the active opener's socket actually makes a connection. Might send a "welcome" banner, or initiate a protocol negotiation with the remote endpoint, for example.

handle_close()
Called when the socket is closed.

handle_error()
Called when an exception is raised and not otherwise handled. The default version prints a condensed traceback.

handle_accept()
Called on listening channels (passive openers) when a connection can be established with a new remote endpoint that has issued a *connect()* call for the local endpoint. Deprecated in version 3.2; use *handle_accepted()* instead.

Deprecated since version 3.2.

handle_accepted(*sock*, *addr*)
Called on listening channels (passive openers) when a connection has been established with a new remote endpoint that has issued a *connect()* call for the local endpoint. *sock* is a *new* socket object usable to send and receive data on the connection, and *addr* is the address bound to the socket on the other end of the connection.

New in version 3.2.

readable()
Called each time around the asynchronous loop to determine whether a channel's socket should be added to the list on which read events can occur. The default method simply returns `True`, indicating that by default, all channels will be interested in read events.

writable()
Called each time around the asynchronous loop to determine whether a channel's socket should be added to the list on which write events can occur. The default method simply returns `True`, indicating that by default, all channels will be interested in write events.

In addition, each channel delegates or extends many of the socket methods. Most of these are nearly identical to their socket partners.

create_socket(*family=socket.AF_INET*, *type=socket.SOCK_STREAM*)
This is identical to the creation of a normal socket, and will use the same options for creation. Refer to the *socket* documentation for information on creating sockets.

Changed in version 3.3: *family* and *type* arguments can be omitted.

connect(*address*)
As with the normal socket object, *address* is a tuple with the first element the host to connect to, and the second the port number.

send(*data*)
Send *data* to the remote end-point of the socket.

recv(*buffer_size*)
Read at most *buffer_size* bytes from the socket's remote end-point. An empty bytes object implies that the channel has been closed from the other end.

Note that *recv()* may raise *BlockingIOError* , even though *select.select()* or *select.poll()* has reported the socket ready for reading.

listen(*backlog*)
Listen for connections made to the socket. The *backlog* argument specifies the maximum number of queued connections and should be at least 1; the maximum value is system-dependent (usually 5).

bind(*address*)
Bind the socket to *address*. The socket must not already be bound. (The format of *address* depends on the address family — refer to the *socket* documentation for more information.) To mark the socket as re-usable (setting the `SO_REUSEADDR` option), call the *dispatcher* object's `set_reuse_addr()` method.

accept()
Accept a connection. The socket must be bound to an address and listening for connections. The return value can be either `None` or a pair `(conn, address)` where *conn* is a *new* socket object usable to send and receive data on the connection, and *address* is the address bound to the socket on the other end of the connection. When `None` is returned it means the connection didn't take place, in which case the server should just ignore this event and keep listening for further incoming connections.

close()
Close the socket. All future operations on the socket object will fail. The remote end-point will receive no more data (after queued data is flushed). Sockets are automatically closed when they are garbage-collected.

class asyncore.dispatcher_with_send
A *dispatcher* subclass which adds simple buffered output capability, useful for simple clients. For more sophisticated usage use *asynchat.async_chat*.

class asyncore.file_dispatcher
A file_dispatcher takes a file descriptor or *file object* along with an optional map argument and wraps it for use with the `poll()` or `loop()` functions. If provided a file object or anything with a `fileno()` method, that method will be called and passed to the *file_wrapper* constructor. Availability: UNIX.

class asyncore.file_wrapper
A file_wrapper takes an integer file descriptor and calls *os.dup()* to duplicate the handle so that the original handle may be closed independently of the file_wrapper. This class implements sufficient methods to emulate a socket for use by the *file_dispatcher* class. Availability: UNIX.

19.6.1 asyncore Example basic HTTP client

Here is a very basic HTTP client that uses the *dispatcher* class to implement its socket handling:

```
import asyncore

class HTTPClient(asyncore.dispatcher):

    def __init__(self, host, path):
        asyncore.dispatcher.__init__(self)
```

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```
        self.create_socket()
        self.connect( (host, 80) )
        self.buffer = bytes('GET %s HTTP/1.0\r\nHost: %s\r\n\r\n' %
                            (path, host), 'ascii')

    def handle_connect(self):
        pass

    def handle_close(self):
        self.close()

    def handle_read(self):
        print(self.recv(8192))

    def writable(self):
        return (len(self.buffer) > 0)

    def handle_write(self):
        sent = self.send(self.buffer)
        self.buffer = self.buffer[sent:]


client = HTTPClient('www.python.org', '/')
asyncore.loop()
```

19.6.2 asyncore Example basic echo server

Here is a basic echo server that uses the *dispatcher* class to accept connections and dispatches the incoming connections to a handler:

```
import asyncore

class EchoHandler(asyncore.dispatcher_with_send):

    def handle_read(self):
        data = self.recv(8192)
        if data:
            self.send(data)

class EchoServer(asyncore.dispatcher):

    def __init__(self, host, port):
        asyncore.dispatcher.__init__(self)
        self.create_socket()
        self.set_reuse_addr()
        self.bind((host, port))
        self.listen(5)

    def handle_accepted(self, sock, addr):
        print('Incoming connection from %s' % repr(addr))
        handler = EchoHandler(sock)

server = EchoServer('localhost', 8080)
asyncore.loop()
```

19.7 asynchat — Asynchronous socket command/response handler

Source code: Lib/asynchat.py

Deprecated since version 3.6: Please use *asyncio* instead.

Note: This module exists for backwards compatibility only. For new code we recommend using *asyncio*.

This module builds on the *asyncore* infrastructure, simplifying asynchronous clients and servers and making it easier to handle protocols whose elements are terminated by arbitrary strings, or are of variable length. *asynchat* defines the abstract class *async_chat* that you subclass, providing implementations of the `collect_incoming_data()` and `found_terminator()` methods. It uses the same asynchronous loop as *asyncore*, and the two types of channel, *asyncore.dispatcher* and *asynchat.async_chat*, can freely be mixed in the channel map. Typically an *asyncore.dispatcher* server channel generates new *asynchat.async_chat* channel objects as it receives incoming connection requests.

class asynchat.async_chat

This class is an abstract subclass of *asyncore.dispatcher*. To make practical use of the code you must subclass *async_chat*, providing meaningful *collect_incoming_data()* and *found_terminator()* methods. The *asyncore.dispatcher* methods can be used, although not all make sense in a message/response context.

Like *asyncore.dispatcher*, *async_chat* defines a set of events that are generated by an analysis of socket conditions after a `select()` call. Once the polling loop has been started the *async_chat* object's methods are called by the event-processing framework with no action on the part of the programmer.

Two class attributes can be modified, to improve performance, or possibly even to conserve memory.

ac_in_buffer_size

The asynchronous input buffer size (default `4096`).

ac_out_buffer_size

The asynchronous output buffer size (default `4096`).

Unlike *asyncore.dispatcher*, *async_chat* allows you to define a FIFO queue of *producers*. A producer need have only one method, `more()`, which should return data to be transmitted on the channel. The producer indicates exhaustion (*i.e.* that it contains no more data) by having its `more()` method return the empty bytes object. At this point the *async_chat* object removes the producer from the queue and starts using the next producer, if any. When the producer queue is empty the `handle_write()` method does nothing. You use the channel object's *set_terminator()* method to describe how to recognize the end of, or an important breakpoint in, an incoming transmission from the remote endpoint.

To build a functioning *async_chat* subclass your input methods *collect_incoming_data()* and *found_terminator()* must handle the data that the channel receives asynchronously. The methods are described below.

async_chat.close_when_done()

Pushes a `None` on to the producer queue. When this producer is popped off the queue it causes the channel to be closed.

async_chat.collect_incoming_data(*data*)

Called with *data* holding an arbitrary amount of received data. The default method, which must be overridden, raises a *NotImplementedError* exception.

async_chat.discard_buffers()

In emergencies this method will discard any data held in the input and/or output buffers and the producer queue.

async_chat.found_terminator()
: Called when the incoming data stream matches the termination condition set by *set_terminator()*. The default method, which must be overridden, raises a *NotImplementedError* exception. The buffered input data should be available via an instance attribute.

async_chat.get_terminator()
: Returns the current terminator for the channel.

async_chat.push(*data*)
: Pushes data on to the channel's queue to ensure its transmission. This is all you need to do to have the channel write the data out to the network, although it is possible to use your own producers in more complex schemes to implement encryption and chunking, for example.

async_chat.push_with_producer(*producer*)
: Takes a producer object and adds it to the producer queue associated with the channel. When all currently-pushed producers have been exhausted the channel will consume this producer's data by calling its `more()` method and send the data to the remote endpoint.

async_chat.set_terminator(*term*)
: Sets the terminating condition to be recognized on the channel. `term` may be any of three types of value, corresponding to three different ways to handle incoming protocol data.

term	Description
string	Will call *found_terminator()* when the string is found in the input stream
integer	Will call *found_terminator()* when the indicated number of characters have been received
`None`	The channel continues to collect data forever

Note that any data following the terminator will be available for reading by the channel after *found_terminator()* is called.

19.7.1 asynchat Example

The following partial example shows how HTTP requests can be read with *async_chat*. A web server might create an `http_request_handler` object for each incoming client connection. Notice that initially the channel terminator is set to match the blank line at the end of the HTTP headers, and a flag indicates that the headers are being read.

Once the headers have been read, if the request is of type POST (indicating that further data are present in the input stream) then the `Content-Length:` header is used to set a numeric terminator to read the right amount of data from the channel.

The `handle_request()` method is called once all relevant input has been marshalled, after setting the channel terminator to `None` to ensure that any extraneous data sent by the web client are ignored.

```
import asynchat

class http_request_handler(asynchat.async_chat):

    def __init__(self, sock, addr, sessions, log):
        asynchat.async_chat.__init__(self, sock=sock)
        self.addr = addr
        self.sessions = sessions
        self.ibuffer = []
        self.obuffer = b""
        self.set_terminator(b"\r\n\r\n")
        self.reading_headers = True
```

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```
        self.handling = False
        self.cgi_data = None
        self.log = log

    def collect_incoming_data(self, data):
        """Buffer the data"""
        self.ibuffer.append(data)

    def found_terminator(self):
        if self.reading_headers:
            self.reading_headers = False
            self.parse_headers(b"".join(self.ibuffer))
            self.ibuffer = []
            if self.op.upper() == b"POST":
                clen = self.headers.getheader("content-length")
                self.set_terminator(int(clen))
            else:
                self.handling = True
                self.set_terminator(None)
                self.handle_request()
        elif not self.handling:
            self.set_terminator(None)  # browsers sometimes over-send
            self.cgi_data = parse(self.headers, b"".join(self.ibuffer))
            self.handling = True
            self.ibuffer = []
            self.handle_request()
```

19.8 `signal` — Set handlers for asynchronous events

This module provides mechanisms to use signal handlers in Python.

19.8.1 General rules

The *`signal.signal()`* function allows defining custom handlers to be executed when a signal is received. A small number of default handlers are installed: `SIGPIPE` is ignored (so write errors on pipes and sockets can be reported as ordinary Python exceptions) and `SIGINT` is translated into a *`KeyboardInterrupt`* exception.

A handler for a particular signal, once set, remains installed until it is explicitly reset (Python emulates the BSD style interface regardless of the underlying implementation), with the exception of the handler for `SIGCHLD`, which follows the underlying implementation.

Execution of Python signal handlers

A Python signal handler does not get executed inside the low-level (C) signal handler. Instead, the low-level signal handler sets a flag which tells the *virtual machine* to execute the corresponding Python signal handler at a later point(for example at the next *bytecode* instruction). This has consequences:

- It makes little sense to catch synchronous errors like `SIGFPE` or `SIGSEGV` that are caused by an invalid operation in C code. Python will return from the signal handler to the C code, which is likely to raise the same signal again, causing Python to apparently hang. From Python 3.3 onwards, you can use the *`faulthandler`* module to report on synchronous errors.

- A long-running calculation implemented purely in C (such as regular expression matching on a large body of text) may run uninterrupted for an arbitrary amount of time, regardless of any signals received. The Python signal handlers will be called when the calculation finishes.

Signals and threads

Python signal handlers are always executed in the main Python thread, even if the signal was received in another thread. This means that signals can't be used as a means of inter-thread communication. You can use the synchronization primitives from the *threading* module instead.

Besides, only the main thread is allowed to set a new signal handler.

19.8.2 Module contents

Changed in version 3.5: signal (SIG*), handler (*SIG_DFL*, *SIG_IGN*) and sigmask (*SIG_BLOCK*, *SIG_UNBLOCK*, *SIG_SETMASK*) related constants listed below were turned into *enums*. *getsignal()*, *pthread_sigmask()*, *sigpending()* and *sigwait()* functions return human-readable *enums*.

The variables defined in the *signal* module are:

`signal.SIG_DFL`
: This is one of two standard signal handling options; it will simply perform the default function for the signal. For example, on most systems the default action for `SIGQUIT` is to dump core and exit, while the default action for `SIGCHLD` is to simply ignore it.

`signal.SIG_IGN`
: This is another standard signal handler, which will simply ignore the given signal.

`SIG*`
: All the signal numbers are defined symbolically. For example, the hangup signal is defined as `signal.SIGHUP`; the variable names are identical to the names used in C programs, as found in `<signal.h>`. The Unix man page for '`signal()`' lists the existing signals (on some systems this is *signal(2)*, on others the list is in *signal(7)*). Note that not all systems define the same set of signal names; only those names defined by the system are defined by this module.

`signal.CTRL_C_EVENT`
: The signal corresponding to the `Ctrl+C` keystroke event. This signal can only be used with *os.kill()*.

  Availability: Windows.

  New in version 3.2.

`signal.CTRL_BREAK_EVENT`
: The signal corresponding to the `Ctrl+Break` keystroke event. This signal can only be used with *os.kill()*.

  Availability: Windows.

  New in version 3.2.

`signal.NSIG`
: One more than the number of the highest signal number.

`signal.ITIMER_REAL`
: Decrements interval timer in real time, and delivers `SIGALRM` upon expiration.

`signal.ITIMER_VIRTUAL`
: Decrements interval timer only when the process is executing, and delivers SIGVTALRM upon expiration.

signal.ITIMER_PROF
: Decrements interval timer both when the process executes and when the system is executing on behalf of the process. Coupled with ITIMER_VIRTUAL, this timer is usually used to profile the time spent by the application in user and kernel space. SIGPROF is delivered upon expiration.

signal.SIG_BLOCK
: A possible value for the *how* parameter to *pthread_sigmask()* indicating that signals are to be blocked.

  New in version 3.3.

signal.SIG_UNBLOCK
: A possible value for the *how* parameter to *pthread_sigmask()* indicating that signals are to be unblocked.

  New in version 3.3.

signal.SIG_SETMASK
: A possible value for the *how* parameter to *pthread_sigmask()* indicating that the signal mask is to be replaced.

  New in version 3.3.

The *signal* module defines one exception:

exception signal.ItimerError
: Raised to signal an error from the underlying *setitimer()* or *getitimer()* implementation. Expect this error if an invalid interval timer or a negative time is passed to *setitimer()*. This error is a subtype of *OSError*.

  New in version 3.3: This error used to be a subtype of *IOError*, which is now an alias of *OSError*.

The *signal* module defines the following functions:

signal.alarm(*time*)
: If *time* is non-zero, this function requests that a SIGALRM signal be sent to the process in *time* seconds. Any previously scheduled alarm is canceled (only one alarm can be scheduled at any time). The returned value is then the number of seconds before any previously set alarm was to have been delivered. If *time* is zero, no alarm is scheduled, and any scheduled alarm is canceled. If the return value is zero, no alarm is currently scheduled. (See the Unix man page *alarm(2)*.) Availability: Unix.

signal.getsignal(*signalnum*)
: Return the current signal handler for the signal *signalnum*. The returned value may be a callable Python object, or one of the special values *signal.SIG_IGN*, *signal.SIG_DFL* or *None*. Here, *signal.SIG_IGN* means that the signal was previously ignored, *signal.SIG_DFL* means that the default way of handling the signal was previously in use, and None means that the previous signal handler was not installed from Python.

signal.pause()
: Cause the process to sleep until a signal is received; the appropriate handler will then be called. Returns nothing. Not on Windows. (See the Unix man page *signal(2)*.)

  See also *sigwait()*, *sigwaitinfo()*, *sigtimedwait()* and *sigpending()*.

signal.pthread_kill(*thread_id*, *signalnum*)
: Send the signal *signalnum* to the thread *thread_id*, another thread in the same process as the caller. The target thread can be executing any code (Python or not). However, if the target thread is executing the Python interpreter, the Python signal handlers will be *executed by the main thread*. Therefore, the only point of sending a signal to a particular Python thread would be to force a running system call to fail with *InterruptedError*.

  Use *threading.get_ident()* or the *ident* attribute of *threading.Thread* objects to get a suitable value for *thread_id*.

If *signalnum* is 0, then no signal is sent, but error checking is still performed; this can be used to check if the target thread is still running.

Availability: Unix (see the man page *pthread_kill(3)* for further information).

See also *os.kill()*.

New in version 3.3.

signal.**pthread_sigmask**(*how*, *mask*)
Fetch and/or change the signal mask of the calling thread. The signal mask is the set of signals whose delivery is currently blocked for the caller. Return the old signal mask as a set of signals.

The behavior of the call is dependent on the value of *how*, as follows.

- *SIG_BLOCK*: The set of blocked signals is the union of the current set and the *mask* argument.
- *SIG_UNBLOCK*: The signals in *mask* are removed from the current set of blocked signals. It is permissible to attempt to unblock a signal which is not blocked.
- *SIG_SETMASK*: The set of blocked signals is set to the *mask* argument.

mask is a set of signal numbers (e.g. {`signal.SIGINT`, `signal.SIGTERM`}). Use `range(1, signal.NSIG)` for a full mask including all signals.

For example, `signal.pthread_sigmask(signal.SIG_BLOCK, [])` reads the signal mask of the calling thread.

Availability: Unix. See the man page *sigprocmask(3)* and *pthread_sigmask(3)* for further information.

See also *pause()*, *sigpending()* and *sigwait()*.

New in version 3.3.

signal.**setitimer**(*which*, *seconds*, *interval=0.0*)
Sets given interval timer (one of *signal.ITIMER_REAL*, *signal.ITIMER_VIRTUAL* or *signal.ITIMER_PROF*) specified by *which* to fire after *seconds* (float is accepted, different from *alarm()*) and after that every *interval* seconds (if *interval* is non-zero). The interval timer specified by *which* can be cleared by setting *seconds* to zero.

When an interval timer fires, a signal is sent to the process. The signal sent is dependent on the timer being used; *signal.ITIMER_REAL* will deliver `SIGALRM`, *signal.ITIMER_VIRTUAL* sends `SIGVTALRM`, and *signal.ITIMER_PROF* will deliver `SIGPROF`.

The old values are returned as a tuple: (delay, interval).

Attempting to pass an invalid interval timer will cause an *ItimerError*. Availability: Unix.

signal.**getitimer**(*which*)
Returns current value of a given interval timer specified by *which*. Availability: Unix.

signal.**set_wakeup_fd**(*fd*, ***, *warn_on_full_buffer=True*)
Set the wakeup file descriptor to *fd*. When a signal is received, the signal number is written as a single byte into the fd. This can be used by a library to wakeup a poll or select call, allowing the signal to be fully processed.

The old wakeup fd is returned (or -1 if file descriptor wakeup was not enabled). If *fd* is -1, file descriptor wakeup is disabled. If not -1, *fd* must be non-blocking. It is up to the library to remove any bytes from *fd* before calling poll or select again.

When threads are enabled, this function can only be called from the main thread; attempting to call it from other threads will cause a *ValueError* exception to be raised.

There are two common ways to use this function. In both approaches, you use the fd to wake up when a signal arrives, but then they differ in how they determine *which* signal or signals have arrived.

In the first approach, we read the data out of the fd's buffer, and the byte values give you the signal numbers. This is simple, but in rare cases it can run into a problem: generally the fd will have a limited amount of buffer space, and if too many signals arrive too quickly, then the buffer may become full, and some signals may be lost. If you use this approach, then you should set `warn_on_full_buffer=True`, which will at least cause a warning to be printed to stderr when signals are lost.

In the second approach, we use the wakeup fd *only* for wakeups, and ignore the actual byte values. In this case, all we care about is whether the fd's buffer is empty or non-empty; a full buffer doesn't indicate a problem at all. If you use this approach, then you should set `warn_on_full_buffer=False`, so that your users are not confused by spurious warning messages.

Changed in version 3.5: On Windows, the function now also supports socket handles.

Changed in version 3.7: Added `warn_on_full_buffer` parameter.

`signal.siginterrupt`(*signalnum*, *flag*)

Change system call restart behaviour: if *flag* is *False*, system calls will be restarted when interrupted by signal *signalnum*, otherwise system calls will be interrupted. Returns nothing. Availability: Unix (see the man page *siginterrupt(3)* for further information).

Note that installing a signal handler with *signal()* will reset the restart behaviour to interruptible by implicitly calling `siginterrupt()` with a true *flag* value for the given signal.

`signal.signal`(*signalnum*, *handler*)

Set the handler for signal *signalnum* to the function *handler*. *handler* can be a callable Python object taking two arguments (see below), or one of the special values *signal.SIG_IGN* or *signal.SIG_DFL*. The previous signal handler will be returned (see the description of *getsignal()* above). (See the Unix man page *signal(2)*.)

When threads are enabled, this function can only be called from the main thread; attempting to call it from other threads will cause a *ValueError* exception to be raised.

The *handler* is called with two arguments: the signal number and the current stack frame (`None` or a frame object; for a description of frame objects, see the description in the type hierarchy or see the attribute descriptions in the *inspect* module).

On Windows, *signal()* can only be called with `SIGABRT`, `SIGFPE`, `SIGILL`, `SIGINT`, `SIGSEGV`, `SIGTERM`, or `SIGBREAK`. A *ValueError* will be raised in any other case. Note that not all systems define the same set of signal names; an *AttributeError* will be raised if a signal name is not defined as `SIG*` module level constant.

`signal.sigpending`()

Examine the set of signals that are pending for delivery to the calling thread (i.e., the signals which have been raised while blocked). Return the set of the pending signals.

Availability: Unix (see the man page *sigpending(2)* for further information).

See also *pause()*, *pthread_sigmask()* and *sigwait()*.

New in version 3.3.

`signal.sigwait`(*sigset*)

Suspend execution of the calling thread until the delivery of one of the signals specified in the signal set *sigset*. The function accepts the signal (removes it from the pending list of signals), and returns the signal number.

Availability: Unix (see the man page *sigwait(3)* for further information).

See also *pause()*, *pthread_sigmask()*, *sigpending()*, *sigwaitinfo()* and *sigtimedwait()*.

New in version 3.3.

`signal.sigwaitinfo`(*sigset*)

Suspend execution of the calling thread until the delivery of one of the signals specified in the signal

set *sigset*. The function accepts the signal and removes it from the pending list of signals. If one of the signals in *sigset* is already pending for the calling thread, the function will return immediately with information about that signal. The signal handler is not called for the delivered signal. The function raises an *InterruptedError* if it is interrupted by a signal that is not in *sigset*.

The return value is an object representing the data contained in the `siginfo_t` structure, namely: `si_signo`, `si_code`, `si_errno`, `si_pid`, `si_uid`, `si_status`, `si_band`.

Availability: Unix (see the man page *sigwaitinfo(2)* for further information).

See also *pause()*, *sigwait()* and *sigtimedwait()*.

New in version 3.3.

Changed in version 3.5: The function is now retried if interrupted by a signal not in *sigset* and the signal handler does not raise an exception (see **PEP 475** for the rationale).

`signal.sigtimedwait`(*sigset*, *timeout*)

Like *sigwaitinfo()*, but takes an additional *timeout* argument specifying a timeout. If *timeout* is specified as `0`, a poll is performed. Returns *None* if a timeout occurs.

Availability: Unix (see the man page *sigtimedwait(2)* for further information).

See also *pause()*, *sigwait()* and *sigwaitinfo()*.

New in version 3.3.

Changed in version 3.5: The function is now retried with the recomputed *timeout* if interrupted by a signal not in *sigset* and the signal handler does not raise an exception (see **PEP 475** for the rationale).

19.8.3 Example

Here is a minimal example program. It uses the *alarm()* function to limit the time spent waiting to open a file; this is useful if the file is for a serial device that may not be turned on, which would normally cause the *os.open()* to hang indefinitely. The solution is to set a 5-second alarm before opening the file; if the operation takes too long, the alarm signal will be sent, and the handler raises an exception.

```
import signal, os

def handler(signum, frame):
    print('Signal handler called with signal', signum)
    raise OSError("Couldn't open device!")

# Set the signal handler and a 5-second alarm
signal.signal(signal.SIGALRM, handler)
signal.alarm(5)

# This open() may hang indefinitely
fd = os.open('/dev/ttyS0', os.O_RDWR)

signal.alarm(0)          # Disable the alarm
```

19.9 mmap — Memory-mapped file support

Memory-mapped file objects behave like both *bytearray* and like *file objects*. You can use mmap objects in most places where *bytearray* are expected; for example, you can use the *re* module to search through a memory-mapped file. You can also change a single byte by doing `obj[index] = 97`, or change a subsequence

by assigning to a slice: `obj[i1:i2] = b'...'`. You can also read and write data starting at the current file position, and `seek()` through the file to different positions.

A memory-mapped file is created by the *mmap* constructor, which is different on Unix and on Windows. In either case you must provide a file descriptor for a file opened for update. If you wish to map an existing Python file object, use its `fileno()` method to obtain the correct value for the *fileno* parameter. Otherwise, you can open the file using the *os.open()* function, which returns a file descriptor directly (the file still needs to be closed when done).

Note: If you want to create a memory-mapping for a writable, buffered file, you should *flush()* the file first. This is necessary to ensure that local modifications to the buffers are actually available to the mapping.

For both the Unix and Windows versions of the constructor, *access* may be specified as an optional keyword parameter. *access* accepts one of four values: `ACCESS_READ`, `ACCESS_WRITE`, or `ACCESS_COPY` to specify read-only, write-through or copy-on-write memory respectively, or `ACCESS_DEFAULT` to defer to *prot*. *access* can be used on both Unix and Windows. If *access* is not specified, Windows mmap returns a write-through mapping. The initial memory values for all three access types are taken from the specified file. Assignment to an `ACCESS_READ` memory map raises a *TypeError* exception. Assignment to an `ACCESS_WRITE` memory map affects both memory and the underlying file. Assignment to an `ACCESS_COPY` memory map affects memory but does not update the underlying file.

Changed in version 3.7: Added `ACCESS_DEFAULT` constant.

To map anonymous memory, -1 should be passed as the fileno along with the length.

class mmap.mmap(*fileno*, *length*, *tagname=None*, *access=ACCESS_DEFAULT*[, *offset*])

(Windows version) Maps *length* bytes from the file specified by the file handle *fileno*, and creates a mmap object. If *length* is larger than the current size of the file, the file is extended to contain *length* bytes. If *length* is `0`, the maximum length of the map is the current size of the file, except that if the file is empty Windows raises an exception (you cannot create an empty mapping on Windows).

tagname, if specified and not `None`, is a string giving a tag name for the mapping. Windows allows you to have many different mappings against the same file. If you specify the name of an existing tag, that tag is opened, otherwise a new tag of this name is created. If this parameter is omitted or `None`, the mapping is created without a name. Avoiding the use of the tag parameter will assist in keeping your code portable between Unix and Windows.

offset may be specified as a non-negative integer offset. mmap references will be relative to the offset from the beginning of the file. *offset* defaults to 0. *offset* must be a multiple of the ALLOCATIONGRANULARITY.

class mmap.mmap(*fileno*, *length*, *flags=MAP_SHARED*, *prot=PROT_WRITE|PROT_READ*, *access=ACCESS_DEFAULT*[, *offset*])

(Unix version) Maps *length* bytes from the file specified by the file descriptor *fileno*, and returns a mmap object. If *length* is `0`, the maximum length of the map will be the current size of the file when *mmap* is called.

flags specifies the nature of the mapping. `MAP_PRIVATE` creates a private copy-on-write mapping, so changes to the contents of the mmap object will be private to this process, and `MAP_SHARED` creates a mapping that's shared with all other processes mapping the same areas of the file. The default value is `MAP_SHARED`.

prot, if specified, gives the desired memory protection; the two most useful values are `PROT_READ` and `PROT_WRITE`, to specify that the pages may be read or written. *prot* defaults to `PROT_READ | PROT_WRITE`.

access may be specified in lieu of *flags* and *prot* as an optional keyword parameter. It is an error to specify both *flags*, *prot* and *access*. See the description of *access* above for information on how to use this parameter.

offset may be specified as a non-negative integer offset. mmap references will be relative to the offset from the beginning of the file. *offset* defaults to 0. *offset* must be a multiple of the PAGESIZE or ALLOCATIONGRANULARITY.

To ensure validity of the created memory mapping the file specified by the descriptor *fileno* is internally automatically synchronized with physical backing store on Mac OS X and OpenVMS.

This example shows a simple way of using *mmap*:

```
import mmap

# write a simple example file
with open("hello.txt", "wb") as f:
    f.write(b"Hello Python!\n")

with open("hello.txt", "r+b") as f:
    # memory-map the file, size 0 means whole file
    mm = mmap.mmap(f.fileno(), 0)
    # read content via standard file methods
    print(mm.readline())  # prints b"Hello Python!\n"
    # read content via slice notation
    print(mm[:5])  # prints b"Hello"
    # update content using slice notation;
    # note that new content must have same size
    mm[6:] = b" world!\n"
    # ... and read again using standard file methods
    mm.seek(0)
    print(mm.readline())  # prints b"Hello  world!\n"
    # close the map
    mm.close()
```

mmap can also be used as a context manager in a `with` statement:

```
import mmap

with mmap.mmap(-1, 13) as mm:
    mm.write(b"Hello world!")
```

New in version 3.2: Context manager support.

The next example demonstrates how to create an anonymous map and exchange data between the parent and child processes:

```
import mmap
import os

mm = mmap.mmap(-1, 13)
mm.write(b"Hello world!")

pid = os.fork()

if pid == 0:  # In a child process
    mm.seek(0)
    print(mm.readline())

    mm.close()
```

Memory-mapped file objects support the following methods:

`close()`

Closes the mmap. Subsequent calls to other methods of the object will result in a ValueError exception being raised. This will not close the open file.

`closed`
`True` if the file is closed.

New in version 3.2.

`find`(*sub*[, *start*[, *end*]])
Returns the lowest index in the object where the subsequence *sub* is found, such that *sub* is contained in the range [*start*, *end*]. Optional arguments *start* and *end* are interpreted as in slice notation. Returns `-1` on failure.

Changed in version 3.5: Writable *bytes-like object* is now accepted.

`flush`([*offset*[, *size*]])
Flushes changes made to the in-memory copy of a file back to disk. Without use of this call there is no guarantee that changes are written back before the object is destroyed. If *offset* and *size* are specified, only changes to the given range of bytes will be flushed to disk; otherwise, the whole extent of the mapping is flushed.

(Windows version) A nonzero value returned indicates success; zero indicates failure.

(Unix version) A zero value is returned to indicate success. An exception is raised when the call failed.

`move`(*dest*, *src*, *count*)
Copy the *count* bytes starting at offset *src* to the destination index *dest*. If the mmap was created with `ACCESS_READ`, then calls to move will raise a *TypeError* exception.

`read`([*n*])
Return a *bytes* containing up to *n* bytes starting from the current file position. If the argument is omitted, `None` or negative, return all bytes from the current file position to the end of the mapping. The file position is updated to point after the bytes that were returned.

Changed in version 3.3: Argument can be omitted or `None`.

`read_byte`()
Returns a byte at the current file position as an integer, and advances the file position by 1.

`readline`()
Returns a single line, starting at the current file position and up to the next newline.

`resize`(*newsize*)
Resizes the map and the underlying file, if any. If the mmap was created with `ACCESS_READ` or `ACCESS_COPY`, resizing the map will raise a *TypeError* exception.

`rfind`(*sub*[, *start*[, *end*]])
Returns the highest index in the object where the subsequence *sub* is found, such that *sub* is contained in the range [*start*, *end*]. Optional arguments *start* and *end* are interpreted as in slice notation. Returns `-1` on failure.

Changed in version 3.5: Writable *bytes-like object* is now accepted.

`seek`(*pos*[, *whence*])
Set the file's current position. *whence* argument is optional and defaults to `os.SEEK_SET` or `0` (absolute file positioning); other values are `os.SEEK_CUR` or `1` (seek relative to the current position) and `os.SEEK_END` or `2` (seek relative to the file's end).

`size`()
Return the length of the file, which can be larger than the size of the memory-mapped area.

`tell`()
Returns the current position of the file pointer.

write(*bytes*)
Write the bytes in *bytes* into memory at the current position of the file pointer and return the number of bytes written (never less than `len(bytes)`, since if the write fails, a *ValueError* will be raised). The file position is updated to point after the bytes that were written. If the mmap was created with `ACCESS_READ`, then writing to it will raise a *TypeError* exception.

Changed in version 3.5: Writable *bytes-like object* is now accepted.

Changed in version 3.6: The number of bytes written is now returned.

write_byte(*byte*)
Write the integer *byte* into memory at the current position of the file pointer; the file position is advanced by `1`. If the mmap was created with `ACCESS_READ`, then writing to it will raise a *TypeError* exception.

CHAPTER

TWENTY

INTERNET DATA HANDLING

This chapter describes modules which support handling data formats commonly used on the Internet.

20.1 `email` — An email and MIME handling package

Source code: Lib/email/__init__.py

The *email* package is a library for managing email messages. It is specifically *not* designed to do any sending of email messages to SMTP (**RFC 2821**), NNTP, or other servers; those are functions of modules such as *smtplib* and *nntplib*. The *email* package attempts to be as RFC-compliant as possible, supporting **RFC 5233** and **RFC 6532**, as well as such MIME-related RFCs as **RFC 2045**, **RFC 2046**, **RFC 2047**, **RFC 2183**, and **RFC 2231**.

The overall structure of the email package can be divided into three major components, plus a fourth component that controls the behavior of the other components.

The central component of the package is an "object model" that represents email messages. An application interacts with the package primarily through the object model interface defined in the *message* sub-module. The application can use this API to ask questions about an existing email, to construct a new email, or to add or remove email subcomponents that themselves use the same object model interface. That is, following the nature of email messages and their MIME subcomponents, the email object model is a tree structure of objects that all provide the *EmailMessage* API.

The other two major components of the package are the *parser* and the *generator*. The parser takes the serialized version of an email message (a stream of bytes) and converts it into a tree of *EmailMessage* objects. The generator takes an *EmailMessage* and turns it back into a serialized byte stream. (The parser and generator also handle streams of text characters, but this usage is discouraged as it is too easy to end up with messages that are not valid in one way or another.)

The control component is the *policy* module. Every *EmailMessage*, every *generator*, and every *parser* has an associated *policy* object that controls its behavior. Usually an application only needs to specify the policy when an *EmailMessage* is created, either by directly instantiating an *EmailMessage* to create a new email, or by parsing an input stream using a *parser*. But the policy can be changed when the message is serialized using a *generator*. This allows, for example, a generic email message to be parsed from disk, but to serialize it using standard SMTP settings when sending it to an email server.

The email package does its best to hide the details of the various governing RFCs from the application. Conceptually the application should be able to treat the email message as a structured tree of unicode text and binary attachments, without having to worry about how these are represented when serialized. In practice, however, it is often necessary to be aware of at least some of the rules governing MIME messages and their structure, specifically the names and nature of the MIME "content types" and how they identify multipart documents. For the most part this knowledge should only be required for more complex applications, and even then it should only be the high level structure in question, and not the details of how those structures

are represented. Since MIME content types are used widely in modern internet software (not just email), this will be a familiar concept to many programmers.

The following sections describe the functionality of the *email* package. We start with the *message* object model, which is the primary interface an application will use, and follow that with the *parser* and *generator* components. Then we cover the *policy* controls, which completes the treatment of the main components of the library.

The next three sections cover the exceptions the package may raise and the defects (non-compliance with the RFCs) that the *parser* may detect. Then we cover the *headerregistry* and the *contentmanager* subcomponents, which provide tools for doing more detailed manipulation of headers and payloads, respectively. Both of these components contain features relevant to consuming and producing non-trivial messages, but also document their extensibility APIs, which will be of interest to advanced applications.

Following those is a set of examples of using the fundamental parts of the APIs covered in the preceding sections.

The forgoing represent the modern (unicode friendly) API of the email package. The remaining sections, starting with the *Message* class, cover the legacy *compat32* API that deals much more directly with the details of how email messages are represented. The *compat32* API does *not* hide the details of the RFCs from the application, but for applications that need to operate at that level, they can be useful tools. This documentation is also relevant for applications that are still using the *compat32* API for backward compatibility reasons.

Changed in version 3.6: Docs reorganized and rewritten to promote the new *EmailMessage*/*EmailPolicy* API.

Contents of the *email* package documentation:

20.1.1 email.message: Representing an email message

Source code: Lib/email/message.py

New in version 3.6:[1]

The central class in the *email* package is the *EmailMessage* class, imported from the *email.message* module. It is the base class for the *email* object model. *EmailMessage* provides the core functionality for setting and querying header fields, for accessing message bodies, and for creating or modifying structured messages.

An email message consists of *headers* and a *payload* (which is also referred to as the *content*). Headers are **RFC 5322** or **RFC 6532** style field names and values, where the field name and value are separated by a colon. The colon is not part of either the field name or the field value. The payload may be a simple text message, or a binary object, or a structured sequence of sub-messages each with their own set of headers and their own payload. The latter type of payload is indicated by the message having a MIME type such as *multipart/** or *message/rfc822*.

The conceptual model provided by an *EmailMessage* object is that of an ordered dictionary of headers coupled with a *payload* that represents the **RFC 5322** body of the message, which might be a list of sub-`EmailMessage` objects. In addition to the normal dictionary methods for accessing the header names and values, there are methods for accessing specialized information from the headers (for example the MIME content type), for operating on the payload, for generating a serialized version of the message, and for recursively walking over the object tree.

The *EmailMessage* dictionary-like interface is indexed by the header names, which must be ASCII values. The values of the dictionary are strings with some extra methods. Headers are stored and returned in case-preserving form, but field names are matched case-insensitively. Unlike a real dict, there is an ordering to

[1] Originally added in 3.4 as a *provisional module*. Docs for legacy message class moved to *email.message.Message: Representing an email message using the compat32 API*.

the keys, and there can be duplicate keys. Additional methods are provided for working with headers that have duplicate keys.

The *payload* is either a string or bytes object, in the case of simple message objects, or a list of *EmailMessage* objects, for MIME container documents such as *multipart/** and *message/rfc822* message objects.

class email.message.EmailMessage(*policy=default*)

If *policy* is specified use the rules it specifies to update and serialize the representation of the message. If *policy* is not set, use the *default* policy, which follows the rules of the email RFCs except for line endings (instead of the RFC mandated `\r\n`, it uses the Python standard `\n` line endings). For more information see the *policy* documentation.

as_string(*unixfrom=False*, *maxheaderlen=None*, *policy=None*)

Return the entire message flattened as a string. When optional *unixfrom* is true, the envelope header is included in the returned string. *unixfrom* defaults to `False`. For backward compatibility with the base *Message* class *maxheaderlen* is accepted, but defaults to `None`, which means that by default the line length is controlled by the `max_line_length` of the policy. The *policy* argument may be used to override the default policy obtained from the message instance. This can be used to control some of the formatting produced by the method, since the specified *policy* will be passed to the *Generator*.

Flattening the message may trigger changes to the *EmailMessage* if defaults need to be filled in to complete the transformation to a string (for example, MIME boundaries may be generated or modified).

Note that this method is provided as a convenience and may not be the most useful way to serialize messages in your application, especially if you are dealing with multiple messages. See *email.generator.Generator* for a more flexible API for serializing messages. Note also that this method is restricted to producing messages serialized as "7 bit clean" when *utf8* is `False`, which is the default.

Changed in version 3.6: the default behavior when *maxheaderlen* is not specified was changed from defaulting to 0 to defaulting to the value of *max_line_length* from the policy.

__str__()

Equivalent to *as_string(policy=self.policy.clone(utf8=True)*. Allows `str(msg)` to produce a string containing the serialized message in a readable format.

Changed in version 3.4: the method was changed to use `utf8=True`, thus producing an **RFC 6531**-like message representation, instead of being a direct alias for *as_string()*.

as_bytes(*unixfrom=False*, *policy=None*)

Return the entire message flattened as a bytes object. When optional *unixfrom* is true, the envelope header is included in the returned string. *unixfrom* defaults to `False`. The *policy* argument may be used to override the default policy obtained from the message instance. This can be used to control some of the formatting produced by the method, since the specified *policy* will be passed to the *BytesGenerator*.

Flattening the message may trigger changes to the *EmailMessage* if defaults need to be filled in to complete the transformation to a string (for example, MIME boundaries may be generated or modified).

Note that this method is provided as a convenience and may not be the most useful way to serialize messages in your application, especially if you are dealing with multiple messages. See *email.generator.BytesGenerator* for a more flexible API for serializing messages.

__bytes__()

Equivalent to *as_bytes()*. Allows `bytes(msg)` to produce a bytes object containing the serialized message.

is_multipart()
Return `True` if the message's payload is a list of sub-*EmailMessage* objects, otherwise return `False`. When *is_multipart()* returns `False`, the payload should be a string object (which might be a CTE encoded binary payload). Note that *is_multipart()* returning `True` does not necessarily mean that "msg.get_content_maintype() == 'multipart'" will return the `True`. For example, `is_multipart` will return `True` when the *EmailMessage* is of type `message/rfc822`.

set_unixfrom(*unixfrom*)
Set the message's envelope header to *unixfrom*, which should be a string. (See *mboxMessage* for a brief description of this header.)

get_unixfrom()
Return the message's envelope header. Defaults to `None` if the envelope header was never set.

The following methods implement the mapping-like interface for accessing the message's headers. Note that there are some semantic differences between these methods and a normal mapping (i.e. dictionary) interface. For example, in a dictionary there are no duplicate keys, but here there may be duplicate message headers. Also, in dictionaries there is no guaranteed order to the keys returned by *keys()*, but in an *EmailMessage* object, headers are always returned in the order they appeared in the original message, or in which they were added to the message later. Any header deleted and then re-added is always appended to the end of the header list.

These semantic differences are intentional and are biased toward convenience in the most common use cases.

Note that in all cases, any envelope header present in the message is not included in the mapping interface.

__len__()
Return the total number of headers, including duplicates.

__contains__(*name*)
Return true if the message object has a field named *name*. Matching is done without regard to case and *name* does not include the trailing colon. Used for the `in` operator. For example:

```
if 'message-id' in myMessage:
   print('Message-ID:', myMessage['message-id'])
```

__getitem__(*name*)
Return the value of the named header field. *name* does not include the colon field separator. If the header is missing, `None` is returned; a *KeyError* is never raised.

Note that if the named field appears more than once in the message's headers, exactly which of those field values will be returned is undefined. Use the *get_all()* method to get the values of all the extant headers named *name*.

Using the standard (non-`compat32`) policies, the returned value is an instance of a subclass of *email.headerregistry.BaseHeader*.

__setitem__(*name*, *val*)
Add a header to the message with field name *name* and value *val*. The field is appended to the end of the message's existing headers.

Note that this does *not* overwrite or delete any existing header with the same name. If you want to ensure that the new header is the only one present in the message with field name *name*, delete the field first, e.g.:

```
del msg['subject']
msg['subject'] = 'Python roolz!'
```

If the `policy` defines certain headers to be unique (as the standard policies do), this method may raise a *ValueError* when an attempt is made to assign a value to such a header when one already exists. This behavior is intentional for consistency's sake, but do not depend on it as we may choose to make such assignments do an automatic deletion of the existing header in the future.

__delitem__(*name*)
Delete all occurrences of the field with name *name* from the message's headers. No exception is raised if the named field isn't present in the headers.

keys()
Return a list of all the message's header field names.

values()
Return a list of all the message's field values.

items()
Return a list of 2-tuples containing all the message's field headers and values.

get(*name*, *failobj=None*)
Return the value of the named header field. This is identical to *__getitem__()* except that optional *failobj* is returned if the named header is missing (*failobj* defaults to `None`).

Here are some additional useful header related methods:

get_all(*name*, *failobj=None*)
Return a list of all the values for the field named *name*. If there are no such named headers in the message, *failobj* is returned (defaults to `None`).

add_header(*_name*, *_value*, ***_params*)
Extended header setting. This method is similar to *__setitem__()* except that additional header parameters can be provided as keyword arguments. *_name* is the header field to add and *_value* is the *primary* value for the header.

For each item in the keyword argument dictionary *_params*, the key is taken as the parameter name, with underscores converted to dashes (since dashes are illegal in Python identifiers). Normally, the parameter will be added as `key="value"` unless the value is `None`, in which case only the key will be added.

If the value contains non-ASCII characters, the charset and language may be explicitly controlled by specifying the value as a three tuple in the format `(CHARSET, LANGUAGE, VALUE)`, where `CHARSET` is a string naming the charset to be used to encode the value, `LANGUAGE` can usually be set to `None` or the empty string (see **RFC 2231** for other possibilities), and `VALUE` is the string value containing non-ASCII code points. If a three tuple is not passed and the value contains non-ASCII characters, it is automatically encoded in **RFC 2231** format using a `CHARSET` of `utf-8` and a `LANGUAGE` of `None`.

Here is an example:

```
msg.add_header('Content-Disposition', 'attachment', filename='bud.gif')
```

This will add a header that looks like

```
Content-Disposition: attachment; filename="bud.gif"
```

An example of the extended interface with non-ASCII characters:

```
msg.add_header('Content-Disposition', 'attachment',
               filename=('iso-8859-1', '', 'Fußballer.ppt'))
```

replace_header(*_name*, *_value*)
Replace a header. Replace the first header found in the message that matches *_name*, retaining

header order and field name case of the original header. If no matching header is found, raise a *KeyError*.

get_content_type()
Return the message's content type, coerced to lower case of the form *maintype/subtype*. If there is no *Content-Type* header in the message return the value returned by *get_default_type()*. If the *Content-Type* header is invalid, return `text/plain`.

(According to **RFC 2045**, messages always have a default type, *get_content_type()* will always return a value. **RFC 2045** defines a message's default type to be *text/plain* unless it appears inside a *multipart/digest* container, in which case it would be *message/rfc822*. If the *Content-Type* header has an invalid type specification, **RFC 2045** mandates that the default type be *text/plain*.)

get_content_maintype()
Return the message's main content type. This is the *maintype* part of the string returned by *get_content_type()*.

get_content_subtype()
Return the message's sub-content type. This is the *subtype* part of the string returned by *get_content_type()*.

get_default_type()
Return the default content type. Most messages have a default content type of *text/plain*, except for messages that are subparts of *multipart/digest* containers. Such subparts have a default content type of *message/rfc822*.

set_default_type(*ctype*)
Set the default content type. *ctype* should either be *text/plain* or *message/rfc822*, although this is not enforced. The default content type is not stored in the *Content-Type* header, so it only affects the return value of the `get_content_type` methods when no *Content-Type* header is present in the message.

set_param(*param*, *value*, *header='Content-Type'*, *requote=True*, *charset=None*, *language=''*, *replace=False*)
Set a parameter in the *Content-Type* header. If the parameter already exists in the header, replace its value with *value*. When *header* is `Content-Type` (the default) and the header does not yet exist in the message, add it, set its value to *text/plain*, and append the new parameter value. Optional *header* specifies an alternative header to *Content-Type*.

If the value contains non-ASCII characters, the charset and language may be explicitly specified using the optional *charset* and *language* parameters. Optional *language* specifies the **RFC 2231** language, defaulting to the empty string. Both *charset* and *language* should be strings. The default is to use the `utf8` *charset* and `None` for the *language*.

If *replace* is `False` (the default) the header is moved to the end of the list of headers. If *replace* is `True`, the header will be updated in place.

Use of the *requote* parameter with *EmailMessage* objects is deprecated.

Note that existing parameter values of headers may be accessed through the `params` attribute of the header value (for example, `msg['Content-Type'].params['charset']`.

Changed in version 3.4: `replace` keyword was added.

del_param(*param*, *header='content-type'*, *requote=True*)
Remove the given parameter completely from the *Content-Type* header. The header will be rewritten in place without the parameter or its value. Optional *header* specifies an alternative to *Content-Type*.

Use of the *requote* parameter with *EmailMessage* objects is deprecated.

get_filename(*failobj=None*)
Return the value of the `filename` parameter of the *Content-Disposition* header of the message. If the header does not have a `filename` parameter, this method falls back to looking for the `name` parameter on the *Content-Type* header. If neither is found, or the header is missing, then *failobj* is returned. The returned string will always be unquoted as per *email.utils.unquote()*.

get_boundary(*failobj=None*)
Return the value of the `boundary` parameter of the *Content-Type* header of the message, or *failobj* if either the header is missing, or has no `boundary` parameter. The returned string will always be unquoted as per *email.utils.unquote()*.

set_boundary(*boundary*)
Set the `boundary` parameter of the *Content-Type* header to *boundary*. *set_boundary()* will always quote *boundary* if necessary. A *HeaderParseError* is raised if the message object has no *Content-Type* header.

Note that using this method is subtly different from deleting the old *Content-Type* header and adding a new one with the new boundary via *add_header()*, because *set_boundary()* preserves the order of the *Content-Type* header in the list of headers.

get_content_charset(*failobj=None*)
Return the `charset` parameter of the *Content-Type* header, coerced to lower case. If there is no *Content-Type* header, or if that header has no `charset` parameter, *failobj* is returned.

get_charsets(*failobj=None*)
Return a list containing the character set names in the message. If the message is a *multipart*, then the list will contain one element for each subpart in the payload, otherwise, it will be a list of length 1.

Each item in the list will be a string which is the value of the `charset` parameter in the *Content-Type* header for the represented subpart. If the subpart has no *Content-Type* header, no `charset` parameter, or is not of the *text* main MIME type, then that item in the returned list will be *failobj*.

is_attachment()
Return `True` if there is a *Content-Disposition* header and its (case insensitive) value is `attachment`, `False` otherwise.

Changed in version 3.4.2: is_attachment is now a method instead of a property, for consistency with *is_multipart()*.

get_content_disposition()
Return the lowercased value (without parameters) of the message's *Content-Disposition* header if it has one, or `None`. The possible values for this method are *inline*, *attachment* or `None` if the message follows **RFC 2183**.

New in version 3.5.

The following methods relate to interrogating and manipulating the content (payload) of the message.

walk()
The *walk()* method is an all-purpose generator which can be used to iterate over all the parts and subparts of a message object tree, in depth-first traversal order. You will typically use *walk()* as the iterator in a `for` loop; each iteration returns the next subpart.

Here's an example that prints the MIME type of every part of a multipart message structure:

```
>>> for part in msg.walk():
...     print(part.get_content_type())
multipart/report
```

(continues on next page)

(continued from previous page)

```
text/plain
message/delivery-status
text/plain
text/plain
message/rfc822
text/plain
```

`walk` iterates over the subparts of any part where *is_multipart()* returns `True`, even though `msg.get_content_maintype() == 'multipart'` may return `False`. We can see this in our example by making use of the `_structure` debug helper function:

```
>>> for part in msg.walk():
...     print(part.get_content_maintype() == 'multipart',
...           part.is_multipart())
True True
False False
False True
False False
False False
False True
False False
>>> _structure(msg)
multipart/report
    text/plain
    message/delivery-status
        text/plain
        text/plain
    message/rfc822
        text/plain
```

Here the `message` parts are not `multiparts`, but they do contain subparts. `is_multipart()` returns `True` and `walk` descends into the subparts.

`get_body`(*preferencelist=('related', 'html', 'plain')*)
Return the MIME part that is the best candidate to be the "body" of the message.

preferencelist must be a sequence of strings from the set `related`, `html`, and `plain`, and indicates the order of preference for the content type of the part returned.

Start looking for candidate matches with the object on which the `get_body` method is called.

If `related` is not included in *preferencelist*, consider the root part (or subpart of the root part) of any related encountered as a candidate if the (sub-)part matches a preference.

When encountering a `multipart/related`, check the `start` parameter and if a part with a matching *Content-ID* is found, consider only it when looking for candidate matches. Otherwise consider only the first (default root) part of the `multipart/related`.

If a part has a *Content-Disposition* header, only consider the part a candidate match if the value of the header is `inline`.

If none of the candidates matches any of the preferences in *preferencelist*, return `None`.

Notes: (1) For most applications the only *preferencelist* combinations that really make sense are `('plain',)`, `('html', 'plain')`, and the default `('related', 'html', 'plain')`. (2) Because matching starts with the object on which `get_body` is called, calling `get_body` on a `multipart/related` will return the object itself unless *preferencelist* has a non-default value. (3) Messages (or message parts) that do not specify a *Content-Type* or whose *Content-Type* header is invalid will be treated as if they are of type `text/plain`, which may occasionally cause `get_body` to return unexpected results.

iter_attachments()
Return an iterator over all of the immediate sub-parts of the message that are not candidate "body" parts. That is, skip the first occurrence of each of `text/plain`, `text/html`, `multipart/related`, or `multipart/alternative` (unless they are explicitly marked as attachments via *Content-Disposition: attachment*), and return all remaining parts. When applied directly to a `multipart/related`, return an iterator over the all the related parts except the root part (ie: the part pointed to by the `start` parameter, or the first part if there is no `start` parameter or the `start` parameter doesn't match the *Content-ID* of any of the parts). When applied directly to a `multipart/alternative` or a non-`multipart`, return an empty iterator.

iter_parts()
Return an iterator over all of the immediate sub-parts of the message, which will be empty for a non-`multipart`. (See also *walk()*.)

get_content(**args*, *content_manager=None*, ***kw*)
Call the *get_content()* method of the *content_manager*, passing self as the message object, and passing along any other arguments or keywords as additional arguments. If *content_manager* is not specified, use the `content_manager` specified by the current *policy*.

set_content(**args*, *content_manager=None*, ***kw*)
Call the *set_content()* method of the *content_manager*, passing self as the message object, and passing along any other arguments or keywords as additional arguments. If *content_manager* is not specified, use the `content_manager` specified by the current *policy*.

make_related(*boundary=None*)
Convert a non-`multipart` message into a `multipart/related` message, moving any existing *Content-* headers and payload into a (new) first part of the `multipart`. If *boundary* is specified, use it as the boundary string in the multipart, otherwise leave the boundary to be automatically created when it is needed (for example, when the message is serialized).

make_alternative(*boundary=None*)
Convert a non-`multipart` or a `multipart/related` into a `multipart/alternative`, moving any existing *Content-* headers and payload into a (new) first part of the `multipart`. If *boundary* is specified, use it as the boundary string in the multipart, otherwise leave the boundary to be automatically created when it is needed (for example, when the message is serialized).

make_mixed(*boundary=None*)
Convert a non-`multipart`, a `multipart/related`, or a `multipart-alternative` into a `multipart/mixed`, moving any existing *Content-* headers and payload into a (new) first part of the `multipart`. If *boundary* is specified, use it as the boundary string in the multipart, otherwise leave the boundary to be automatically created when it is needed (for example, when the message is serialized).

add_related(**args*, *content_manager=None*, ***kw*)
If the message is a `multipart/related`, create a new message object, pass all of the arguments to its *set_content()* method, and *attach()* it to the `multipart`. If the message is a non-`multipart`, call *make_related()* and then proceed as above. If the message is any other type of `multipart`, raise a *TypeError*. If *content_manager* is not specified, use the `content_manager` specified by the current *policy*. If the added part has no *Content-Disposition* header, add one with the value `inline`.

add_alternative(**args*, *content_manager=None*, ***kw*)
If the message is a `multipart/alternative`, create a new message object, pass all of the arguments to its *set_content()* method, and *attach()* it to the `multipart`. If the message is a non-`multipart` or `multipart/related`, call *make_alternative()* and then proceed as above. If the message is any other type of `multipart`, raise a *TypeError*. If *content_manager* is not specified, use the `content_manager` specified by the current *policy*.

add_attachment(**args*, *content_manager=None*, ***kw*)

If the message is a `multipart/mixed`, create a new message object, pass all of the arguments to its *set_content()* method, and *attach()* it to the `multipart`. If the message is a non-`multipart`, `multipart/related`, or `multipart/alternative`, call *make_mixed()* and then proceed as above. If *content_manager* is not specified, use the `content_manager` specified by the current *policy*. If the added part has no *Content-Disposition* header, add one with the value `attachment`. This method can be used both for explicit attachments (*Content-Disposition: attachment* and `inline` attachments (*Content-Disposition: inline*), by passing appropriate options to the `content_manager`.

`clear()`
Remove the payload and all of the headers.

`clear_content()`
Remove the payload and all of the `Content-` headers, leaving all other headers intact and in their original order.

EmailMessage objects have the following instance attributes:

`preamble`
The format of a MIME document allows for some text between the blank line following the headers, and the first multipart boundary string. Normally, this text is never visible in a MIME-aware mail reader because it falls outside the standard MIME armor. However, when viewing the raw text of the message, or when viewing the message in a non-MIME aware reader, this text can become visible.

The *preamble* attribute contains this leading extra-armor text for MIME documents. When the *Parser* discovers some text after the headers but before the first boundary string, it assigns this text to the message's *preamble* attribute. When the *Generator* is writing out the plain text representation of a MIME message, and it finds the message has a *preamble* attribute, it will write this text in the area between the headers and the first boundary. See *email.parser* and *email.generator* for details.

Note that if the message object has no preamble, the *preamble* attribute will be `None`.

`epilogue`
The *epilogue* attribute acts the same way as the *preamble* attribute, except that it contains text that appears between the last boundary and the end of the message. As with the *preamble*, if there is no epilog text this attribute will be `None`.

`defects`
The *defects* attribute contains a list of all the problems found when parsing this message. See *email.errors* for a detailed description of the possible parsing defects.

`class email.message.MIMEPart(`*policy=default*`)`
This class represents a subpart of a MIME message. It is identical to *EmailMessage*, except that no *MIME-Version* headers are added when *set_content()* is called, since sub-parts do not need their own *MIME-Version* headers.

20.1.2 `email.parser`: Parsing email messages

Source code: Lib/email/parser.py

Message object structures can be created in one of two ways: they can be created from whole cloth by creating an *EmailMessage* object, adding headers using the dictionary interface, and adding payload(s) using *set_content()* and related methods, or they can be created by parsing a serialized representation of the email message.

The *email* package provides a standard parser that understands most email document structures, including MIME documents. You can pass the parser a bytes, string or file object, and the parser will return to you the root *EmailMessage* instance of the object structure. For simple, non-MIME messages the payload of this root object will likely be a string containing the text of the message. For MIME messages, the root object will return `True` from its *is_multipart()* method, and the subparts can be accessed via the payload manipulation methods, such as *get_body()*, *iter_parts()*, and *walk()*.

There are actually two parser interfaces available for use, the *Parser* API and the incremental *FeedParser* API. The *Parser* API is most useful if you have the entire text of the message in memory, or if the entire message lives in a file on the file system. *FeedParser* is more appropriate when you are reading the message from a stream which might block waiting for more input (such as reading an email message from a socket). The *FeedParser* can consume and parse the message incrementally, and only returns the root object when you close the parser.

Note that the parser can be extended in limited ways, and of course you can implement your own parser completely from scratch. All of the logic that connects the *email* package's bundled parser and the *EmailMessage* class is embodied in the `policy` class, so a custom parser can create message object trees any way it finds necessary by implementing custom versions of the appropriate `policy` methods.

FeedParser API

The *BytesFeedParser*, imported from the `email.feedparser` module, provides an API that is conducive to incremental parsing of email messages, such as would be necessary when reading the text of an email message from a source that can block (such as a socket). The *BytesFeedParser* can of course be used to parse an email message fully contained in a *bytes-like object*, string, or file, but the *BytesParser* API may be more convenient for such use cases. The semantics and results of the two parser APIs are identical.

The *BytesFeedParser*'s API is simple; you create an instance, feed it a bunch of bytes until there's no more to feed it, then close the parser to retrieve the root message object. The *BytesFeedParser* is extremely accurate when parsing standards-compliant messages, and it does a very good job of parsing non-compliant messages, providing information about how a message was deemed broken. It will populate a message object's *defects* attribute with a list of any problems it found in a message. See the *email.errors* module for the list of defects that it can find.

Here is the API for the *BytesFeedParser*:

class email.parser.BytesFeedParser(*_factory=None*, ***, *policy=policy.compat32*)

Create a *BytesFeedParser* instance. Optional *_factory* is a no-argument callable; if not specified use the *message_factory* from the *policy*. Call *_factory* whenever a new message object is needed.

If *policy* is specified use the rules it specifies to update the representation of the message. If *policy* is not set, use the *compat32* policy, which maintains backward compatibility with the Python 3.2 version of the email package and provides *Message* as the default factory. All other policies provide *EmailMessage* as the default *_factory*. For more information on what else *policy* controls, see the *policy* documentation.

Note: **The policy keyword should always be specified**; The default will change to *email.policy.default* in a future version of Python.

New in version 3.2.

Changed in version 3.3: Added the *policy* keyword.

Changed in version 3.6: *_factory* defaults to the policy `message_factory`.

feed(*data*)

Feed the parser some more data. *data* should be a *bytes-like object* containing one or more lines. The lines can be partial and the parser will stitch such partial lines together properly. The lines can have any of the three common line endings: carriage return, newline, or carriage return and newline (they can even be mixed).

`close()`
Complete the parsing of all previously fed data and return the root message object. It is undefined what happens if *feed()* is called after this method has been called.

`class email.parser.FeedParser(_factory=None, *, policy=policy.compat32)`
Works like *BytesFeedParser* except that the input to the *feed()* method must be a string. This is of limited utility, since the only way for such a message to be valid is for it to contain only ASCII text or, if `utf8` is `True`, no binary attachments.

Changed in version 3.3: Added the *policy* keyword.

Parser API

The *BytesParser* class, imported from the *email.parser* module, provides an API that can be used to parse a message when the complete contents of the message are available in a *bytes-like object* or file. The *email.parser* module also provides *Parser* for parsing strings, and header-only parsers, *BytesHeaderParser* and *HeaderParser*, which can be used if you're only interested in the headers of the message. *BytesHeaderParser* and *HeaderParser* can be much faster in these situations, since they do not attempt to parse the message body, instead setting the payload to the raw body.

`class email.parser.BytesParser(_class=None, *, policy=policy.compat32)`
Create a *BytesParser* instance. The *_class* and *policy* arguments have the same meaning and semantics as the *_factory* and *policy* arguments of *BytesFeedParser*.

Note: **The policy keyword should always be specified**; The default will change to *email.policy.default* in a future version of Python.

Changed in version 3.3: Removed the *strict* argument that was deprecated in 2.4. Added the *policy* keyword.

Changed in version 3.6: *_class* defaults to the policy `message_factory`.

`parse(fp, headersonly=False)`
Read all the data from the binary file-like object *fp*, parse the resulting bytes, and return the message object. *fp* must support both the *readline()* and the `read()` methods.

The bytes contained in *fp* must be formatted as a block of **RFC 5322** (or, if `utf8` is `True`, **RFC 6532**) style headers and header continuation lines, optionally preceded by an envelope header. The header block is terminated either by the end of the data or by a blank line. Following the header block is the body of the message (which may contain MIME-encoded subparts, including subparts with a *Content-Transfer-Encoding* of `8bit`.

Optional *headersonly* is a flag specifying whether to stop parsing after reading the headers or not. The default is `False`, meaning it parses the entire contents of the file.

`parsebytes(bytes, headersonly=False)`
Similar to the *parse()* method, except it takes a *bytes-like object* instead of a file-like object. Calling this method on a *bytes-like object* is equivalent to wrapping *bytes* in a *BytesIO* instance first and calling *parse()*.

Optional *headersonly* is as with the *parse()* method.

New in version 3.2.

`class email.parser.BytesHeaderParser(_class=None, *, policy=policy.compat32)`
Exactly like *BytesParser*, except that *headersonly* defaults to `True`.

New in version 3.3.

`class email.parser.Parser(_class=None, *, policy=policy.compat32)`
This class is parallel to *BytesParser*, but handles string input.

Changed in version 3.3: Removed the *strict* argument. Added the *policy* keyword.

Changed in version 3.6: *_class* defaults to the policy `message_factory`.

parse(*fp*, *headersonly=False*)
Read all the data from the text-mode file-like object *fp*, parse the resulting text, and return the root message object. *fp* must support both the *readline()* and the *read()* methods on file-like objects.

Other than the text mode requirement, this method operates like *BytesParser.parse()*.

parsestr(*text*, *headersonly=False*)
Similar to the *parse()* method, except it takes a string object instead of a file-like object. Calling this method on a string is equivalent to wrapping *text* in a *StringIO* instance first and calling *parse()*.

Optional *headersonly* is as with the *parse()* method.

class email.parser.HeaderParser(*_class=None*, ***, *policy=policy.compat32*)
Exactly like *Parser*, except that *headersonly* defaults to `True`.

Since creating a message object structure from a string or a file object is such a common task, four functions are provided as a convenience. They are available in the top-level *email* package namespace.

email.message_from_bytes(*s*, *_class=None*, ***, *policy=policy.compat32*)
Return a message object structure from a *bytes-like object*. This is equivalent to `BytesParser().parsebytes(s)`. Optional *_class* and *strict* are interpreted as with the *BytesParser* class constructor.

New in version 3.2.

Changed in version 3.3: Removed the *strict* argument. Added the *policy* keyword.

message_from_binary_file(fp, _class=None, *, policy=policy.compat32)
Return a message object structure tree from an open binary *file object*. This is equivalent to `BytesParser().parse(fp)`. *_class* and *policy* are interpreted as with the *BytesParser* class constructor.

New in version 3.2.

Changed in version 3.3: Removed the *strict* argument. Added the *policy* keyword.

email.message_from_string(*s*, *_class=None*, ***, *policy=policy.compat32*)
Return a message object structure from a string. This is equivalent to `Parser().parsestr(s)`. *_class* and *policy* are interpreted as with the *Parser* class constructor.

Changed in version 3.3: Removed the *strict* argument. Added the *policy* keyword.

email.message_from_file(*fp*, *_class=None*, ***, *policy=policy.compat32*)
Return a message object structure tree from an open *file object*. This is equivalent to `Parser().parse(fp)`. *_class* and *policy* are interpreted as with the *Parser* class constructor.

Changed in version 3.3: Removed the *strict* argument. Added the *policy* keyword.

Changed in version 3.6: *_class* defaults to the policy `message_factory`.

Here's an example of how you might use *message_from_bytes()* at an interactive Python prompt:

```
>>> import email
>>> msg = email.message_from_bytes(myBytes)
```

Additional notes

Here are some notes on the parsing semantics:

- Most non-*multipart* type messages are parsed as a single message object with a string payload. These objects will return `False` for *is_multipart()*, and *iter_parts()* will yield an empty list.
- All *multipart* type messages will be parsed as a container message object with a list of sub-message objects for their payload. The outer container message will return `True` for *is_multipart()*, and *iter_parts()* will yield a list of subparts.
- Most messages with a content type of *message/** (such as *message/delivery-status* and *message/rfc822*) will also be parsed as container object containing a list payload of length 1. Their *is_multipart()* method will return `True`. The single element yielded by *iter_parts()* will be a sub-message object.
- Some non-standards-compliant messages may not be internally consistent about their *multipart*-edness. Such messages may have a *Content-Type* header of type *multipart*, but their *is_multipart()* method may return `False`. If such messages were parsed with the *FeedParser*, they will have an instance of the `MultipartInvariantViolationDefect` class in their *defects* attribute list. See *email.errors* for details.

20.1.3 `email.generator`: Generating MIME documents

Source code: Lib/email/generator.py

One of the most common tasks is to generate the flat (serialized) version of the email message represented by a message object structure. You will need to do this if you want to send your message via *smtplib.SMTP.sendmail()* or the *nntplib* module, or print the message on the console. Taking a message object structure and producing a serialized representation is the job of the generator classes.

As with the *email.parser* module, you aren't limited to the functionality of the bundled generator; you could write one from scratch yourself. However the bundled generator knows how to generate most email in a standards-compliant way, should handle MIME and non-MIME email messages just fine, and is designed so that the bytes-oriented parsing and generation operations are inverses, assuming the same non-transforming *policy* is used for both. That is, parsing the serialized byte stream via the *BytesParser* class and then regenerating the serialized byte stream using *BytesGenerator* should produce output identical to the input[1]. (On the other hand, using the generator on an *EmailMessage* constructed by program may result in changes to the *EmailMessage* object as defaults are filled in.)

The *Generator* class can be used to flatten a message into a text (as opposed to binary) serialized representation, but since Unicode cannot represent binary data directly, the message is of necessity transformed into something that contains only ASCII characters, using the standard email RFC Content Transfer Encoding techniques for encoding email messages for transport over channels that are not "8 bit clean".

`class email.generator.BytesGenerator(`*outfp*, *mangle_from_=None*, *maxheaderlen=None*, ***, *policy=None*`)`

Return a *BytesGenerator* object that will write any message provided to the *flatten()* method, or any surrogateescape encoded text provided to the *write()* method, to the *file-like object* *outfp*. *outfp* must support a `write` method that accepts binary data.

If optional *mangle_from_* is `True`, put a `>` character in front of any line in the body that starts with the exact string `"From "`, that is `From` followed by a space at the beginning of a line. *mangle_from_* defaults to the value of the *mangle_from_* setting of the *policy* (which is `True` for the *compat32* policy and `False` for all others). *mangle_from_* is intended for use when messages are stored in unix mbox format (see *mailbox* and WHY THE CONTENT-LENGTH FORMAT IS BAD).

[1] This statement assumes that you use the appropriate setting for `unixfrom`, and that there are no `policy` settings calling for automatic adjustments (for example, `refold_source` must be `none`, which is *not* the default). It is also not 100% true, since if the message does not conform to the RFC standards occasionally information about the exact original text is lost during parsing error recovery. It is a goal to fix these latter edge cases when possible.

If *maxheaderlen* is not `None`, refold any header lines that are longer than *maxheaderlen*, or if `0`, do not rewrap any headers. If *manheaderlen* is `None` (the default), wrap headers and other message lines according to the *policy* settings.

If *policy* is specified, use that policy to control message generation. If *policy* is `None` (the default), use the policy associated with the *Message* or *EmailMessage* object passed to `flatten` to control the message generation. See *email.policy* for details on what *policy* controls.

New in version 3.2.

Changed in version 3.3: Added the *policy* keyword.

Changed in version 3.6: The default behavior of the *mangle_from_* and *maxheaderlen* parameters is to follow the policy.

`flatten`(*msg*, *unixfrom=False*, *linesep=None*)

Print the textual representation of the message object structure rooted at *msg* to the output file specified when the *BytesGenerator* instance was created.

If the *policy* option *cte_type* is `8bit` (the default), copy any headers in the original parsed message that have not been modified to the output with any bytes with the high bit set reproduced as in the original, and preserve the non-ASCII *Content-Transfer-Encoding* of any body parts that have them. If `cte_type` is `7bit`, convert the bytes with the high bit set as needed using an ASCII-compatible *Content-Transfer-Encoding*. That is, transform parts with non-ASCII *Content-Transfer-Encoding* (*Content-Transfer-Encoding: 8bit*) to an ASCII compatible *Content-Transfer-Encoding*, and encode RFC-invalid non-ASCII bytes in headers using the MIME `unknown-8bit` character set, thus rendering them RFC-compliant.

If *unixfrom* is `True`, print the envelope header delimiter used by the Unix mailbox format (see *mailbox*) before the first of the **RFC 5322** headers of the root message object. If the root object has no envelope header, craft a standard one. The default is `False`. Note that for subparts, no envelope header is ever printed.

If *linesep* is not `None`, use it as the separator character between all the lines of the flattened message. If *linesep* is `None` (the default), use the value specified in the *policy*.

`clone`(*fp*)

Return an independent clone of this *BytesGenerator* instance with the exact same option settings, and *fp* as the new *outfp*.

`write`(*s*)

Encode *s* using the `ASCII` codec and the `surrogateescape` error handler, and pass it to the *write* method of the *outfp* passed to the *BytesGenerator*'s constructor.

As a convenience, *EmailMessage* provides the methods *as_bytes()* and `bytes(aMessage)` (a.k.a. *__bytes__()*), which simplify the generation of a serialized binary representation of a message object. For more detail, see *email.message*.

Because strings cannot represent binary data, the *Generator* class must convert any binary data in any message it flattens to an ASCII compatible format, by converting them to an ASCII compatible *Content-Transfer_Encoding*. Using the terminology of the email RFCs, you can think of this as *Generator* serializing to an I/O stream that is not "8 bit clean". In other words, most applications will want to be using *BytesGenerator*, and not *Generator*.

`class email.generator.Generator`(*outfp*, *mangle_from_=None*, *maxheaderlen=None*, ***, *policy=None*)

Return a *Generator* object that will write any message provided to the *flatten()* method, or any text provided to the *write()* method, to the *file-like object* *outfp*. *outfp* must support a `write` method that accepts string data.

If optional *mangle_from_* is `True`, put a `>` character in front of any line in the body that starts with the exact string `"From "`, that is `From` followed by a space at the beginning of a line. *mangle_from_*

defaults to the value of the *mangle_from_* setting of the *policy* (which is `True` for the *compat32* policy and `False` for all others). *mangle_from_* is intended for use when messages are stored in unix mbox format (see *mailbox* and WHY THE CONTENT-LENGTH FORMAT IS BAD).

If *maxheaderlen* is not `None`, refold any header lines that are longer than *maxheaderlen*, or if `0`, do not rewrap any headers. If *manheaderlen* is `None` (the default), wrap headers and other message lines according to the *policy* settings.

If *policy* is specified, use that policy to control message generation. If *policy* is `None` (the default), use the policy associated with the *Message* or *EmailMessage* object passed to `flatten` to control the message generation. See *email.policy* for details on what *policy* controls.

Changed in version 3.3: Added the *policy* keyword.

Changed in version 3.6: The default behavior of the *mangle_from_* and *maxheaderlen* parameters is to follow the policy.

`flatten`(*msg*, *unixfrom=False*, *linesep=None*)

Print the textual representation of the message object structure rooted at *msg* to the output file specified when the *Generator* instance was created.

If the *policy* option *cte_type* is `8bit`, generate the message as if the option were set to `7bit`. (This is required because strings cannot represent non-ASCII bytes.) Convert any bytes with the high bit set as needed using an ASCII-compatible *Content-Transfer-Encoding*. That is, transform parts with non-ASCII *Cotnent-Transfer-Encoding* (*Content-Transfer-Encoding: 8bit*) to an ASCII compatible *Content-Transfer-Encoding*, and encode RFC-invalid non-ASCII bytes in headers using the MIME `unknown-8bit` character set, thus rendering them RFC-compliant.

If *unixfrom* is `True`, print the envelope header delimiter used by the Unix mailbox format (see *mailbox*) before the first of the **RFC 5322** headers of the root message object. If the root object has no envelope header, craft a standard one. The default is `False`. Note that for subparts, no envelope header is ever printed.

If *linesep* is not `None`, use it as the separator character between all the lines of the flattened message. If *linesep* is `None` (the default), use the value specified in the *policy*.

Changed in version 3.2: Added support for re-encoding `8bit` message bodies, and the *linesep* argument.

`clone`(*fp*)

Return an independent clone of this *Generator* instance with the exact same options, and *fp* as the new *outfp*.

`write`(*s*)

Write *s* to the *write* method of the *outfp* passed to the *Generator*'s constructor. This provides just enough file-like API for *Generator* instances to be used in the *print()* function.

As a convenience, *EmailMessage* provides the methods *as_string()* and `str(aMessage)` (a.k.a. *__str__()*), which simplify the generation of a formatted string representation of a message object. For more detail, see *email.message*.

The *email.generator* module also provides a derived class, *DecodedGenerator*, which is like the *Generator* base class, except that non-*text* parts are not serialized, but are instead represented in the output stream by a string derived from a template filled in with information about the part.

`class email.generator.DecodedGenerator`(*outfp*, *mangle_from_=None*, *maxheaderlen=None*, *fmt=None*, ***, *policy=None*)

Act like *Generator*, except that for any subpart of the message passed to *Generator.flatten()*, if the subpart is of main type *text*, print the decoded payload of the subpart, and if the main type is not *text*, instead of printing it fill in the string *fmt* using information from the part and print the resulting filled-in string.

To fill in *fmt*, execute `fmt % part_info`, where `part_info` is a dictionary composed of the following keys and values:

- `type` – Full MIME type of the non-*text* part
- `maintype` – Main MIME type of the non-*text* part
- `subtype` – Sub-MIME type of the non-*text* part
- `filename` – Filename of the non-*text* part
- `description` – Description associated with the non-*text* part
- `encoding` – Content transfer encoding of the non-*text* part

If *fmt* is `None`, use the following default *fmt*:

"[Non-text (%(type)s) part of message omitted, filename %(filename)s]"

Optional *_mangle_from_* and *maxheaderlen* are as with the *Generator* base class.

20.1.4 `email.policy`: Policy Objects

New in version 3.3.

Source code: Lib/email/policy.py

The *email* package's prime focus is the handling of email messages as described by the various email and MIME RFCs. However, the general format of email messages (a block of header fields each consisting of a name followed by a colon followed by a value, the whole block followed by a blank line and an arbitrary 'body'), is a format that has found utility outside of the realm of email. Some of these uses conform fairly closely to the main email RFCs, some do not. Even when working with email, there are times when it is desirable to break strict compliance with the RFCs, such as generating emails that interoperate with email servers that do not themselves follow the standards, or that implement extensions you want to use in ways that violate the standards.

Policy objects give the email package the flexibility to handle all these disparate use cases.

A *Policy* object encapsulates a set of attributes and methods that control the behavior of various components of the email package during use. *Policy* instances can be passed to various classes and methods in the email package to alter the default behavior. The settable values and their defaults are described below.

There is a default policy used by all classes in the email package. For all of the *parser* classes and the related convenience functions, and for the *Message* class, this is the *Compat32* policy, via its corresponding pre-defined instance *compat32*. This policy provides for complete backward compatibility (in some cases, including bug compatibility) with the pre-Python3.3 version of the email package.

This default value for the *policy* keyword to *EmailMessage* is the *EmailPolicy* policy, via its pre-defined instance *default*.

When a *Message* or *EmailMessage* object is created, it acquires a policy. If the message is created by a *parser*, a policy passed to the parser will be the policy used by the message it creates. If the message is created by the program, then the policy can be specified when it is created. When a message is passed to a *generator*, the generator uses the policy from the message by default, but you can also pass a specific policy to the generator that will override the one stored on the message object.

The default value for the *policy* keyword for the *email.parser* classes and the parser convenience functions **will be changing** in a future version of Python. Therefore you should **always specify explicitly which policy you want to use** when calling any of the classes and functions described in the *parser* module.

The first part of this documentation covers the features of *Policy*, an *abstract base class* that defines the features that are common to all policy objects, including *compat32*. This includes certain hook methods

that are called internally by the email package, which a custom policy could override to obtain different behavior. The second part describes the concrete classes *EmailPolicy* and *Compat32*, which implement the hooks that provide the standard behavior and the backward compatible behavior and features, respectively.

Policy instances are immutable, but they can be cloned, accepting the same keyword arguments as the class constructor and returning a new *Policy* instance that is a copy of the original but with the specified attributes values changed.

As an example, the following code could be used to read an email message from a file on disk and pass it to the system `sendmail` program on a Unix system:

```
>>> from email import message_from_binary_file
>>> from email.generator import BytesGenerator
>>> from email import policy
>>> from subprocess import Popen, PIPE
>>> with open('mymsg.txt', 'rb') as f:
...     msg = message_from_binary_file(f, policy=policy.default)
>>> p = Popen(['sendmail', msg['To'].addresses[0]], stdin=PIPE)
>>> g = BytesGenerator(p.stdin, policy=msg.policy.clone(linesep='\r\n'))
>>> g.flatten(msg)
>>> p.stdin.close()
>>> rc = p.wait()
```

Here we are telling *BytesGenerator* to use the RFC correct line separator characters when creating the binary string to feed into `sendmail's stdin`, where the default policy would use `\n` line separators.

Some email package methods accept a *policy* keyword argument, allowing the policy to be overridden for that method. For example, the following code uses the *as_bytes()* method of the *msg* object from the previous example and writes the message to a file using the native line separators for the platform on which it is running:

```
>>> import os
>>> with open('converted.txt', 'wb') as f:
...     f.write(msg.as_bytes(policy=msg.policy.clone(linesep=os.linesep)))
17
```

Policy objects can also be combined using the addition operator, producing a policy object whose settings are a combination of the non-default values of the summed objects:

```
>>> compat_SMTP = policy.compat32.clone(linesep='\r\n')
>>> compat_strict = policy.compat32.clone(raise_on_defect=True)
>>> compat_strict_SMTP = compat_SMTP + compat_strict
```

This operation is not commutative; that is, the order in which the objects are added matters. To illustrate:

```
>>> policy100 = policy.compat32.clone(max_line_length=100)
>>> policy80 = policy.compat32.clone(max_line_length=80)
>>> apolicy = policy100 + policy80
>>> apolicy.max_line_length
80
>>> apolicy = policy80 + policy100
>>> apolicy.max_line_length
100
```

class email.policy.**Policy**(***kw*)

This is the *abstract base class* for all policy classes. It provides default implementations for a couple of trivial methods, as well as the implementation of the immutability property, the *clone()* method, and the constructor semantics.

The constructor of a policy class can be passed various keyword arguments. The arguments that may be specified are any non-method properties on this class, plus any additional non-method properties on the concrete class. A value specified in the constructor will override the default value for the corresponding attribute.

This class defines the following properties, and thus values for the following may be passed in the constructor of any policy class:

max_line_length
The maximum length of any line in the serialized output, not counting the end of line character(s). Default is 78, per **RFC 5322**. A value of `0` or *None* indicates that no line wrapping should be done at all.

linesep
The string to be used to terminate lines in serialized output. The default is `\n` because that's the internal end-of-line discipline used by Python, though `\r\n` is required by the RFCs.

cte_type
Controls the type of Content Transfer Encodings that may be or are required to be used. The possible values are:

`7bit`	all data must be "7 bit clean" (ASCII-only). This means that where necessary data will be encoded using either quoted-printable or base64 encoding.
`8bit`	data is not constrained to be 7 bit clean. Data in headers is still required to be ASCII-only and so will be encoded (see *fold_binary()* and *utf8* below for exceptions), but body parts may use the `8bit` CTE.

A `cte_type` value of `8bit` only works with `BytesGenerator`, not `Generator`, because strings cannot contain binary data. If a `Generator` is operating under a policy that specifies `cte_type=8bit`, it will act as if `cte_type` is `7bit`.

raise_on_defect
If *True*, any defects encountered will be raised as errors. If *False* (the default), defects will be passed to the *register_defect()* method.

mangle_from_
If *True*, lines starting with *"From "* in the body are escaped by putting a `>` in front of them. This parameter is used when the message is being serialized by a generator. Default: *False*.

New in version 3.5: The *mangle_from_* parameter.

message_factory
A factory function for constructing a new empty message object. Used by the parser when building messages. Defaults to `None`, in which case *Message* is used.

New in version 3.6.

The following *Policy* method is intended to be called by code using the email library to create policy instances with custom settings:

clone(***kw*)
Return a new *Policy* instance whose attributes have the same values as the current instance, except where those attributes are given new values by the keyword arguments.

The remaining *Policy* methods are called by the email package code, and are not intended to be called by an application using the email package. A custom policy must implement all of these methods.

handle_defect(*obj*, *defect*)
Handle a *defect* found on *obj*. When the email package calls this method, *defect* will always be a subclass of `Defect`.

The default implementation checks the *raise_on_defect* flag. If it is `True`, *defect* is raised as an exception. If it is `False` (the default), *obj* and *defect* are passed to *register_defect()*.

register_defect(*obj*, *defect*)
Register a *defect* on *obj*. In the email package, *defect* will always be a subclass of `Defect`.

The default implementation calls the `append` method of the `defects` attribute of *obj*. When the email package calls *handle_defect*, *obj* will normally have a `defects` attribute that has an `append` method. Custom object types used with the email package (for example, custom `Message` objects) should also provide such an attribute, otherwise defects in parsed messages will raise unexpected errors.

header_max_count(*name*)
Return the maximum allowed number of headers named *name*.

Called when a header is added to an *EmailMessage* or *Message* object. If the returned value is not `0` or `None`, and there are already a number of headers with the name *name* greater than or equal to the value returned, a *ValueError* is raised.

Because the default behavior of `Message.__setitem__` is to append the value to the list of headers, it is easy to create duplicate headers without realizing it. This method allows certain headers to be limited in the number of instances of that header that may be added to a `Message` programmatically. (The limit is not observed by the parser, which will faithfully produce as many headers as exist in the message being parsed.)

The default implementation returns `None` for all header names.

header_source_parse(*sourcelines*)
The email package calls this method with a list of strings, each string ending with the line separation characters found in the source being parsed. The first line includes the field header name and separator. All whitespace in the source is preserved. The method should return the `(name, value)` tuple that is to be stored in the `Message` to represent the parsed header.

If an implementation wishes to retain compatibility with the existing email package policies, *name* should be the case preserved name (all characters up to the '`:`' separator), while *value* should be the unfolded value (all line separator characters removed, but whitespace kept intact), stripped of leading whitespace.

sourcelines may contain surrogateescaped binary data.

There is no default implementation

header_store_parse(*name*, *value*)
The email package calls this method with the name and value provided by the application program when the application program is modifying a `Message` programmatically (as opposed to a `Message` created by a parser). The method should return the `(name, value)` tuple that is to be stored in the `Message` to represent the header.

If an implementation wishes to retain compatibility with the existing email package policies, the *name* and *value* should be strings or string subclasses that do not change the content of the passed in arguments.

There is no default implementation

header_fetch_parse(*name*, *value*)
The email package calls this method with the *name* and *value* currently stored in the `Message` when that header is requested by the application program, and whatever the method returns is what is passed back to the application as the value of the header being retrieved. Note that there may be more than one header with the same name stored in the `Message`; the method is passed the specific name and value of the header destined to be returned to the application.

value may contain surrogateescaped binary data. There should be no surrogateescaped binary data in the value returned by the method.

There is no default implementation

fold(*name*, *value*)
The email package calls this method with the *name* and *value* currently stored in the `Message` for a given header. The method should return a string that represents that header "folded" correctly (according to the policy settings) by composing the *name* with the *value* and inserting *linesep* characters at the appropriate places. See **RFC 5322** for a discussion of the rules for folding email headers.

value may contain surrogateescaped binary data. There should be no surrogateescaped binary data in the string returned by the method.

fold_binary(*name*, *value*)
The same as *fold()*, except that the returned value should be a bytes object rather than a string.

value may contain surrogateescaped binary data. These could be converted back into binary data in the returned bytes object.

class email.policy.EmailPolicy(***kw*)
This concrete *Policy* provides behavior that is intended to be fully compliant with the current email RFCs. These include (but are not limited to) **RFC 5322**, **RFC 2047**, and the current MIME RFCs.

This policy adds new header parsing and folding algorithms. Instead of simple strings, headers are `str` subclasses with attributes that depend on the type of the field. The parsing and folding algorithm fully implement **RFC 2047** and **RFC 5322**.

The default value for the *message_factory* attribute is *EmailMessage*.

In addition to the settable attributes listed above that apply to all policies, this policy adds the following additional attributes:

New in version 3.6:[1]

utf8
If `False`, follow **RFC 5322**, supporting non-ASCII characters in headers by encoding them as "encoded words". If `True`, follow **RFC 6532** and use `utf-8` encoding for headers. Messages formatted in this way may be passed to SMTP servers that support the `SMTPUTF8` extension (**RFC 6531**).

refold_source
If the value for a header in the `Message` object originated from a *parser* (as opposed to being set by a program), this attribute indicates whether or not a generator should refold that value when transforming the message back into serialized form. The possible values are:

`none`	all source values use original folding
`long`	source values that have any line that is longer than `max_line_length` will be refolded
`all`	all values are refolded.

The default is `long`.

header_factory
A callable that takes two arguments, `name` and `value`, where `name` is a header field name and `value` is an unfolded header field value, and returns a string subclass that represents that header. A default `header_factory` (see *headerregistry*) is provided that supports custom parsing for the various address and date **RFC 5322** header field types, and the major MIME header field stypes. Support for additional custom parsing will be added in the future.

content_manager
An object with at least two methods: get_content and set_content. When the *get_content()* or *set_content()* method of an *EmailMessage* object is called, it calls the corresponding method

[1] Originally added in 3.3 as a *provisional feature*.

of this object, passing it the message object as its first argument, and any arguments or keywords that were passed to it as additional arguments. By default `content_manager` is set to *raw_data_manager*.

New in version 3.4.

The class provides the following concrete implementations of the abstract methods of *Policy*:

header_max_count(*name*)
Returns the value of the *max_count* attribute of the specialized class used to represent the header with the given name.

header_source_parse(*sourcelines*)
The name is parsed as everything up to the ':' and returned unmodified. The value is determined by stripping leading whitespace off the remainder of the first line, joining all subsequent lines together, and stripping any trailing carriage return or linefeed characters.

header_store_parse(*name*, *value*)
The name is returned unchanged. If the input value has a `name` attribute and it matches *name* ignoring case, the value is returned unchanged. Otherwise the *name* and *value* are passed to `header_factory`, and the resulting header object is returned as the value. In this case a `ValueError` is raised if the input value contains CR or LF characters.

header_fetch_parse(*name*, *value*)
If the value has a `name` attribute, it is returned to unmodified. Otherwise the *name*, and the *value* with any CR or LF characters removed, are passed to the `header_factory`, and the resulting header object is returned. Any surrogateescaped bytes get turned into the unicode unknown-character glyph.

fold(*name*, *value*)
Header folding is controlled by the *refold_source* policy setting. A value is considered to be a 'source value' if and only if it does not have a `name` attribute (having a `name` attribute means it is a header object of some sort). If a source value needs to be refolded according to the policy, it is converted into a header object by passing the *name* and the *value* with any CR and LF characters removed to the `header_factory`. Folding of a header object is done by calling its `fold` method with the current policy.

Source values are split into lines using *splitlines()*. If the value is not to be refolded, the lines are rejoined using the `linesep` from the policy and returned. The exception is lines containing non-ascii binary data. In that case the value is refolded regardless of the `refold_source` setting, which causes the binary data to be CTE encoded using the `unknown-8bit` charset.

fold_binary(*name*, *value*)
The same as *fold()* if *cte_type* is `7bit`, except that the returned value is bytes.

If *cte_type* is `8bit`, non-ASCII binary data is converted back into bytes. Headers with binary data are not refolded, regardless of the `refold_header` setting, since there is no way to know whether the binary data consists of single byte characters or multibyte characters.

The following instances of *EmailPolicy* provide defaults suitable for specific application domains. Note that in the future the behavior of these instances (in particular the `HTTP` instance) may be adjusted to conform even more closely to the RFCs relevant to their domains.

email.policy.default
An instance of `EmailPolicy` with all defaults unchanged. This policy uses the standard Python `\n` line endings rather than the RFC-correct `\r\n`.

email.policy.SMTP
Suitable for serializing messages in conformance with the email RFCs. Like `default`, but with `linesep` set to `\r\n`, which is RFC compliant.

email.policy.SMTPUTF8
: The same as SMTP except that *utf8* is True. Useful for serializing messages to a message store without using encoded words in the headers. Should only be used for SMTP transmission if the sender or recipient addresses have non-ASCII characters (the *smtplib.SMTP.send_message()* method handles this automatically).

email.policy.HTTP
: Suitable for serializing headers with for use in HTTP traffic. Like SMTP except that max_line_length is set to None (unlimited).

email.policy.strict
: Convenience instance. The same as default except that raise_on_defect is set to True. This allows any policy to be made strict by writing:

```
somepolicy + policy.strict
```

With all of these *EmailPolicies*, the effective API of the email package is changed from the Python 3.2 API in the following ways:

- Setting a header on a *Message* results in that header being parsed and a header object created.
- Fetching a header value from a *Message* results in that header being parsed and a header object created and returned.
- Any header object, or any header that is refolded due to the policy settings, is folded using an algorithm that fully implements the RFC folding algorithms, including knowing where encoded words are required and allowed.

From the application view, this means that any header obtained through the *EmailMessage* is a header object with extra attributes, whose string value is the fully decoded unicode value of the header. Likewise, a header may be assigned a new value, or a new header created, using a unicode string, and the policy will take care of converting the unicode string into the correct RFC encoded form.

The header objects and their attributes are described in *headerregistry*.

class email.policy.Compat32(***kw*)
: This concrete *Policy* is the backward compatibility policy. It replicates the behavior of the email package in Python 3.2. The *policy* module also defines an instance of this class, *compat32*, that is used as the default policy. Thus the default behavior of the email package is to maintain compatibility with Python 3.2.

  The following attributes have values that are different from the *Policy* default:

  mangle_from_
  : The default is True.

  The class provides the following concrete implementations of the abstract methods of *Policy*:

  header_source_parse(*sourcelines*)
  : The name is parsed as everything up to the ':' and returned unmodified. The value is determined by stripping leading whitespace off the remainder of the first line, joining all subsequent lines together, and stripping any trailing carriage return or linefeed characters.

  header_store_parse(*name*, *value*)
  : The name and value are returned unmodified.

  header_fetch_parse(*name*, *value*)
  : If the value contains binary data, it is converted into a *Header* object using the unknown-8bit charset. Otherwise it is returned unmodified.

  fold(*name*, *value*)
  : Headers are folded using the *Header* folding algorithm, which preserves existing line breaks in the

value, and wraps each resulting line to the `max_line_length`. Non-ASCII binary data are CTE encoded using the `unknown-8bit` charset.

`fold_binary`(*name*, *value*)
Headers are folded using the *Header* folding algorithm, which preserves existing line breaks in the value, and wraps each resulting line to the `max_line_length`. If `cte_type` is `7bit`, non-ascii binary data is CTE encoded using the `unknown-8bit` charset. Otherwise the original source header is used, with its existing line breaks and any (RFC invalid) binary data it may contain.

`email.policy.compat32`
An instance of *Compat32*, providing backward compatibility with the behavior of the email package in Python 3.2.

20.1.5 `email.errors`: Exception and Defect classes

Source code: Lib/email/errors.py

The following exception classes are defined in the *email.errors* module:

exception `email.errors.MessageError`
This is the base class for all exceptions that the *email* package can raise. It is derived from the standard *Exception* class and defines no additional methods.

exception `email.errors.MessageParseError`
This is the base class for exceptions raised by the *Parser* class. It is derived from *MessageError*. This class is also used internally by the parser used by *headerregistry*.

exception `email.errors.HeaderParseError`
Raised under some error conditions when parsing the **RFC 5322** headers of a message, this class is derived from *MessageParseError*. The *set_boundary()* method will raise this error if the content type is unknown when the method is called. *Header* may raise this error for certain base64 decoding errors, and when an attempt is made to create a header that appears to contain an embedded header (that is, there is what is supposed to be a continuation line that has no leading whitespace and looks like a header).

exception `email.errors.BoundaryError`
Deprecated and no longer used.

exception `email.errors.MultipartConversionError`
Raised when a payload is added to a *Message* object using `add_payload()`, but the payload is already a scalar and the message's *Content-Type* main type is not either *multipart* or missing. *MultipartConversionError* multiply inherits from *MessageError* and the built-in *TypeError*.

Since `Message.add_payload()` is deprecated, this exception is rarely raised in practice. However the exception may also be raised if the *attach()* method is called on an instance of a class derived from *MIMENonMultipart* (e.g. *MIMEImage*).

Here is the list of the defects that the *FeedParser* can find while parsing messages. Note that the defects are added to the message where the problem was found, so for example, if a message nested inside a *multipart/alternative* had a malformed header, that nested message object would have a defect, but the containing messages would not.

All defect classes are subclassed from `email.errors.MessageDefect`.

- `NoBoundaryInMultipartDefect` – A message claimed to be a multipart, but had no *boundary* parameter.
- `StartBoundaryNotFoundDefect` – The start boundary claimed in the *Content-Type* header was never found.

- `CloseBoundaryNotFoundDefect` – A start boundary was found, but no corresponding close boundary was ever found.

  New in version 3.3.

- `FirstHeaderLineIsContinuationDefect` – The message had a continuation line as its first header line.

- `MisplacedEnvelopeHeaderDefect` - A "Unix From" header was found in the middle of a header block.

- `MissingHeaderBodySeparatorDefect` - A line was found while parsing headers that had no leading white space but contained no ':'. Parsing continues assuming that the line represents the first line of the body.

  New in version 3.3.

- `MalformedHeaderDefect` – A header was found that was missing a colon, or was otherwise malformed.

  Deprecated since version 3.3: This defect has not been used for several Python versions.

- `MultipartInvariantViolationDefect` – A message claimed to be a *multipart*, but no subparts were found. Note that when a message has this defect, its *is_multipart()* method may return false even though its content type claims to be *multipart*.

- `InvalidBase64PaddingDefect` – When decoding a block of base64 encoded bytes, the padding was not correct. Enough padding is added to perform the decode, but the resulting decoded bytes may be invalid.

- `InvalidBase64CharactersDefect` – When decoding a block of base64 encoded bytes, characters outside the base64 alphabet were encountered. The characters are ignored, but the resulting decoded bytes may be invalid.

- `InvalidBase64LengthDefect` – When decoding a block of base64 encoded bytes, the number of non-padding base64 characters was invalid (1 more than a multiple of 4). The encoded block was kept as-is.

20.1.6 `email.headerregistry`: Custom Header Objects

Source code: Lib/email/headerregistry.py

New in version 3.6:[1]

Headers are represented by customized subclasses of *str*. The particular class used to represent a given header is determined by the *header_factory* of the *policy* in effect when the headers are created. This section documents the particular `header_factory` implemented by the email package for handling **RFC 5322** compliant email messages, which not only provides customized header objects for various header types, but also provides an extension mechanism for applications to add their own custom header types.

When using any of the policy objects derived from *EmailPolicy*, all headers are produced by *HeaderRegistry* and have *BaseHeader* as their last base class. Each header class has an additional base class that is determined by the type of the header. For example, many headers have the class *UnstructuredHeader* as their other base class. The specialized second class for a header is determined by the name of the header, using a lookup table stored in the *HeaderRegistry*. All of this is managed transparently for the typical application program, but interfaces are provided for modifying the default behavior for use by more complex applications.

The sections below first document the header base classes and their attributes, followed by the API for modifying the behavior of *HeaderRegistry*, and finally the support classes used to represent the data parsed from structured headers.

[1] Originally added in 3.3 as a *provisional module*

class email.headerregistry.BaseHeader(*name*, *value*)

name and *value* are passed to BaseHeader from the *header_factory* call. The string value of any header object is the *value* fully decoded to unicode.

This base class defines the following read-only properties:

name

The name of the header (the portion of the field before the ':'). This is exactly the value passed in the *header_factory* call for *name*; that is, case is preserved.

defects

A tuple of HeaderDefect instances reporting any RFC compliance problems found during parsing. The email package tries to be complete about detecting compliance issues. See the *errors* module for a discussion of the types of defects that may be reported.

max_count

The maximum number of headers of this type that can have the same name. A value of None means unlimited. The BaseHeader value for this attribute is None; it is expected that specialized header classes will override this value as needed.

BaseHeader also provides the following method, which is called by the email library code and should not in general be called by application programs:

fold(***, *policy*)

Return a string containing *linesep* characters as required to correctly fold the header according to *policy*. A *cte_type* of 8bit will be treated as if it were 7bit, since headers may not contain arbitrary binary data. If *utf8* is False, non-ASCII data will be **RFC 2047** encoded.

BaseHeader by itself cannot be used to create a header object. It defines a protocol that each specialized header cooperates with in order to produce the header object. Specifically, BaseHeader requires that the specialized class provide a *classmethod()* named parse. This method is called as follows:

```
parse(string, kwds)
```

kwds is a dictionary containing one pre-initialized key, defects. defects is an empty list. The parse method should append any detected defects to this list. On return, the kwds dictionary *must* contain values for at least the keys decoded and defects. decoded should be the string value for the header (that is, the header value fully decoded to unicode). The parse method should assume that *string* may contain content-transfer-encoded parts, but should correctly handle all valid unicode characters as well so that it can parse un-encoded header values.

BaseHeader's __new__ then creates the header instance, and calls its init method. The specialized class only needs to provide an init method if it wishes to set additional attributes beyond those provided by BaseHeader itself. Such an init method should look like this:

```
def init(self, *args, **kw):
    self._myattr = kw.pop('myattr')
    super().init(*args, **kw)
```

That is, anything extra that the specialized class puts in to the kwds dictionary should be removed and handled, and the remaining contents of kw (and args) passed to the BaseHeader init method.

class email.headerregistry.UnstructuredHeader

An "unstructured" header is the default type of header in **RFC 5322**. Any header that does not have a specified syntax is treated as unstructured. The classic example of an unstructured header is the *Subject* header.

In **RFC 5322**, an unstructured header is a run of arbitrary text in the ASCII character set. **RFC 2047**, however, has an **RFC 5322** compatible mechanism for encoding non-ASCII text as ASCII characters within a header value. When a *value* containing encoded words is passed to the constructor, the UnstructuredHeader parser converts such encoded words into unicode, following the **RFC 2047**

rules for unstructured text. The parser uses heuristics to attempt to decode certain non-compliant encoded words. Defects are registered in such cases, as well as defects for issues such as invalid characters within the encoded words or the non-encoded text.

This header type provides no additional attributes.

class email.headerregistry.DateHeader

RFC 5322 specifies a very specific format for dates within email headers. The `DateHeader` parser recognizes that date format, as well as recognizing a number of variant forms that are sometimes found "in the wild".

This header type provides the following additional attributes:

datetime

If the header value can be recognized as a valid date of one form or another, this attribute will contain a *datetime* instance representing that date. If the timezone of the input date is specified as `-0000` (indicating it is in UTC but contains no information about the source timezone), then *datetime* will be a naive *datetime*. If a specific timezone offset is found (including *+0000*), then *datetime* will contain an aware `datetime` that uses *datetime.timezone* to record the timezone offset.

The `decoded` value of the header is determined by formatting the `datetime` according to the **RFC 5322** rules; that is, it is set to:

```
email.utils.format_datetime(self.datetime)
```

When creating a `DateHeader`, *value* may be *datetime* instance. This means, for example, that the following code is valid and does what one would expect:

```
msg['Date'] = datetime(2011, 7, 15, 21)
```

Because this is a naive `datetime` it will be interpreted as a UTC timestamp, and the resulting value will have a timezone of `-0000`. Much more useful is to use the *localtime()* function from the *utils* module:

```
msg['Date'] = utils.localtime()
```

This example sets the date header to the current time and date using the current timezone offset.

class email.headerregistry.AddressHeader

Address headers are one of the most complex structured header types. The `AddressHeader` class provides a generic interface to any address header.

This header type provides the following additional attributes:

groups

A tuple of *Group* objects encoding the addresses and groups found in the header value. Addresses that are not part of a group are represented in this list as single-address `Groups` whose *display_name* is `None`.

addresses

A tuple of *Address* objects encoding all of the individual addresses from the header value. If the header value contains any groups, the individual addresses from the group are included in the list at the point where the group occurs in the value (that is, the list of addresses is "flattened" into a one dimensional list).

The `decoded` value of the header will have all encoded words decoded to unicode. *idna* encoded domain names are also decoded to unicode. The `decoded` value is set by *join*ing the *str* value of the elements of the `groups` attribute with `', '`.

A list of *Address* and *Group* objects in any combination may be used to set the value of an address header. `Group` objects whose `display_name` is `None` will be interpreted as single addresses, which allows

an address list to be copied with groups intact by using the list obtained from the `groups` attribute of the source header.

class email.headerregistry.SingleAddressHeader
A subclass of *AddressHeader* that adds one additional attribute:

address
The single address encoded by the header value. If the header value actually contains more than one address (which would be a violation of the RFC under the default *policy*), accessing this attribute will result in a *ValueError*.

Many of the above classes also have a `Unique` variant (for example, `UniqueUnstructuredHeader`). The only difference is that in the `Unique` variant, *max_count* is set to 1.

class email.headerregistry.MIMEVersionHeader
There is really only one valid value for the *MIME-Version* header, and that is `1.0`. For future proofing, this header class supports other valid version numbers. If a version number has a valid value per **RFC 2045**, then the header object will have non-`None` values for the following attributes:

version
The version number as a string, with any whitespace and/or comments removed.

major
The major version number as an integer

minor
The minor version number as an integer

class email.headerregistry.ParameterizedMIMEHeader
MIME headers all start with the prefix 'Content-'. Each specific header has a certain value, described under the class for that header. Some can also take a list of supplemental parameters, which have a common format. This class serves as a base for all the MIME headers that take parameters.

params
A dictionary mapping parameter names to parameter values.

class email.headerregistry.ContentTypeHeader
A *ParameterizedMIMEHeader* class that handles the *Content-Type* header.

content_type
The content type string, in the form `maintype/subtype`.

maintype

subtype

class email.headerregistry.ContentDispositionHeader
A *ParameterizedMIMEHeader* class that handles the *Content-Disposition* header.

content-disposition
`inline` and `attachment` are the only valid values in common use.

class email.headerregistry.ContentTransferEncoding
Handles the *Content-Transfer-Encoding* header.

cte
Valid values are `7bit`, `8bit`, `base64`, and `quoted-printable`. See **RFC 2045** for more information.

class email.headerregistry.HeaderRegistry(*base_class=BaseHeader*, *default_class=UnstructuredHeader*, *use_default_map=True*)
This is the factory used by *EmailPolicy* by default. `HeaderRegistry` builds the class used to create a header instance dynamically, using *base_class* and a specialized class retrieved from a registry that it holds. When a given header name does not appear in the registry, the class specified by *default_class*

is used as the specialized class. When *use_default_map* is `True` (the default), the standard mapping of header names to classes is copied in to the registry during initialization. *base_class* is always the last class in the generated class's `__bases__` list.

The default mappings are:

subject UniqueUnstructuredHeader

date UniqueDateHeader

resent-date DateHeader

orig-date UniqueDateHeader

sender UniqueSingleAddressHeader

resent-sender SingleAddressHeader

to UniqueAddressHeader

resent-to AddressHeader

cc UniqueAddressHeader

resent-cc AddressHeader

from UniqueAddressHeader

resent-from AddressHeader

reply-to UniqueAddressHeader

`HeaderRegistry` has the following methods:

`map_to_type`(*self*, *name*, *cls*)
: *name* is the name of the header to be mapped. It will be converted to lower case in the registry. *cls* is the specialized class to be used, along with *base_class*, to create the class used to instantiate headers that match *name*.

`__getitem__`(*name*)
: Construct and return a class to handle creating a *name* header.

`__call__`(*name*, *value*)
: Retrieves the specialized header associated with *name* from the registry (using *default_class* if *name* does not appear in the registry) and composes it with *base_class* to produce a class, calls the constructed class's constructor, passing it the same argument list, and finally returns the class instance created thereby.

The following classes are the classes used to represent data parsed from structured headers and can, in general, be used by an application program to construct structured values to assign to specific headers.

`class email.headerregistry.Address`(*display_name=''*, *username=''*, *domain=''*, *addr_spec=None*)
: The class used to represent an email address. The general form of an address is:

```
[display_name] <username@domain>
```

or:

```
username@domain
```

where each part must conform to specific syntax rules spelled out in **RFC 5322**.

As a convenience *addr_spec* can be specified instead of *username* and *domain*, in which case *username* and *domain* will be parsed from the *addr_spec*. An *addr_spec* must be a properly RFC quoted string; if it is not `Address` will raise an error. Unicode characters are allowed and will be property encoded

when serialized. However, per the RFCs, unicode is *not* allowed in the username portion of the address.

display_name
The display name portion of the address, if any, with all quoting removed. If the address does not have a display name, this attribute will be an empty string.

username
The `username` portion of the address, with all quoting removed.

domain
The `domain` portion of the address.

addr_spec
The `username@domain` portion of the address, correctly quoted for use as a bare address (the second form shown above). This attribute is not mutable.

__str__()
The `str` value of the object is the address quoted according to **RFC 5322** rules, but with no Content Transfer Encoding of any non-ASCII characters.

To support SMTP (**RFC 5321**), `Address` handles one special case: if `username` and `domain` are both the empty string (or `None`), then the string value of the `Address` is `<>`.

class email.headerregistry.Group(*display_name=None*, *addresses=None*)
The class used to represent an address group. The general form of an address group is:

```
display_name: [address-list];
```

As a convenience for processing lists of addresses that consist of a mixture of groups and single addresses, a `Group` may also be used to represent single addresses that are not part of a group by setting *display_name* to `None` and providing a list of the single address as *addresses*.

display_name
The `display_name` of the group. If it is `None` and there is exactly one `Address` in `addresses`, then the `Group` represents a single address that is not in a group.

addresses
A possibly empty tuple of *`Address`* objects representing the addresses in the group.

__str__()
The `str` value of a `Group` is formatted according to **RFC 5322**, but with no Content Transfer Encoding of any non-ASCII characters. If `display_name` is none and there is a single `Address` in the `addresses` list, the `str` value will be the same as the `str` of that single `Address`.

20.1.7 email.contentmanager: Managing MIME Content

Source code: Lib/email/contentmanager.py

New in version 3.6:[1]

class email.contentmanager.ContentManager
Base class for content managers. Provides the standard registry mechanisms to register converters between MIME content and other representations, as well as the `get_content` and `set_content` dispatch methods.

[1] Originally added in 3.4 as a *provisional module*

get_content(*msg*, **args*, ***kw*)
Look up a handler function based on the `mimetype` of *msg* (see next paragraph), call it, passing through all arguments, and return the result of the call. The expectation is that the handler will extract the payload from *msg* and return an object that encodes information about the extracted data.

To find the handler, look for the following keys in the registry, stopping with the first one found:

- the string representing the full MIME type (`maintype/subtype`)
- the string representing the `maintype`
- the empty string

If none of these keys produce a handler, raise a *KeyError* for the full MIME type.

set_content(*msg*, *obj*, **args*, ***kw*)
If the `maintype` is `multipart`, raise a *TypeError*; otherwise look up a handler function based on the type of *obj* (see next paragraph), call *clear_content()* on the *msg*, and call the handler function, passing through all arguments. The expectation is that the handler will transform and store *obj* into *msg*, possibly making other changes to *msg* as well, such as adding various MIME headers to encode information needed to interpret the stored data.

To find the handler, obtain the type of *obj* (`typ = type(obj)`), and look for the following keys in the registry, stopping with the first one found:

- the type itself (`typ`)
- the type's fully qualified name (`typ.__module__ + '.' + typ.__qualname__`).
- the type's qualname (`typ.__qualname__`)
- the type's name (`typ.__name__`).

If none of the above match, repeat all of the checks above for each of the types in the *MRO* (`typ.__mro__`). Finally, if no other key yields a handler, check for a handler for the key `None`. If there is no handler for `None`, raise a *KeyError* for the fully qualified name of the type.

Also add a ***MIME-Version*** header if one is not present (see also *MIMEPart*).

add_get_handler(*key*, *handler*)
Record the function *handler* as the handler for *key*. For the possible values of *key*, see *get_content()*.

add_set_handler(*typekey*, *handler*)
Record *handler* as the function to call when an object of a type matching *typekey* is passed to *set_content()*. For the possible values of *typekey*, see *set_content()*.

Content Manager Instances

Currently the email package provides only one concrete content manager, *raw_data_manager*, although more may be added in the future. *raw_data_manager* is the *content_manager* provided by *EmailPolicy* and its derivatives.

email.contentmanager.raw_data_manager
This content manager provides only a minimum interface beyond that provided by *Message* itself: it deals only with text, raw byte strings, and *Message* objects. Nevertheless, it provides significant advantages compared to the base API: `get_content` on a text part will return a unicode string without the application needing to manually decode it, `set_content` provides a rich set of options for controlling the headers added to a part and controlling the content transfer encoding, and it enables the use of the various `add_` methods, thereby simplifying the creation of multipart messages.

`email.contentmanager.get_content`(*msg*, *errors='replace'*)
Return the payload of the part as either a string (for `text` parts), an *EmailMessage* object (for `message/rfc822` parts), or a `bytes` object (for all other non-multipart types). Raise a *KeyError* if called on a `multipart`. If the part is a `text` part and *errors* is specified, use it as the error handler when decoding the payload to unicode. The default error handler is `replace`.

`email.contentmanager.set_content`(*msg*, *<'str'>*, *subtype="plain"*, *charset='utf-8'* *cte=None*, *disposition=None*, *filename=None*, *cid=None*, *params=None*, *headers=None*)
`email.contentmanager.set_content`(*msg*, *<'bytes'>*, *maintype*, *subtype*, *cte="base64"*, *disposition=None*, *filename=None*, *cid=None*, *params=None*, *headers=None*)
`email.contentmanager.set_content`(*msg*, *<'EmailMessage'>*, *cte=None*, *disposition=None*, *filename=None*, *cid=None*, *params=None*, *headers=None*)
Add headers and payload to *msg*:

Add a *Content-Type* header with a `maintype/subtype` value.

- For `str`, set the MIME `maintype` to `text`, and set the subtype to *subtype* if it is specified, or `plain` if it is not.
- For `bytes`, use the specified *maintype* and *subtype*, or raise a *TypeError* if they are not specified.
- For *EmailMessage* objects, set the maintype to `message`, and set the subtype to *subtype* if it is specified or `rfc822` if it is not. If *subtype* is `partial`, raise an error (`bytes` objects must be used to construct `message/partial` parts).

If *charset* is provided (which is valid only for `str`), encode the string to bytes using the specified character set. The default is `utf-8`. If the specified *charset* is a known alias for a standard MIME charset name, use the standard charset instead.

If *cte* is set, encode the payload using the specified content transfer encoding, and set the *Content-Transfer-Encoding* header to that value. Possible values for *cte* are `quoted-printable`, `base64`, `7bit`, `8bit`, and `binary`. If the input cannot be encoded in the specified encoding (for example, specifying a *cte* of `7bit` for an input that contains non-ASCII values), raise a *ValueError*.

- For `str` objects, if *cte* is not set use heuristics to determine the most compact encoding.
- For *EmailMessage*, per **RFC 2046**, raise an error if a *cte* of `quoted-printable` or `base64` is requested for *subtype* `rfc822`, and for any *cte* other than `7bit` for *subtype* `external-body`. For `message/rfc822`, use `8bit` if *cte* is not specified. For all other values of *subtype*, use `7bit`.

Note: A *cte* of `binary` does not actually work correctly yet. The `EmailMessage` object as modified by `set_content` is correct, but *BytesGenerator* does not serialize it correctly.

If *disposition* is set, use it as the value of the *Content-Disposition* header. If not specified, and *filename* is specified, add the header with the value `attachment`. If *disposition* is not specified and *filename* is also not specified, do not add the header. The only valid values for *disposition* are `attachment` and `inline`.

If *filename* is specified, use it as the value of the `filename` parameter of the *Content-Disposition* header.

If *cid* is specified, add a *Content-ID* header with *cid* as its value.

If *params* is specified, iterate its `items` method and use the resulting `(key, value)` pairs to set additional parameters on the *Content-Type* header.

If *headers* is specified and is a list of strings of the form `headername: headervalue` or a list of `header` objects (distinguished from strings by having a `name` attribute), add the headers to *msg*.

20.1.8 `email`: Examples

Here are a few examples of how to use the *email* package to read, write, and send simple email messages, as well as more complex MIME messages.

First, let's see how to create and send a simple text message (both the text content and the addresses may contain unicode characters):

```
# Import smtplib for the actual sending function
import smtplib

# Import the email modules we'll need
from email.message import EmailMessage

# Open the plain text file whose name is in textfile for reading.
with open(textfile) as fp:
    # Create a text/plain message
    msg = EmailMessage()
    msg.set_content(fp.read())

# me == the sender's email address
# you == the recipient's email address
msg['Subject'] = 'The contents of %s' % textfile
msg['From'] = me
msg['To'] = you

# Send the message via our own SMTP server.
s = smtplib.SMTP('localhost')
s.send_message(msg)
s.quit()
```

Parsing **RFC 822** headers can easily be done by the using the classes from the *parser* module:

```
# Import the email modules we'll need
from email.parser import BytesParser, Parser
from email.policy import default

# If the e-mail headers are in a file, uncomment these two lines:
# with open(messagefile, 'rb') as fp:
#     headers = BytesParser(policy=default).parse(fp)

#  Or for parsing headers in a string (this is an uncommon operation), use:
headers = Parser(policy=default).parsestr(
        'From: Foo Bar <user@example.com>\n'
        'To: <someone_else@example.com>\n'
        'Subject: Test message\n'
        '\n'
        'Body would go here\n')

#  Now the header items can be accessed as a dictionary:
print('To: {}'.format(headers['to']))
print('From: {}'.format(headers['from']))
print('Subject: {}'.format(headers['subject']))
```

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```
# You can also access the parts of the addresses:
print('Recipient username: {}'.format(headers['to'].addresses[0].username))
print('Sender name: {}'.format(headers['from'].addresses[0].display_name))
```

Here's an example of how to send a MIME message containing a bunch of family pictures that may be residing in a directory:

```
# Import smtplib for the actual sending function
import smtplib

# And imghdr to find the types of our images
import imghdr

# Here are the email package modules we'll need
from email.message import EmailMessage

# Create the container email message.
msg = EmailMessage()
msg['Subject'] = 'Our family reunion'
# me == the sender's email address
# family = the list of all recipients' email addresses
msg['From'] = me
msg['To'] = ', '.join(family)
msg.preamble = 'Our family reunion'

# Open the files in binary mode.  Use imghdr to figure out the
# MIME subtype for each specific image.
for file in pngfiles:
    with open(file, 'rb') as fp:
        img_data = fp.read()
    msg.add_attachment(img_data, maintype='image',
                                 subtype=imghdr.what(None, img_data))

# Send the email via our own SMTP server.
with smtplib.SMTP('localhost') as s:
    s.send_message(msg)
```

Here's an example of how to send the entire contents of a directory as an email message:[1]

```
#!/usr/bin/env python3

"""Send the contents of a directory as a MIME message."""

import os
import smtplib
# For guessing MIME type based on file name extension
import mimetypes

from argparse import ArgumentParser

from email.message import EmailMessage
from email.policy import SMTP


def main():
```

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[1] Thanks to Matthew Dixon Cowles for the original inspiration and examples.

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```
    parser = ArgumentParser(description="""\
Send the contents of a directory as a MIME message.
Unless the -o option is given, the email is sent by forwarding to your local
SMTP server, which then does the normal delivery process.  Your local machine
must be running an SMTP server.
""")
    parser.add_argument('-d', '--directory',
                        help="""Mail the contents of the specified directory,
                        otherwise use the current directory.  Only the regular
                        files in the directory are sent, and we don't recurse to
                        subdirectories.""")
    parser.add_argument('-o', '--output',
                        metavar='FILE',
                        help="""Print the composed message to FILE instead of
                        sending the message to the SMTP server.""")
    parser.add_argument('-s', '--sender', required=True,
                        help='The value of the From: header (required)')
    parser.add_argument('-r', '--recipient', required=True,
                        action='append', metavar='RECIPIENT',
                        default=[], dest='recipients',
                        help='A To: header value (at least one required)')
    args = parser.parse_args()
    directory = args.directory
    if not directory:
        directory = '.'
    # Create the message
    msg = EmailMessage()
    msg['Subject'] = 'Contents of directory %s' % os.path.abspath(directory)
    msg['To'] = ', '.join(args.recipients)
    msg['From'] = args.sender
    msg.preamble = 'You will not see this in a MIME-aware mail reader.\n'

    for filename in os.listdir(directory):
        path = os.path.join(directory, filename)
        if not os.path.isfile(path):
            continue
        # Guess the content type based on the file's extension.  Encoding
        # will be ignored, although we should check for simple things like
        # gzip'd or compressed files.
        ctype, encoding = mimetypes.guess_type(path)
        if ctype is None or encoding is not None:
            # No guess could be made, or the file is encoded (compressed), so
            # use a generic bag-of-bits type.
            ctype = 'application/octet-stream'
        maintype, subtype = ctype.split('/', 1)
        with open(path, 'rb') as fp:
            msg.add_attachment(fp.read(),
                               maintype=maintype,
                               subtype=subtype,
                               filename=filename)
    # Now send or store the message
    if args.output:
        with open(args.output, 'wb') as fp:
            fp.write(msg.as_bytes(policy=SMTP))
    else:
        with smtplib.SMTP('localhost') as s:
```

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```
            s.send_message(msg)


if __name__ == '__main__':
    main()
```

Here's an example of how to unpack a MIME message like the one above, into a directory of files:

```
#!/usr/bin/env python3

"""Unpack a MIME message into a directory of files."""

import os
import email
import mimetypes

from email.policy import default

from argparse import ArgumentParser


def main():
    parser = ArgumentParser(description="""\
Unpack a MIME message into a directory of files.
""")
    parser.add_argument('-d', '--directory', required=True,
                        help="""Unpack the MIME message into the named
                        directory, which will be created if it doesn't already
                        exist.""")
    parser.add_argument('msgfile')
    args = parser.parse_args()

    with open(args.msgfile, 'rb') as fp:
        msg = email.message_from_binary_file(fp, policy=default)

    try:
        os.mkdir(args.directory)
    except FileExistsError:
        pass

    counter = 1
    for part in msg.walk():
        # multipart/* are just containers
        if part.get_content_maintype() == 'multipart':
            continue
        # Applications should really sanitize the given filename so that an
        # email message can't be used to overwrite important files
        filename = part.get_filename()
        if not filename:
            ext = mimetypes.guess_extension(part.get_content_type())
            if not ext:
                # Use a generic bag-of-bits extension
                ext = '.bin'
            filename = 'part-%03d%s' % (counter, ext)
        counter += 1
        with open(os.path.join(args.directory, filename), 'wb') as fp:
```

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```
            fp.write(part.get_payload(decode=True))


if __name__ == '__main__':
    main()
```

Here's an example of how to create an HTML message with an alternative plain text version. To make things a bit more interesting, we include a related image in the html part, and we save a copy of what we are going to send to disk, as well as sending it.

```
#!/usr/bin/env python3

import smtplib

from email.message import EmailMessage
from email.headerregistry import Address
from email.utils import make_msgid

# Create the base text message.
msg = EmailMessage()
msg['Subject'] = "Ayons asperges pour le déjeuner"
msg['From'] = Address("Pepé Le Pew", "pepe", "example.com")
msg['To'] = (Address("Penelope Pussycat", "penelope", "example.com"),
             Address("Fabrette Pussycat", "fabrette", "example.com"))
msg.set_content("""\
Salut!

Cela ressemble à un excellent recipie[1] déjeuner.

[1] http://www.yummly.com/recipe/Roasted-Asparagus-Epicurious-203718

--Pepé
""")

# Add the html version.  This converts the message into a multipart/alternative
# container, with the original text message as the first part and the new html
# message as the second part.
asparagus_cid = make_msgid()
msg.add_alternative("""\
<html>
  <head></head>
  <body>
    <p>Salut!</p>
    <p>Cela ressemble à un excellent
        <a href="http://www.yummly.com/recipe/Roasted-Asparagus-Epicurious-203718">
            recipie
        </a> déjeuner.
    </p>
    <img src="cid:{asparagus_cid}" />
  </body>
</html>
""".format(asparagus_cid=asparagus_cid[1:-1]), subtype='html')
# note that we needed to peel the <> off the msgid for use in the html.

# Now add the related image to the html part.
with open("roasted-asparagus.jpg", 'rb') as img:
```

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```
    msg.get_payload()[1].add_related(img.read(), 'image', 'jpeg',
                                     cid=asparagus_cid)

# Make a local copy of what we are going to send.
with open('outgoing.msg', 'wb') as f:
    f.write(bytes(msg))

# Send the message via local SMTP server.
with smtplib.SMTP('localhost') as s:
    s.send_message(msg)
```

If we were sent the message from the last example, here is one way we could process it:

```
import os
import sys
import tempfile
import mimetypes
import webbrowser

# Import the email modules we'll need
from email import policy
from email.parser import BytesParser

# An imaginary module that would make this work and be safe.
from imaginary import magic_html_parser

# In a real program you'd get the filename from the arguments.
with open('outgoing.msg', 'rb') as fp:
    msg = BytesParser(policy=policy.default).parse(fp)

# Now the header items can be accessed as a dictionary, and any non-ASCII will
# be converted to unicode:
print('To:', msg['to'])
print('From:', msg['from'])
print('Subject:', msg['subject'])

# If we want to print a preview of the message content, we can extract whatever
# the least formatted payload is and print the first three lines.  Of course,
# if the message has no plain text part printing the first three lines of html
# is probably useless, but this is just a conceptual example.
simplest = msg.get_body(preferencelist=('plain', 'html'))
print()
print(''.join(simplest.get_content().splitlines(keepends=True)[:3]))

ans = input("View full message?")
if ans.lower()[0] == 'n':
    sys.exit()

# We can extract the richest alternative in order to display it:
richest = msg.get_body()
partfiles = {}
if richest['content-type'].maintype == 'text':
    if richest['content-type'].subtype == 'plain':
        for line in richest.get_content().splitlines():
            print(line)
        sys.exit()
```

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```
    elif richest['content-type'].subtype == 'html':
        body = richest
    else:
        print("Don't know how to display {}".format(richest.get_content_type()))
        sys.exit()
elif richest['content-type'].content_type == 'multipart/related':
    body = richest.get_body(preferencelist=('html'))
    for part in richest.iter_attachments():
        fn = part.get_filename()
        if fn:
            extension = os.path.splitext(part.get_filename())[1]
        else:
            extension = mimetypes.guess_extension(part.get_content_type())
        with tempfile.NamedTemporaryFile(suffix=extension, delete=False) as f:
            f.write(part.get_content())
            # again strip the <> to go from email form of cid to html form.
            partfiles[part['content-id'][1:-1]] = f.name
else:
    print("Don't know how to display {}".format(richest.get_content_type()))
    sys.exit()
with tempfile.NamedTemporaryFile(mode='w', delete=False) as f:
    # The magic_html_parser has to rewrite the href="cid:...." attributes to
    # point to the filenames in partfiles.  It also has to do a safety-sanitize
    # of the html.  It could be written using html.parser.
    f.write(magic_html_parser(body.get_content(), partfiles))
webbrowser.open(f.name)
os.remove(f.name)
for fn in partfiles.values():
    os.remove(fn)

# Of course, there are lots of email messages that could break this simple
# minded program, but it will handle the most common ones.
```

Up to the prompt, the output from the above is:

```
To: Penelope Pussycat <penelope@example.com>, Fabrette Pussycat <fabrette@example.com>
From: Pepé Le Pew <pepe@example.com>
Subject: Ayons asperges pour le déjeuner

Salut!

Cela ressemble à un excellent recipie[1] déjeuner.
```

Legacy API:

20.1.9 email.message.Message: Representing an email message using the compat32 API

The *Message* class is very similar to the *EmailMessage* class, without the methods added by that class, and with the default behavior of certain other methods being slightly different. We also document here some methods that, while supported by the *EmailMessage* class, are not recommended unless you are dealing with legacy code.

The philosophy and structure of the two classes is otherwise the same.

This document describes the behavior under the default (for *Message*) policy *Compat32*. If you are going to use another policy, you should be using the *EmailMessage* class instead.

An email message consists of *headers* and a *payload*. Headers must be **RFC 5233** style names and values, where the field name and value are separated by a colon. The colon is not part of either the field name or the field value. The payload may be a simple text message, or a binary object, or a structured sequence of sub-messages each with their own set of headers and their own payload. The latter type of payload is indicated by the message having a MIME type such as *multipart/** or *message/rfc822*.

The conceptual model provided by a *Message* object is that of an ordered dictionary of headers with additional methods for accessing both specialized information from the headers, for accessing the payload, for generating a serialized version of the message, and for recursively walking over the object tree. Note that duplicate headers are supported but special methods must be used to access them.

The *Message* pseudo-dictionary is indexed by the header names, which must be ASCII values. The values of the dictionary are strings that are supposed to contain only ASCII characters; there is some special handling for non-ASCII input, but it doesn't always produce the correct results. Headers are stored and returned in case-preserving form, but field names are matched case-insensitively. There may also be a single envelope header, also known as the *Unix-From* header or the `From_` header. The *payload* is either a string or bytes, in the case of simple message objects, or a list of *Message* objects, for MIME container documents (e.g. *multipart/** and *message/rfc822*).

Here are the methods of the *Message* class:

class email.message.Message(*policy=compat32*)

If *policy* is specified (it must be an instance of a *policy* class) use the rules it specifies to update and serialize the representation of the message. If *policy* is not set, use the *compat32* policy, which maintains backward compatibility with the Python 3.2 version of the email package. For more information see the *policy* documentation.

Changed in version 3.3: The *policy* keyword argument was added.

as_string(*unixfrom=False*, *maxheaderlen=0*, *policy=None*)

Return the entire message flattened as a string. When optional *unixfrom* is true, the envelope header is included in the returned string. *unixfrom* defaults to `False`. For backward compatibility reasons, *maxheaderlen* defaults to `0`, so if you want a different value you must override it explicitly (the value specified for *max_line_length* in the policy will be ignored by this method). The *policy* argument may be used to override the default policy obtained from the message instance. This can be used to control some of the formatting produced by the method, since the specified *policy* will be passed to the `Generator`.

Flattening the message may trigger changes to the *Message* if defaults need to be filled in to complete the transformation to a string (for example, MIME boundaries may be generated or modified).

Note that this method is provided as a convenience and may not always format the message the way you want. For example, by default it does not do the mangling of lines that begin with `From` that is required by the unix mbox format. For more flexibility, instantiate a *Generator* instance and use its *flatten()* method directly. For example:

```
from io import StringIO
from email.generator import Generator
fp = StringIO()
g = Generator(fp, mangle_from_=True, maxheaderlen=60)
g.flatten(msg)
text = fp.getvalue()
```

If the message object contains binary data that is not encoded according to RFC standards, the non-compliant data will be replaced by unicode "unknown character" code points. (See also *as_bytes()* and *BytesGenerator*.)

Changed in version 3.4: the *policy* keyword argument was added.

__str__()
Equivalent to *as_string()*. Allows `str(msg)` to produce a string containing the formatted message.

as_bytes(*unixfrom=False*, *policy=None*)
Return the entire message flattened as a bytes object. When optional *unixfrom* is true, the envelope header is included in the returned string. *unixfrom* defaults to `False`. The *policy* argument may be used to override the default policy obtained from the message instance. This can be used to control some of the formatting produced by the method, since the specified *policy* will be passed to the `BytesGenerator`.

Flattening the message may trigger changes to the *Message* if defaults need to be filled in to complete the transformation to a string (for example, MIME boundaries may be generated or modified).

Note that this method is provided as a convenience and may not always format the message the way you want. For example, by default it does not do the mangling of lines that begin with `From` that is required by the unix mbox format. For more flexibility, instantiate a *BytesGenerator* instance and use its *flatten()* method directly. For example:

```
from io import BytesIO
from email.generator import BytesGenerator
fp = BytesIO()
g = BytesGenerator(fp, mangle_from_=True, maxheaderlen=60)
g.flatten(msg)
text = fp.getvalue()
```

New in version 3.4.

__bytes__()
Equivalent to *as_bytes()*. Allows `bytes(msg)` to produce a bytes object containing the formatted message.

New in version 3.4.

is_multipart()
Return `True` if the message's payload is a list of sub-*Message* objects, otherwise return `False`. When *is_multipart()* returns `False`, the payload should be a string object (which might be a CTE encoded binary payload. (Note that *is_multipart()* returning `True` does not necessarily mean that "msg.get_content_maintype() == 'multipart'" will return the `True`. For example, `is_multipart` will return `True` when the *Message* is of type `message/rfc822`.)

set_unixfrom(*unixfrom*)
Set the message's envelope header to *unixfrom*, which should be a string.

get_unixfrom()
Return the message's envelope header. Defaults to `None` if the envelope header was never set.

attach(*payload*)
Add the given *payload* to the current payload, which must be `None` or a list of *Message* objects before the call. After the call, the payload will always be a list of *Message* objects. If you want to set the payload to a scalar object (e.g. a string), use *set_payload()* instead.

This is a legacy method. On the `EmailMessage` class its functionality is replaced by *set_content()* and the related `make` and `add` methods.

get_payload(*i=None*, *decode=False*)
Return the current payload, which will be a list of *Message* objects when *is_multipart()* is `True`, or a string when *is_multipart()* is `False`. If the payload is a list and you mutate the list object, you modify the message's payload in place.

With optional argument *i*, *get_payload()* will return the *i*-th element of the payload, counting from zero, if *is_multipart()* is `True`. An *IndexError* will be raised if *i* is less than 0 or greater than or equal to the number of items in the payload. If the payload is a string (i.e. *is_multipart()* is `False`) and *i* is given, a *TypeError* is raised.

Optional *decode* is a flag indicating whether the payload should be decoded or not, according to the *Content-Transfer-Encoding* header. When `True` and the message is not a multipart, the payload will be decoded if this header's value is `quoted-printable` or `base64`. If some other encoding is used, or *Content-Transfer-Encoding* header is missing, the payload is returned as-is (undecoded). In all cases the returned value is binary data. If the message is a multipart and the *decode* flag is `True`, then `None` is returned. If the payload is base64 and it was not perfectly formed (missing padding, characters outside the base64 alphabet), then an appropriate defect will be added to the message's defect property (`InvalidBase64PaddingDefect` or `InvalidBase64CharactersDefect`, respectively).

When *decode* is `False` (the default) the body is returned as a string without decoding the *Content-Transfer-Encoding*. However, for a *Content-Transfer-Encoding* of 8bit, an attempt is made to decode the original bytes using the `charset` specified by the *Content-Type* header, using the `replace` error handler. If no `charset` is specified, or if the `charset` given is not recognized by the email package, the body is decoded using the default ASCII charset.

This is a legacy method. On the `EmailMessage` class its functionality is replaced by *get_content()* and *iter_parts()*.

set_payload(*payload*, *charset=None*)
Set the entire message object's payload to *payload*. It is the client's responsibility to ensure the payload invariants. Optional *charset* sets the message's default character set; see *set_charset()* for details.

This is a legacy method. On the `EmailMessage` class its functionality is replaced by *set_content()*.

set_charset(*charset*)
Set the character set of the payload to *charset*, which can either be a *Charset* instance (see *email.charset*), a string naming a character set, or `None`. If it is a string, it will be converted to a *Charset* instance. If *charset* is `None`, the `charset` parameter will be removed from the *Content-Type* header (the message will not be otherwise modified). Anything else will generate a *TypeError*.

If there is no existing *MIME-Version* header one will be added. If there is no existing *Content-Type* header, one will be added with a value of *text/plain*. Whether the *Content-Type* header already exists or not, its `charset` parameter will be set to *charset.output_charset*. If *charset.input_charset* and *charset.output_charset* differ, the payload will be re-encoded to the *output_charset*. If there is no existing *Content-Transfer-Encoding* header, then the payload will be transfer-encoded, if needed, using the specified *Charset*, and a header with the appropriate value will be added. If a *Content-Transfer-Encoding* header already exists, the payload is assumed to already be correctly encoded using that *Content-Transfer-Encoding* and is not modified.

This is a legacy method. On the `EmailMessage` class its functionality is replaced by the *charset* parameter of the `email.emailmessage.EmailMessage.set_content()` method.

get_charset()
Return the *Charset* instance associated with the message's payload.

This is a legacy method. On the `EmailMessage` class it always returns `None`.

The following methods implement a mapping-like interface for accessing the message's **RFC 2822** headers. Note that there are some semantic differences between these methods and a normal mapping (i.e. dictionary) interface. For example, in a dictionary there are no duplicate keys, but here there may be duplicate message headers. Also, in dictionaries there is no guaranteed order to the keys returned

by *keys()*, but in a *Message* object, headers are always returned in the order they appeared in the original message, or were added to the message later. Any header deleted and then re-added are always appended to the end of the header list.

These semantic differences are intentional and are biased toward maximal convenience.

Note that in all cases, any envelope header present in the message is not included in the mapping interface.

In a model generated from bytes, any header values that (in contravention of the RFCs) contain non-ASCII bytes will, when retrieved through this interface, be represented as *Header* objects with a charset of *unknown-8bit*.

__len__()
Return the total number of headers, including duplicates.

__contains__(*name*)
Return true if the message object has a field named *name*. Matching is done case-insensitively and *name* should not include the trailing colon. Used for the `in` operator, e.g.:

```
if 'message-id' in myMessage:
   print('Message-ID:', myMessage['message-id'])
```

__getitem__(*name*)
Return the value of the named header field. *name* should not include the colon field separator. If the header is missing, `None` is returned; a *KeyError* is never raised.

Note that if the named field appears more than once in the message's headers, exactly which of those field values will be returned is undefined. Use the *get_all()* method to get the values of all the extant named headers.

__setitem__(*name*, *val*)
Add a header to the message with field name *name* and value *val*. The field is appended to the end of the message's existing fields.

Note that this does *not* overwrite or delete any existing header with the same name. If you want to ensure that the new header is the only one present in the message with field name *name*, delete the field first, e.g.:

```
del msg['subject']
msg['subject'] = 'Python roolz!'
```

__delitem__(*name*)
Delete all occurrences of the field with name *name* from the message's headers. No exception is raised if the named field isn't present in the headers.

keys()
Return a list of all the message's header field names.

values()
Return a list of all the message's field values.

items()
Return a list of 2-tuples containing all the message's field headers and values.

get(*name*, *failobj=None*)
Return the value of the named header field. This is identical to *__getitem__()* except that optional *failobj* is returned if the named header is missing (defaults to `None`).

Here are some additional useful methods:

get_all(*name*, *failobj=None*)
Return a list of all the values for the field named *name*. If there are no such named headers in the message, *failobj* is returned (defaults to `None`).

add_header(*_name*, *_value*, ***_params*)
Extended header setting. This method is similar to *__setitem__()* except that additional header parameters can be provided as keyword arguments. *_name* is the header field to add and *_value* is the *primary* value for the header.

For each item in the keyword argument dictionary *_params*, the key is taken as the parameter name, with underscores converted to dashes (since dashes are illegal in Python identifiers). Normally, the parameter will be added as `key="value"` unless the value is `None`, in which case only the key will be added. If the value contains non-ASCII characters, it can be specified as a three tuple in the format `(CHARSET, LANGUAGE, VALUE)`, where `CHARSET` is a string naming the charset to be used to encode the value, `LANGUAGE` can usually be set to `None` or the empty string (see **RFC 2231** for other possibilities), and `VALUE` is the string value containing non-ASCII code points. If a three tuple is not passed and the value contains non-ASCII characters, it is automatically encoded in **RFC 2231** format using a `CHARSET` of `utf-8` and a `LANGUAGE` of `None`.

Here's an example:

```
msg.add_header('Content-Disposition', 'attachment', filename='bud.gif')
```

This will add a header that looks like

```
Content-Disposition: attachment; filename="bud.gif"
```

An example with non-ASCII characters:

```
msg.add_header('Content-Disposition', 'attachment',
               filename=('iso-8859-1', '', 'Fußballer.ppt'))
```

Which produces

```
Content-Disposition: attachment; filename*="iso-8859-1''Fu%DFballer.ppt"
```

replace_header(*_name*, *_value*)
Replace a header. Replace the first header found in the message that matches *_name*, retaining header order and field name case. If no matching header was found, a *KeyError* is raised.

get_content_type()
Return the message's content type. The returned string is coerced to lower case of the form *maintype/subtype*. If there was no *Content-Type* header in the message the default type as given by *get_default_type()* will be returned. Since according to **RFC 2045**, messages always have a default type, *get_content_type()* will always return a value.

RFC 2045 defines a message's default type to be *text/plain* unless it appears inside a *multipart/digest* container, in which case it would be *message/rfc822*. If the *Content-Type* header has an invalid type specification, **RFC 2045** mandates that the default type be *text/plain*.

get_content_maintype()
Return the message's main content type. This is the *maintype* part of the string returned by *get_content_type()*.

get_content_subtype()
Return the message's sub-content type. This is the *subtype* part of the string returned by *get_content_type()*.

get_default_type()
Return the default content type. Most messages have a default content type of *text/plain*, except for messages that are subparts of *multipart/digest* containers. Such subparts have a default content type of *message/rfc822*.

set_default_type(*ctype*)
Set the default content type. *ctype* should either be *text/plain* or *message/rfc822*, although this is not enforced. The default content type is not stored in the *Content-Type* header.

get_params(*failobj=None*, *header='content-type'*, *unquote=True*)
Return the message's *Content-Type* parameters, as a list. The elements of the returned list are 2-tuples of key/value pairs, as split on the `'='` sign. The left hand side of the `'='` is the key, while the right hand side is the value. If there is no `'='` sign in the parameter the value is the empty string, otherwise the value is as described in *get_param()* and is unquoted if optional *unquote* is `True` (the default).

Optional *failobj* is the object to return if there is no *Content-Type* header. Optional *header* is the header to search instead of *Content-Type*.

This is a legacy method. On the `EmailMessage` class its functionality is replaced by the *params* property of the individual header objects returned by the header access methods.

get_param(*param*, *failobj=None*, *header='content-type'*, *unquote=True*)
Return the value of the *Content-Type* header's parameter *param* as a string. If the message has no *Content-Type* header or if there is no such parameter, then *failobj* is returned (defaults to `None`).

Optional *header* if given, specifies the message header to use instead of *Content-Type*.

Parameter keys are always compared case insensitively. The return value can either be a string, or a 3-tuple if the parameter was **RFC 2231** encoded. When it's a 3-tuple, the elements of the value are of the form `(CHARSET, LANGUAGE, VALUE)`. Note that both `CHARSET` and `LANGUAGE` can be `None`, in which case you should consider `VALUE` to be encoded in the `us-ascii` charset. You can usually ignore `LANGUAGE`.

If your application doesn't care whether the parameter was encoded as in **RFC 2231**, you can collapse the parameter value by calling *email.utils.collapse_rfc2231_value()*, passing in the return value from *get_param()*. This will return a suitably decoded Unicode string when the value is a tuple, or the original string unquoted if it isn't. For example:

```
rawparam = msg.get_param('foo')
param = email.utils.collapse_rfc2231_value(rawparam)
```

In any case, the parameter value (either the returned string, or the `VALUE` item in the 3-tuple) is always unquoted, unless *unquote* is set to `False`.

This is a legacy method. On the `EmailMessage` class its functionality is replaced by the *params* property of the individual header objects returned by the header access methods.

set_param(*param*, *value*, *header='Content-Type'*, *requote=True*, *charset=None*, *language=''*, *replace=False*)
Set a parameter in the *Content-Type* header. If the parameter already exists in the header, its value will be replaced with *value*. If the *Content-Type* header as not yet been defined for this message, it will be set to *text/plain* and the new parameter value will be appended as per **RFC 2045**.

Optional *header* specifies an alternative header to *Content-Type*, and all parameters will be quoted as necessary unless optional *requote* is `False` (the default is `True`).

If optional *charset* is specified, the parameter will be encoded according to **RFC 2231**. Optional *language* specifies the RFC 2231 language, defaulting to the empty string. Both *charset* and *language* should be strings.

If *replace* is `False` (the default) the header is moved to the end of the list of headers. If *replace* is `True`, the header will be updated in place.

Changed in version 3.4: `replace` keyword was added.

del_param(*param*, *header='content-type'*, *requote=True*)
Remove the given parameter completely from the *Content-Type* header. The header will be rewritten in place without the parameter or its value. All values will be quoted as necessary unless *requote* is `False` (the default is `True`). Optional *header* specifies an alternative to *Content-Type*.

set_type(*type*, *header='Content-Type'*, *requote=True*)
Set the main type and subtype for the *Content-Type* header. *type* must be a string in the form *maintype/subtype*, otherwise a *ValueError* is raised.

This method replaces the *Content-Type* header, keeping all the parameters in place. If *requote* is `False`, this leaves the existing header's quoting as is, otherwise the parameters will be quoted (the default).

An alternative header can be specified in the *header* argument. When the *Content-Type* header is set a *MIME-Version* header is also added.

This is a legacy method. On the `EmailMessage` class its functionality is replaced by the `make_` and `add_` methods.

get_filename(*failobj=None*)
Return the value of the `filename` parameter of the *Content-Disposition* header of the message. If the header does not have a `filename` parameter, this method falls back to looking for the `name` parameter on the *Content-Type* header. If neither is found, or the header is missing, then *failobj* is returned. The returned string will always be unquoted as per *email.utils.unquote()*.

get_boundary(*failobj=None*)
Return the value of the `boundary` parameter of the *Content-Type* header of the message, or *failobj* if either the header is missing, or has no `boundary` parameter. The returned string will always be unquoted as per *email.utils.unquote()*.

set_boundary(*boundary*)
Set the `boundary` parameter of the *Content-Type* header to *boundary*. *set_boundary()* will always quote *boundary* if necessary. A *HeaderParseError* is raised if the message object has no *Content-Type* header.

Note that using this method is subtly different than deleting the old *Content-Type* header and adding a new one with the new boundary via *add_header()*, because *set_boundary()* preserves the order of the *Content-Type* header in the list of headers. However, it does *not* preserve any continuation lines which may have been present in the original *Content-Type* header.

get_content_charset(*failobj=None*)
Return the `charset` parameter of the *Content-Type* header, coerced to lower case. If there is no *Content-Type* header, or if that header has no `charset` parameter, *failobj* is returned.

Note that this method differs from *get_charset()* which returns the *Charset* instance for the default encoding of the message body.

get_charsets(*failobj=None*)
Return a list containing the character set names in the message. If the message is a *multipart*, then the list will contain one element for each subpart in the payload, otherwise, it will be a list of length 1.

Each item in the list will be a string which is the value of the `charset` parameter in the *Content-Type* header for the represented subpart. However, if the subpart has no *Content-Type* header, no `charset` parameter, or is not of the *text* main MIME type, then that item in the returned list will be *failobj*.

get_content_disposition()
Return the lowercased value (without parameters) of the message's *Content-Disposition* header if it has one, or `None`. The possible values for this method are *inline*, *attachment* or `None` if the message follows **RFC 2183**.

New in version 3.5.

walk()
The *walk()* method is an all-purpose generator which can be used to iterate over all the parts and subparts of a message object tree, in depth-first traversal order. You will typically use *walk()* as the iterator in a `for` loop; each iteration returns the next subpart.

Here's an example that prints the MIME type of every part of a multipart message structure:

```
>>> for part in msg.walk():
...     print(part.get_content_type())
multipart/report
text/plain
message/delivery-status
text/plain
text/plain
message/rfc822
text/plain
```

`walk` iterates over the subparts of any part where *is_multipart()* returns `True`, even though `msg.get_content_maintype() == 'multipart'` may return `False`. We can see this in our example by making use of the `_structure` debug helper function:

```
>>> for part in msg.walk():
...     print(part.get_content_maintype() == 'multipart',
...           part.is_multipart())
True True
False False
False True
False False
False False
False True
False False
>>> _structure(msg)
multipart/report
    text/plain
    message/delivery-status
        text/plain
        text/plain
    message/rfc822
        text/plain
```

Here the `message` parts are not `multiparts`, but they do contain subparts. `is_multipart()` returns `True` and `walk` descends into the subparts.

Message objects can also optionally contain two instance attributes, which can be used when generating the plain text of a MIME message.

preamble
The format of a MIME document allows for some text between the blank line following the headers, and the first multipart boundary string. Normally, this text is never visible in a MIME-aware mail reader because it falls outside the standard MIME armor. However, when viewing the raw text of the message, or when viewing the message in a non-MIME aware reader, this text can become visible.

The *preamble* attribute contains this leading extra-armor text for MIME documents. When the *Parser* discovers some text after the headers but before the first boundary string, it assigns this text to the message's *preamble* attribute. When the *Generator* is writing out the plain text representation of a MIME message, and it finds the message has a *preamble* attribute, it will write this text in the area between the headers and the first boundary. See *email.parser* and *email.generator* for details.

Note that if the message object has no preamble, the *preamble* attribute will be `None`.

epilogue
The *epilogue* attribute acts the same way as the *preamble* attribute, except that it contains text that appears between the last boundary and the end of the message.

You do not need to set the epilogue to the empty string in order for the *Generator* to print a newline at the end of the file.

defects
The *defects* attribute contains a list of all the problems found when parsing this message. See *email.errors* for a detailed description of the possible parsing defects.

20.1.10 email.mime: Creating email and MIME objects from scratch

Source code: Lib/email/mime/

This module is part of the legacy (`Compat32`) email API. Its functionality is partially replaced by the *contentmanager* in the new API, but in certain applications these classes may still be useful, even in non-legacy code.

Ordinarily, you get a message object structure by passing a file or some text to a parser, which parses the text and returns the root message object. However you can also build a complete message structure from scratch, or even individual *Message* objects by hand. In fact, you can also take an existing structure and add new *Message* objects, move them around, etc. This makes a very convenient interface for slicing-and-dicing MIME messages.

You can create a new object structure by creating *Message* instances, adding attachments and all the appropriate headers manually. For MIME messages though, the *email* package provides some convenient subclasses to make things easier.

Here are the classes:

class email.mime.base.MIMEBase(*_maintype*, *_subtype*, ***, *policy=compat32*, ***_params*)
Module: `email.mime.base`

This is the base class for all the MIME-specific subclasses of *Message*. Ordinarily you won't create instances specifically of *MIMEBase*, although you could. *MIMEBase* is provided primarily as a convenient base class for more specific MIME-aware subclasses.

_maintype is the *Content-Type* major type (e.g. *text* or *image*), and *_subtype* is the *Content-Type* minor type (e.g. *plain* or *gif*). *_params* is a parameter key/value dictionary and is passed directly to *Message.add_header*.

If *policy* is specified, (defaults to the *compat32* policy) it will be passed to *Message*.

The *MIMEBase* class always adds a *Content-Type* header (based on *_maintype*, *_subtype*, and *_params*), and a *MIME-Version* header (always set to `1.0`).

Changed in version 3.6: Added *policy* keyword-only parameter.

class email.mime.nonmultipart.MIMENonMultipart

Module: email.mime.nonmultipart

A subclass of *MIMEBase*, this is an intermediate base class for MIME messages that are not *multipart*. The primary purpose of this class is to prevent the use of the *attach()* method, which only makes sense for *multipart* messages. If *attach()* is called, a *MultipartConversionError* exception is raised.

class email.mime.multipart.MIMEMultipart(*_subtype='mixed'*, *boundary=None*, *_subparts=None*, ***, *policy=compat32*, ***_params*)

Module: email.mime.multipart

A subclass of *MIMEBase*, this is an intermediate base class for MIME messages that are *multipart*. Optional *_subtype* defaults to *mixed*, but can be used to specify the subtype of the message. A *Content-Type* header of *multipart/_subtype* will be added to the message object. A *MIME-Version* header will also be added.

Optional *boundary* is the multipart boundary string. When None (the default), the boundary is calculated when needed (for example, when the message is serialized).

_subparts is a sequence of initial subparts for the payload. It must be possible to convert this sequence to a list. You can always attach new subparts to the message by using the *Message.attach* method.

Optional *policy* argument defaults to *compat32*.

Additional parameters for the *Content-Type* header are taken from the keyword arguments, or passed into the *_params* argument, which is a keyword dictionary.

Changed in version 3.6: Added *policy* keyword-only parameter.

class email.mime.application.MIMEApplication(*_data*, *_subtype='octet-stream'*, *_encoder=email.encoders.encode_base64*, ***, *policy=compat32*, ***_params*)

Module: email.mime.application

A subclass of *MIMENonMultipart*, the *MIMEApplication* class is used to represent MIME message objects of major type *application*. *_data* is a string containing the raw byte data. Optional *_subtype* specifies the MIME subtype and defaults to *octet-stream*.

Optional *_encoder* is a callable (i.e. function) which will perform the actual encoding of the data for transport. This callable takes one argument, which is the *MIMEApplication* instance. It should use *get_payload()* and *set_payload()* to change the payload to encoded form. It should also add any *Content-Transfer-Encoding* or other headers to the message object as necessary. The default encoding is base64. See the *email.encoders* module for a list of the built-in encoders.

Optional *policy* argument defaults to *compat32*.

_params are passed straight through to the base class constructor.

Changed in version 3.6: Added *policy* keyword-only parameter.

class email.mime.audio.MIMEAudio(*_audiodata*, *_subtype=None*, *_encoder=email.encoders.encode_base64*, ***, *policy=compat32*, ***_params*)

Module: email.mime.audio

A subclass of *MIMENonMultipart*, the *MIMEAudio* class is used to create MIME message objects of major type *audio*. *_audiodata* is a string containing the raw audio data. If this data can be decoded by the standard Python module *sndhdr*, then the subtype will be automatically included in the *Content-Type* header. Otherwise you can explicitly specify the audio subtype via the *_subtype* argument. If the minor type could not be guessed and *_subtype* was not given, then *TypeError* is raised.

Optional *_encoder* is a callable (i.e. function) which will perform the actual encoding of the audio data for transport. This callable takes one argument, which is the *MIMEAudio* instance. It should use *get_payload()* and *set_payload()* to change the payload to encoded form. It should also add

any *Content-Transfer-Encoding* or other headers to the message object as necessary. The default encoding is base64. See the *email.encoders* module for a list of the built-in encoders.

Optional *policy* argument defaults to *compat32*.

_params are passed straight through to the base class constructor.

Changed in version 3.6: Added *policy* keyword-only parameter.

class email.mime.image.MIMEImage(*_imagedata*, *_subtype=None*, *_encoder=email.encoders.encode_base64*, ***, *policy=compat32*, ***_params*)

Module: email.mime.image

A subclass of *MIMENonMultipart*, the *MIMEImage* class is used to create MIME message objects of major type *image*. *_imagedata* is a string containing the raw image data. If this data can be decoded by the standard Python module *imghdr*, then the subtype will be automatically included in the *Content-Type* header. Otherwise you can explicitly specify the image subtype via the *_subtype* argument. If the minor type could not be guessed and *_subtype* was not given, then *TypeError* is raised.

Optional *_encoder* is a callable (i.e. function) which will perform the actual encoding of the image data for transport. This callable takes one argument, which is the *MIMEImage* instance. It should use *get_payload()* and *set_payload()* to change the payload to encoded form. It should also add any *Content-Transfer-Encoding* or other headers to the message object as necessary. The default encoding is base64. See the *email.encoders* module for a list of the built-in encoders.

Optional *policy* argument defaults to *compat32*.

_params are passed straight through to the *MIMEBase* constructor.

Changed in version 3.6: Added *policy* keyword-only parameter.

class email.mime.message.MIMEMessage(*_msg*, *_subtype='rfc822'*, ***, *policy=compat32*)

Module: email.mime.message

A subclass of *MIMENonMultipart*, the *MIMEMessage* class is used to create MIME objects of main type *message*. *_msg* is used as the payload, and must be an instance of class *Message* (or a subclass thereof), otherwise a *TypeError* is raised.

Optional *_subtype* sets the subtype of the message; it defaults to *rfc822*.

Optional *policy* argument defaults to *compat32*.

Changed in version 3.6: Added *policy* keyword-only parameter.

class email.mime.text.MIMEText(*_text*, *_subtype='plain'*, *_charset=None*, ***, *policy=compat32*)

Module: email.mime.text

A subclass of *MIMENonMultipart*, the *MIMEText* class is used to create MIME objects of major type *text*. *_text* is the string for the payload. *_subtype* is the minor type and defaults to *plain*. *_charset* is the character set of the text and is passed as an argument to the *MIMENonMultipart* constructor; it defaults to `us-ascii` if the string contains only `ascii` code points, and `utf-8` otherwise. The *_charset* parameter accepts either a string or a *Charset* instance.

Unless the *_charset* argument is explicitly set to `None`, the MIMEText object created will have both a *Content-Type* header with a `charset` parameter, and a *Content-Transfer-Encoding* header. This means that a subsequent `set_payload` call will not result in an encoded payload, even if a charset is passed in the `set_payload` command. You can "reset" this behavior by deleting the `Content-Transfer-Encoding` header, after which a `set_payload` call will automatically encode the new payload (and add a new *Content-Transfer-Encoding* header).

Optional *policy* argument defaults to *compat32*.

Changed in version 3.5: *_charset* also accepts *Charset* instances.

Changed in version 3.6: Added *policy* keyword-only parameter.

20.1.11 email.header: Internationalized headers

Source code: Lib/email/header.py

This module is part of the legacy (Compat32) email API. In the current API encoding and decoding of headers is handled transparently by the dictionary-like API of the *EmailMessage* class. In addition to uses in legacy code, this module can be useful in applications that need to completely control the character sets used when encoding headers.

The remaining text in this section is the original documentation of the module.

RFC 2822 is the base standard that describes the format of email messages. It derives from the older **RFC 822** standard which came into widespread use at a time when most email was composed of ASCII characters only. **RFC 2822** is a specification written assuming email contains only 7-bit ASCII characters.

Of course, as email has been deployed worldwide, it has become internationalized, such that language specific character sets can now be used in email messages. The base standard still requires email messages to be transferred using only 7-bit ASCII characters, so a slew of RFCs have been written describing how to encode email containing non-ASCII characters into **RFC 2822**-compliant format. These RFCs include **RFC 2045**, **RFC 2046**, **RFC 2047**, and **RFC 2231**. The *email* package supports these standards in its *email.header* and *email.charset* modules.

If you want to include non-ASCII characters in your email headers, say in the *Subject* or *To* fields, you should use the *Header* class and assign the field in the *Message* object to an instance of *Header* instead of using a string for the header value. Import the *Header* class from the *email.header* module. For example:

```
>>> from email.message import Message
>>> from email.header import Header
>>> msg = Message()
>>> h = Header('p\xf6stal', 'iso-8859-1')
>>> msg['Subject'] = h
>>> msg.as_string()
'Subject: =?iso-8859-1?q?p=F6stal?=\n\n'
```

Notice here how we wanted the *Subject* field to contain a non-ASCII character? We did this by creating a *Header* instance and passing in the character set that the byte string was encoded in. When the subsequent *Message* instance was flattened, the *Subject* field was properly **RFC 2047** encoded. MIME-aware mail readers would show this header using the embedded ISO-8859-1 character.

Here is the *Header* class description:

class email.header.Header(*s=None*, *charset=None*, *maxlinelen=None*, *header_name=None*, *continuation_ws=' '*, *errors='strict'*)

Create a MIME-compliant header that can contain strings in different character sets.

Optional *s* is the initial header value. If None (the default), the initial header value is not set. You can later append to the header with *append()* method calls. *s* may be an instance of *bytes* or *str*, but see the *append()* documentation for semantics.

Optional *charset* serves two purposes: it has the same meaning as the *charset* argument to the *append()* method. It also sets the default character set for all subsequent *append()* calls that omit the *charset* argument. If *charset* is not provided in the constructor (the default), the us-ascii character set is used both as *s*'s initial charset and as the default for subsequent *append()* calls.

The maximum line length can be specified explicitly via *maxlinelen*. For splitting the first line to a shorter value (to account for the field header which isn't included in *s*, e.g. *Subject*) pass in the name of the field in *header_name*. The default *maxlinelen* is 76, and the default value for *header_name* is None, meaning it is not taken into account for the first line of a long, split header.

Optional *continuation_ws* must be **RFC 2822**-compliant folding whitespace, and is usually either a space or a hard tab character. This character will be prepended to continuation lines. *continuation_ws* defaults to a single space character.

Optional *errors* is passed straight through to the *append()* method.

append(*s*, *charset=None*, *errors='strict'*)
Append the string *s* to the MIME header.

Optional *charset*, if given, should be a *Charset* instance (see *email.charset*) or the name of a character set, which will be converted to a *Charset* instance. A value of `None` (the default) means that the *charset* given in the constructor is used.

s may be an instance of *bytes* or *str*. If it is an instance of *bytes*, then *charset* is the encoding of that byte string, and a *UnicodeError* will be raised if the string cannot be decoded with that character set.

If *s* is an instance of *str*, then *charset* is a hint specifying the character set of the characters in the string.

In either case, when producing an **RFC 2822**-compliant header using **RFC 2047** rules, the string will be encoded using the output codec of the charset. If the string cannot be encoded using the output codec, a UnicodeError will be raised.

Optional *errors* is passed as the errors argument to the decode call if *s* is a byte string.

encode(*splitchars=';, \t'*, *maxlinelen=None*, *linesep='\n'*)
Encode a message header into an RFC-compliant format, possibly wrapping long lines and encapsulating non-ASCII parts in base64 or quoted-printable encodings.

Optional *splitchars* is a string containing characters which should be given extra weight by the splitting algorithm during normal header wrapping. This is in very rough support of **RFC 2822**'s 'higher level syntactic breaks': split points preceded by a splitchar are preferred during line splitting, with the characters preferred in the order in which they appear in the string. Space and tab may be included in the string to indicate whether preference should be given to one over the other as a split point when other split chars do not appear in the line being split. Splitchars does not affect **RFC 2047** encoded lines.

maxlinelen, if given, overrides the instance's value for the maximum line length.

linesep specifies the characters used to separate the lines of the folded header. It defaults to the most useful value for Python application code (`\n`), but `\r\n` can be specified in order to produce headers with RFC-compliant line separators.

Changed in version 3.2: Added the *linesep* argument.

The *Header* class also provides a number of methods to support standard operators and built-in functions.

__str__()
Returns an approximation of the *Header* as a string, using an unlimited line length. All pieces are converted to unicode using the specified encoding and joined together appropriately. Any pieces with a charset of `'unknown-8bit'` are decoded as ASCII using the `'replace'` error handler.

Changed in version 3.2: Added handling for the `'unknown-8bit'` charset.

__eq__(*other*)
This method allows you to compare two *Header* instances for equality.

__ne__(*other*)
This method allows you to compare two *Header* instances for inequality.

The *email.header* module also provides the following convenient functions.

email.header.decode_header(*header*)
Decode a message header value without converting the character set. The header value is in *header*.

This function returns a list of `(decoded_string, charset)` pairs containing each of the decoded parts of the header. *charset* is `None` for non-encoded parts of the header, otherwise a lower case string containing the name of the character set specified in the encoded string.

Here's an example:

```
>>> from email.header import decode_header
>>> decode_header('=?iso-8859-1?q?p=F6stal?=')
[(b'p\xf6stal', 'iso-8859-1')]
```

email.header.make_header(*decoded_seq*, *maxlinelen=None*, *header_name=None*, *continuation_ws=' '*)
Create a *Header* instance from a sequence of pairs as returned by *decode_header()*.

decode_header() takes a header value string and returns a sequence of pairs of the format `(decoded_string, charset)` where *charset* is the name of the character set.

This function takes one of those sequence of pairs and returns a *Header* instance. Optional *maxlinelen*, *header_name*, and *continuation_ws* are as in the *Header* constructor.

20.1.12 email.charset: Representing character sets

Source code: Lib/email/charset.py

This module is part of the legacy (`Compat32`) email API. In the new API only the aliases table is used.

The remaining text in this section is the original documentation of the module.

This module provides a class *Charset* for representing character sets and character set conversions in email messages, as well as a character set registry and several convenience methods for manipulating this registry. Instances of *Charset* are used in several other modules within the *email* package.

Import this class from the *email.charset* module.

class email.charset.Charset(*input_charset=DEFAULT_CHARSET*)
Map character sets to their email properties.

This class provides information about the requirements imposed on email for a specific character set. It also provides convenience routines for converting between character sets, given the availability of the applicable codecs. Given a character set, it will do its best to provide information on how to use that character set in an email message in an RFC-compliant way.

Certain character sets must be encoded with quoted-printable or base64 when used in email headers or bodies. Certain character sets must be converted outright, and are not allowed in email.

Optional *input_charset* is as described below; it is always coerced to lower case. After being alias normalized it is also used as a lookup into the registry of character sets to find out the header encoding, body encoding, and output conversion codec to be used for the character set. For example, if *input_charset* is `iso-8859-1`, then headers and bodies will be encoded using quoted-printable and no output conversion codec is necessary. If *input_charset* is `euc-jp`, then headers will be encoded with base64, bodies will not be encoded, but output text will be converted from the `euc-jp` character set to the `iso-2022-jp` character set.

Charset instances have the following data attributes:

input_charset
The initial character set specified. Common aliases are converted to their *official* email names (e.g. `latin_1` is converted to `iso-8859-1`). Defaults to 7-bit `us-ascii`.

header_encoding
If the character set must be encoded before it can be used in an email header, this attribute will be set to `Charset.QP` (for quoted-printable), `Charset.BASE64` (for base64 encoding), or `Charset.SHORTEST` for the shortest of QP or BASE64 encoding. Otherwise, it will be `None`.

body_encoding
Same as *header_encoding*, but describes the encoding for the mail message's body, which indeed may be different than the header encoding. `Charset.SHORTEST` is not allowed for *body_encoding*.

output_charset
Some character sets must be converted before they can be used in email headers or bodies. If the *input_charset* is one of them, this attribute will contain the name of the character set output will be converted to. Otherwise, it will be `None`.

input_codec
The name of the Python codec used to convert the *input_charset* to Unicode. If no conversion codec is necessary, this attribute will be `None`.

output_codec
The name of the Python codec used to convert Unicode to the *output_charset*. If no conversion codec is necessary, this attribute will have the same value as the *input_codec*.

Charset instances also have the following methods:

get_body_encoding()
Return the content transfer encoding used for body encoding.

This is either the string `quoted-printable` or `base64` depending on the encoding used, or it is a function, in which case you should call the function with a single argument, the Message object being encoded. The function should then set the *Content-Transfer-Encoding* header itself to whatever is appropriate.

Returns the string `quoted-printable` if *body_encoding* is `QP`, returns the string `base64` if *body_encoding* is `BASE64`, and returns the string `7bit` otherwise.

get_output_charset()
Return the output character set.

This is the *output_charset* attribute if that is not `None`, otherwise it is *input_charset*.

header_encode(*string***)**
Header-encode the string *string*.

The type of encoding (base64 or quoted-printable) will be based on the *header_encoding* attribute.

header_encode_lines(*string*, *maxlengths***)**
Header-encode a *string* by converting it first to bytes.

This is similar to *header_encode()* except that the string is fit into maximum line lengths as given by the argument *maxlengths*, which must be an iterator: each element returned from this iterator will provide the next maximum line length.

body_encode(*string***)**
Body-encode the string *string*.

The type of encoding (base64 or quoted-printable) will be based on the *body_encoding* attribute.

The *Charset* class also provides a number of methods to support standard operations and built-in functions.

__str__()
Returns *input_charset* as a string coerced to lower case. `__repr__()` is an alias for *__str__()*.

__eq__(*other***)**
This method allows you to compare two *Charset* instances for equality.

`__ne__`(*other*)
This method allows you to compare two *Charset* instances for inequality.

The *email.charset* module also provides the following functions for adding new entries to the global character set, alias, and codec registries:

`email.charset.add_charset`(*charset*, *header_enc=None*, *body_enc=None*, *output_charset=None*)
Add character properties to the global registry.

charset is the input character set, and must be the canonical name of a character set.

Optional *header_enc* and *body_enc* is either `Charset.QP` for quoted-printable, `Charset.BASE64` for base64 encoding, `Charset.SHORTEST` for the shortest of quoted-printable or base64 encoding, or `None` for no encoding. `SHORTEST` is only valid for *header_enc*. The default is `None` for no encoding.

Optional *output_charset* is the character set that the output should be in. Conversions will proceed from input charset, to Unicode, to the output charset when the method `Charset.convert()` is called. The default is to output in the same character set as the input.

Both *input_charset* and *output_charset* must have Unicode codec entries in the module's character set-to-codec mapping; use *add_codec()* to add codecs the module does not know about. See the *codecs* module's documentation for more information.

The global character set registry is kept in the module global dictionary `CHARSETS`.

`email.charset.add_alias`(*alias*, *canonical*)
Add a character set alias. *alias* is the alias name, e.g. `latin-1`. *canonical* is the character set's canonical name, e.g. `iso-8859-1`.

The global charset alias registry is kept in the module global dictionary `ALIASES`.

`email.charset.add_codec`(*charset*, *codecname*)
Add a codec that map characters in the given character set to and from Unicode.

charset is the canonical name of a character set. *codecname* is the name of a Python codec, as appropriate for the second argument to the *str*'s *encode()* method.

20.1.13 `email.encoders`: Encoders

Source code: Lib/email/encoders.py

This module is part of the legacy (`Compat32`) email API. In the new API the functionality is provided by the *cte* parameter of the *set_content()* method.

The remaining text in this section is the original documentation of the module.

When creating *Message* objects from scratch, you often need to encode the payloads for transport through compliant mail servers. This is especially true for *image/** and *text/** type messages containing binary data.

The *email* package provides some convenient encodings in its `encoders` module. These encoders are actually used by the *MIMEAudio* and *MIMEImage* class constructors to provide default encodings. All encoder functions take exactly one argument, the message object to encode. They usually extract the payload, encode it, and reset the payload to this newly encoded value. They should also set the *Content-Transfer-Encoding* header as appropriate.

Note that these functions are not meaningful for a multipart message. They must be applied to individual subparts instead, and will raise a *TypeError* if passed a message whose type is multipart.

Here are the encoding functions provided:

email.encoders.encode_quopri(*msg*)
: Encodes the payload into quoted-printable form and sets the *Content-Transfer-Encoding* header to `quoted-printable`[1]. This is a good encoding to use when most of your payload is normal printable data, but contains a few unprintable characters.

email.encoders.encode_base64(*msg*)
: Encodes the payload into base64 form and sets the *Content-Transfer-Encoding* header to `base64`. This is a good encoding to use when most of your payload is unprintable data since it is a more compact form than quoted-printable. The drawback of base64 encoding is that it renders the text non-human readable.

email.encoders.encode_7or8bit(*msg*)
: This doesn't actually modify the message's payload, but it does set the *Content-Transfer-Encoding* header to either `7bit` or `8bit` as appropriate, based on the payload data.

email.encoders.encode_noop(*msg*)
: This does nothing; it doesn't even set the *Content-Transfer-Encoding* header.

20.1.14 email.utils: Miscellaneous utilities

Source code: Lib/email/utils.py

There are a couple of useful utilities provided in the *email.utils* module:

email.utils.localtime(*dt=None*)
: Return local time as an aware datetime object. If called without arguments, return current time. Otherwise *dt* argument should be a *datetime* instance, and it is converted to the local time zone according to the system time zone database. If *dt* is naive (that is, `dt.tzinfo` is `None`), it is assumed to be in local time. In this case, a positive or zero value for *isdst* causes `localtime` to presume initially that summer time (for example, Daylight Saving Time) is or is not (respectively) in effect for the specified time. A negative value for *isdst* causes the `localtime` to attempt to divine whether summer time is in effect for the specified time.

  New in version 3.3.

email.utils.make_msgid(*idstring=None*, *domain=None*)
: Returns a string suitable for an **RFC 2822**-compliant *Message-ID* header. Optional *idstring* if given, is a string used to strengthen the uniqueness of the message id. Optional *domain* if given provides the portion of the msgid after the '@'. The default is the local hostname. It is not normally necessary to override this default, but may be useful certain cases, such as a constructing distributed system that uses a consistent domain name across multiple hosts.

  Changed in version 3.2: Added the *domain* keyword.

The remaining functions are part of the legacy (`Compat32`) email API. There is no need to directly use these with the new API, since the parsing and formatting they provide is done automatically by the header parsing machinery of the new API.

email.utils.quote(*str*)
: Return a new string with backslashes in *str* replaced by two backslashes, and double quotes replaced by backslash-double quote.

email.utils.unquote(*str*)
: Return a new string which is an *unquoted* version of *str*. If *str* ends and begins with double quotes, they are stripped off. Likewise if *str* ends and begins with angle brackets, they are stripped off.

[1] Note that encoding with *encode_quopri()* also encodes all tabs and space characters in the data.

email.utils.**parseaddr**(*address*)
Parse address – which should be the value of some address-containing field such as *To* or *Cc* – into its constituent *realname* and *email address* parts. Returns a tuple of that information, unless the parse fails, in which case a 2-tuple of `('', '')` is returned.

email.utils.**formataddr**(*pair*, *charset='utf-8'*)
The inverse of *parseaddr()*, this takes a 2-tuple of the form `(realname, email_address)` and returns the string value suitable for a *To* or *Cc* header. If the first element of *pair* is false, then the second element is returned unmodified.

Optional *charset* is the character set that will be used in the **RFC 2047** encoding of the `realname` if the `realname` contains non-ASCII characters. Can be an instance of *str* or a *Charset*. Defaults to `utf-8`.

Changed in version 3.3: Added the *charset* option.

email.utils.**getaddresses**(*fieldvalues*)
This method returns a list of 2-tuples of the form returned by `parseaddr()`. *fieldvalues* is a sequence of header field values as might be returned by *Message.get_all*. Here's a simple example that gets all the recipients of a message:

```
from email.utils import getaddresses

tos = msg.get_all('to', [])
ccs = msg.get_all('cc', [])
resent_tos = msg.get_all('resent-to', [])
resent_ccs = msg.get_all('resent-cc', [])
all_recipients = getaddresses(tos + ccs + resent_tos + resent_ccs)
```

email.utils.**parsedate**(*date*)
Attempts to parse a date according to the rules in **RFC 2822**. however, some mailers don't follow that format as specified, so *parsedate()* tries to guess correctly in such cases. *date* is a string containing an **RFC 2822** date, such as `"Mon, 20 Nov 1995 19:12:08 -0500"`. If it succeeds in parsing the date, *parsedate()* returns a 9-tuple that can be passed directly to *time.mktime()*; otherwise `None` will be returned. Note that indexes 6, 7, and 8 of the result tuple are not usable.

email.utils.**parsedate_tz**(*date*)
Performs the same function as *parsedate()*, but returns either `None` or a 10-tuple; the first 9 elements make up a tuple that can be passed directly to *time.mktime()*, and the tenth is the offset of the date's timezone from UTC (which is the official term for Greenwich Mean Time)[1]. If the input string has no timezone, the last element of the tuple returned is `None`. Note that indexes 6, 7, and 8 of the result tuple are not usable.

email.utils.**parsedate_to_datetime**(*date*)
The inverse of *format_datetime()*. Performs the same function as *parsedate()*, but on success returns a *datetime*. If the input date has a timezone of `-0000`, the `datetime` will be a naive `datetime`, and if the date is conforming to the RFCs it will represent a time in UTC but with no indication of the actual source timezone of the message the date comes from. If the input date has any other valid timezone offset, the `datetime` will be an aware `datetime` with the corresponding a *timezone tzinfo*.

New in version 3.3.

email.utils.**mktime_tz**(*tuple*)
Turn a 10-tuple as returned by *parsedate_tz()* into a UTC timestamp (seconds since the Epoch). If the timezone item in the tuple is `None`, assume local time.

email.utils.**formatdate**(*timeval=None*, *localtime=False*, *usegmt=False*)
Returns a date string as per **RFC 2822**, e.g.:

[1] Note that the sign of the timezone offset is the opposite of the sign of the `time.timezone` variable for the same timezone; the latter variable follows the POSIX standard while this module follows **RFC 2822**.

```
Fri, 09 Nov 2001 01:08:47 -0000
```

Optional *timeval* if given is a floating point time value as accepted by *time.gmtime()* and *time.localtime()*, otherwise the current time is used.

Optional *localtime* is a flag that when `True`, interprets *timeval*, and returns a date relative to the local timezone instead of UTC, properly taking daylight savings time into account. The default is `False` meaning UTC is used.

Optional *usegmt* is a flag that when `True`, outputs a date string with the timezone as an ascii string `GMT`, rather than a numeric `-0000`. This is needed for some protocols (such as HTTP). This only applies when *localtime* is `False`. The default is `False`.

`email.utils.format_datetime`(*dt*, *usegmt=False*)
Like `formatdate`, but the input is a *datetime* instance. If it is a naive datetime, it is assumed to be "UTC with no information about the source timezone", and the conventional `-0000` is used for the timezone. If it is an aware `datetime`, then the numeric timezone offset is used. If it is an aware timezone with offset zero, then *usegmt* may be set to `True`, in which case the string `GMT` is used instead of the numeric timezone offset. This provides a way to generate standards conformant HTTP date headers.

New in version 3.3.

`email.utils.decode_rfc2231`(*s*)
Decode the string *s* according to **RFC 2231**.

`email.utils.encode_rfc2231`(*s*, *charset=None*, *language=None*)
Encode the string *s* according to **RFC 2231**. Optional *charset* and *language*, if given is the character set name and language name to use. If neither is given, *s* is returned as-is. If *charset* is given but *language* is not, the string is encoded using the empty string for *language*.

`email.utils.collapse_rfc2231_value`(*value*, *errors='replace'*, *fallback_charset='us-ascii'*)
When a header parameter is encoded in **RFC 2231** format, *Message.get_param* may return a 3-tuple containing the character set, language, and value. *collapse_rfc2231_value()* turns this into a unicode string. Optional *errors* is passed to the *errors* argument of *str*'s *encode()* method; it defaults to `'replace'`. Optional *fallback_charset* specifies the character set to use if the one in the **RFC 2231** header is not known by Python; it defaults to `'us-ascii'`.

For convenience, if the *value* passed to *collapse_rfc2231_value()* is not a tuple, it should be a string and it is returned unquoted.

`email.utils.decode_params`(*params*)
Decode parameters list according to **RFC 2231**. *params* is a sequence of 2-tuples containing elements of the form `(content-type, string-value)`.

20.1.15 `email.iterators`: Iterators

Source code: Lib/email/iterators.py

Iterating over a message object tree is fairly easy with the *Message.walk* method. The *email.iterators* module provides some useful higher level iterations over message object trees.

`email.iterators.body_line_iterator`(*msg*, *decode=False*)
This iterates over all the payloads in all the subparts of *msg*, returning the string payloads line-by-line. It skips over all the subpart headers, and it skips over any subpart with a payload that isn't a Python string. This is somewhat equivalent to reading the flat text representation of the message from a file using *readline()*, skipping over all the intervening headers.

Optional *decode* is passed through to *Message.get_payload*.

email.iterators.**typed_subpart_iterator**(*msg*, *maintype='text'*, *subtype=None*)

This iterates over all the subparts of *msg*, returning only those subparts that match the MIME type specified by *maintype* and *subtype*.

Note that *subtype* is optional; if omitted, then subpart MIME type matching is done only with the main type. *maintype* is optional too; it defaults to ***text***.

Thus, by default *typed_subpart_iterator()* returns each subpart that has a MIME type of ***text/***.

The following function has been added as a useful debugging tool. It should *not* be considered part of the supported public interface for the package.

email.iterators.**_structure**(*msg*, *fp=None*, *level=0*, *include_default=False*)

Prints an indented representation of the content types of the message object structure. For example:

```
>>> msg = email.message_from_file(somefile)
>>> _structure(msg)
multipart/mixed
    text/plain
    text/plain
    multipart/digest
        message/rfc822
            text/plain
        message/rfc822
            text/plain
        message/rfc822
            text/plain
        message/rfc822
            text/plain
        message/rfc822
            text/plain
    text/plain
```

Optional *fp* is a file-like object to print the output to. It must be suitable for Python's *print()* function. *level* is used internally. *include_default*, if true, prints the default type as well.

See also:

Module ***smtplib*** SMTP (Simple Mail Transport Protocol) client

Module ***poplib*** POP (Post Office Protocol) client

Module ***imaplib*** IMAP (Internet Message Access Protocol) client

Module ***nntplib*** NNTP (Net News Transport Protocol) client

Module ***mailbox*** Tools for creating, reading, and managing collections of messages on disk using a variety standard formats.

Module ***smtpd*** SMTP server framework (primarily useful for testing)

20.2 json — JSON encoder and decoder

Source code: Lib/json/__init__.py

JSON (JavaScript Object Notation), specified by **RFC 7159** (which obsoletes **RFC 4627**) and by ECMA-404, is a lightweight data interchange format inspired by JavaScript object literal syntax (although it is not a strict subset of JavaScript[1]).

[1] As noted in the errata for RFC 7159, JSON permits literal U+2028 (LINE SEPARATOR) and U+2029 (PARAGRAPH SEPARATOR) characters in strings, whereas JavaScript (as of ECMAScript Edition 5.1) does not.

json exposes an API familiar to users of the standard library *marshal* and *pickle* modules.

Encoding basic Python object hierarchies:

```
>>> import json
>>> json.dumps(['foo', {'bar': ('baz', None, 1.0, 2)}])
'["foo", {"bar": ["baz", null, 1.0, 2]}]'
>>> print(json.dumps("\"foo\bar"))
"\"foo\bar"
>>> print(json.dumps('\u1234'))
"\u1234"
>>> print(json.dumps('\\'))
"\\"
>>> print(json.dumps({"c": 0, "b": 0, "a": 0}, sort_keys=True))
{"a": 0, "b": 0, "c": 0}
>>> from io import StringIO
>>> io = StringIO()
>>> json.dump(['streaming API'], io)
>>> io.getvalue()
'["streaming API"]'
```

Compact encoding:

```
>>> import json
>>> json.dumps([1, 2, 3, {'4': 5, '6': 7}], separators=(',', ':'))
'[1,2,3,{"4":5,"6":7}]'
```

Pretty printing:

```
>>> import json
>>> print(json.dumps({'4': 5, '6': 7}, sort_keys=True, indent=4))
{
    "4": 5,
    "6": 7
}
```

Decoding JSON:

```
>>> import json
>>> json.loads('["foo", {"bar":["baz", null, 1.0, 2]}]')
['foo', {'bar': ['baz', None, 1.0, 2]}]
>>> json.loads('"\\"foo\\bar"')
'"foo\x08ar'
>>> from io import StringIO
>>> io = StringIO('["streaming API"]')
>>> json.load(io)
['streaming API']
```

Specializing JSON object decoding:

```
>>> import json
>>> def as_complex(dct):
...     if '__complex__' in dct:
...         return complex(dct['real'], dct['imag'])
...     return dct
...
>>> json.loads('{"__complex__": true, "real": 1, "imag": 2}',
...     object_hook=as_complex)
(1+2j)
```

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```
>>> import decimal
>>> json.loads('1.1', parse_float=decimal.Decimal)
Decimal('1.1')
```

Extending *JSONEncoder*:

```
>>> import json
>>> class ComplexEncoder(json.JSONEncoder):
...     def default(self, obj):
...         if isinstance(obj, complex):
...             return [obj.real, obj.imag]
...         # Let the base class default method raise the TypeError
...         return json.JSONEncoder.default(self, obj)
...
>>> json.dumps(2 + 1j, cls=ComplexEncoder)
'[2.0, 1.0]'
>>> ComplexEncoder().encode(2 + 1j)
'[2.0, 1.0]'
>>> list(ComplexEncoder().iterencode(2 + 1j))
['[2.0', ', 1.0', ']']
```

Using *json.tool* from the shell to validate and pretty-print:

```
$ echo '{"json":"obj"}' | python -m json.tool
{
    "json": "obj"
}
$ echo '{1.2:3.4}' | python -m json.tool
Expecting property name enclosed in double quotes: line 1 column 2 (char 1)
```

See *Command Line Interface* for detailed documentation.

Note: JSON is a subset of YAML 1.2. The JSON produced by this module's default settings (in particular, the default *separators* value) is also a subset of YAML 1.0 and 1.1. This module can thus also be used as a YAML serializer.

20.2.1 Basic Usage

`json.dump`(*obj*, *fp*, ***, *skipkeys=False*, *ensure_ascii=True*, *check_circular=True*, *allow_nan=True*, *cls=None*, *indent=None*, *separators=None*, *default=None*, *sort_keys=False*, ***kw*)

Serialize *obj* as a JSON formatted stream to *fp* (a `.write()`-supporting *file-like object*) using this *conversion table*.

If *skipkeys* is true (default: `False`), then dict keys that are not of a basic type (*str*, *int*, *float*, *bool*, `None`) will be skipped instead of raising a *TypeError*.

The *json* module always produces *str* objects, not *bytes* objects. Therefore, `fp.write()` must support *str* input.

If *ensure_ascii* is true (the default), the output is guaranteed to have all incoming non-ASCII characters escaped. If *ensure_ascii* is false, these characters will be output as-is.

If *check_circular* is false (default: `True`), then the circular reference check for container types will be skipped and a circular reference will result in an *OverflowError* (or worse).

If *allow_nan* is false (default: `True`), then it will be a *ValueError* to serialize out of range *float* values (`nan`, `inf`, `-inf`) in strict compliance of the JSON specification. If *allow_nan* is true, their JavaScript equivalents (`NaN`, `Infinity`, `-Infinity`) will be used.

If *indent* is a non-negative integer or string, then JSON array elements and object members will be pretty-printed with that indent level. An indent level of 0, negative, or `""` will only insert newlines. `None` (the default) selects the most compact representation. Using a positive integer indent indents that many spaces per level. If *indent* is a string (such as `"\t"`), that string is used to indent each level.

Changed in version 3.2: Allow strings for *indent* in addition to integers.

If specified, *separators* should be an `(item_separator, key_separator)` tuple. The default is `(', ', ': ')` if *indent* is `None` and `(',', ': ')` otherwise. To get the most compact JSON representation, you should specify `(',', ':')` to eliminate whitespace.

Changed in version 3.4: Use `(',', ': ')` as default if *indent* is not `None`.

If specified, *default* should be a function that gets called for objects that can't otherwise be serialized. It should return a JSON encodable version of the object or raise a *TypeError*. If not specified, *TypeError* is raised.

If *sort_keys* is true (default: `False`), then the output of dictionaries will be sorted by key.

To use a custom *JSONEncoder* subclass (e.g. one that overrides the `default()` method to serialize additional types), specify it with the *cls* kwarg; otherwise *JSONEncoder* is used.

Changed in version 3.6: All optional parameters are now *keyword-only*.

`json.dumps`(*obj*, ***, *skipkeys=False*, *ensure_ascii=True*, *check_circular=True*, *allow_nan=True*, *cls=None*, *indent=None*, *separators=None*, *default=None*, *sort_keys=False*, ***kw*)

Serialize *obj* to a JSON formatted *str* using this *conversion table*. The arguments have the same meaning as in *dump()*.

Note: Unlike *pickle* and *marshal*, JSON is not a framed protocol, so trying to serialize multiple objects with repeated calls to *dump()* using the same *fp* will result in an invalid JSON file.

Note: Keys in key/value pairs of JSON are always of the type *str*. When a dictionary is converted into JSON, all the keys of the dictionary are coerced to strings. As a result of this, if a dictionary is converted into JSON and then back into a dictionary, the dictionary may not equal the original one. That is, `loads(dumps(x)) != x` if x has non-string keys.

`json.load`(*fp*, ***, *cls=None*, *object_hook=None*, *parse_float=None*, *parse_int=None*, *parse_constant=None*, *object_pairs_hook=None*, ***kw*)

Deserialize *fp* (a `.read()`-supporting *text file* or *binary file* containing a JSON document) to a Python object using this *conversion table*.

object_hook is an optional function that will be called with the result of any object literal decoded (a *dict*). The return value of *object_hook* will be used instead of the *dict*. This feature can be used to implement custom decoders (e.g. JSON-RPC class hinting).

object_pairs_hook is an optional function that will be called with the result of any object literal decoded with an ordered list of pairs. The return value of *object_pairs_hook* will be used instead of the *dict*. This feature can be used to implement custom decoders. If *object_hook* is also defined, the *object_pairs_hook* takes priority.

Changed in version 3.1: Added support for *object_pairs_hook*.

parse_float, if specified, will be called with the string of every JSON float to be decoded. By default, this is equivalent to `float(num_str)`. This can be used to use another datatype or parser for JSON

floats (e.g. *decimal.Decimal*).

parse_int, if specified, will be called with the string of every JSON int to be decoded. By default, this is equivalent to `int(num_str)`. This can be used to use another datatype or parser for JSON integers (e.g. *float*).

parse_constant, if specified, will be called with one of the following strings: `'-Infinity'`, `'Infinity'`, `'NaN'`. This can be used to raise an exception if invalid JSON numbers are encountered.

Changed in version 3.1: *parse_constant* doesn't get called on 'null', 'true', 'false' anymore.

To use a custom *JSONDecoder* subclass, specify it with the `cls` kwarg; otherwise *JSONDecoder* is used. Additional keyword arguments will be passed to the constructor of the class.

If the data being deserialized is not a valid JSON document, a *JSONDecodeError* will be raised.

Changed in version 3.6: All optional parameters are now *keyword-only*.

Changed in version 3.6: *fp* can now be a *binary file*. The input encoding should be UTF-8, UTF-16 or UTF-32.

`json.loads`(*s*, ***, *encoding=None*, *cls=None*, *object_hook=None*, *parse_float=None*, *parse_int=None*, *parse_constant=None*, *object_pairs_hook=None*, ***kw*)

Deserialize *s* (a *str*, *bytes* or *bytearray* instance containing a JSON document) to a Python object using this *conversion table*.

The other arguments have the same meaning as in *load()*, except *encoding* which is ignored and deprecated.

If the data being deserialized is not a valid JSON document, a *JSONDecodeError* will be raised.

Changed in version 3.6: *s* can now be of type *bytes* or *bytearray*. The input encoding should be UTF-8, UTF-16 or UTF-32.

20.2.2 Encoders and Decoders

`class json.JSONDecoder`(***, *object_hook=None*, *parse_float=None*, *parse_int=None*, *parse_constant=None*, *strict=True*, *object_pairs_hook=None*)

Simple JSON decoder.

Performs the following translations in decoding by default:

JSON	Python
object	dict
array	list
string	str
number (int)	int
number (real)	float
true	True
false	False
null	None

It also understands `NaN`, `Infinity`, and `-Infinity` as their corresponding `float` values, which is outside the JSON spec.

object_hook, if specified, will be called with the result of every JSON object decoded and its return value will be used in place of the given *dict*. This can be used to provide custom deserializations (e.g. to support JSON-RPC class hinting).

object_pairs_hook, if specified will be called with the result of every JSON object decoded with an ordered list of pairs. The return value of *object_pairs_hook* will be used instead of the *dict*. This

feature can be used to implement custom decoders. If *object_hook* is also defined, the *object_pairs_hook* takes priority.

Changed in version 3.1: Added support for *object_pairs_hook*.

parse_float, if specified, will be called with the string of every JSON float to be decoded. By default, this is equivalent to `float(num_str)`. This can be used to use another datatype or parser for JSON floats (e.g. *decimal.Decimal*).

parse_int, if specified, will be called with the string of every JSON int to be decoded. By default, this is equivalent to `int(num_str)`. This can be used to use another datatype or parser for JSON integers (e.g. *float*).

parse_constant, if specified, will be called with one of the following strings: `'-Infinity'`, `'Infinity'`, `'NaN'`. This can be used to raise an exception if invalid JSON numbers are encountered.

If *strict* is false (`True` is the default), then control characters will be allowed inside strings. Control characters in this context are those with character codes in the 0–31 range, including `'\t'` (tab), `'\n'`, `'\r'` and `'\0'`.

If the data being deserialized is not a valid JSON document, a *JSONDecodeError* will be raised.

Changed in version 3.6: All parameters are now *keyword-only*.

`decode(`*s*`)`
Return the Python representation of *s* (a *str* instance containing a JSON document).

JSONDecodeError will be raised if the given JSON document is not valid.

`raw_decode(`*s*`)`
Decode a JSON document from *s* (a *str* beginning with a JSON document) and return a 2-tuple of the Python representation and the index in *s* where the document ended.

This can be used to decode a JSON document from a string that may have extraneous data at the end.

`class json.JSONEncoder(`**, skipkeys=False, ensure_ascii=True, check_circular=True, allow_nan=True, sort_keys=False, indent=None, separators=None, default=None*`)`
Extensible JSON encoder for Python data structures.

Supports the following objects and types by default:

Python	JSON
dict	object
list, tuple	array
str	string
int, float, int- & float-derived Enums	number
True	true
False	false
None	null

Changed in version 3.4: Added support for int- and float-derived Enum classes.

To extend this to recognize other objects, subclass and implement a *default()* method with another method that returns a serializable object for `o` if possible, otherwise it should call the superclass implementation (to raise *TypeError*).

If *skipkeys* is false (the default), then it is a *TypeError* to attempt encoding of keys that are not *str*, *int*, *float* or `None`. If *skipkeys* is true, such items are simply skipped.

If *ensure_ascii* is true (the default), the output is guaranteed to have all incoming non-ASCII characters escaped. If *ensure_ascii* is false, these characters will be output as-is.

If *check_circular* is true (the default), then lists, dicts, and custom encoded objects will be checked for circular references during encoding to prevent an infinite recursion (which would cause an *OverflowError*). Otherwise, no such check takes place.

If *allow_nan* is true (the default), then `NaN`, `Infinity`, and `-Infinity` will be encoded as such. This behavior is not JSON specification compliant, but is consistent with most JavaScript based encoders and decoders. Otherwise, it will be a *ValueError* to encode such floats.

If *sort_keys* is true (default: `False`), then the output of dictionaries will be sorted by key; this is useful for regression tests to ensure that JSON serializations can be compared on a day-to-day basis.

If *indent* is a non-negative integer or string, then JSON array elements and object members will be pretty-printed with that indent level. An indent level of 0, negative, or `""` will only insert newlines. `None` (the default) selects the most compact representation. Using a positive integer indent indents that many spaces per level. If *indent* is a string (such as `"\t"`), that string is used to indent each level.

Changed in version 3.2: Allow strings for *indent* in addition to integers.

If specified, *separators* should be an `(item_separator, key_separator)` tuple. The default is `(', ', ': ')` if *indent* is `None` and `(',', ': ')` otherwise. To get the most compact JSON representation, you should specify `(',', ':')` to eliminate whitespace.

Changed in version 3.4: Use `(',', ': ')` as default if *indent* is not `None`.

If specified, *default* should be a function that gets called for objects that can't otherwise be serialized. It should return a JSON encodable version of the object or raise a *TypeError*. If not specified, *TypeError* is raised.

Changed in version 3.6: All parameters are now *keyword-only*.

default(*o*)

Implement this method in a subclass such that it returns a serializable object for *o*, or calls the base implementation (to raise a *TypeError*).

For example, to support arbitrary iterators, you could implement default like this:

```
def default(self, o):
   try:
       iterable = iter(o)
   except TypeError:
       pass
   else:
       return list(iterable)
   # Let the base class default method raise the TypeError
   return json.JSONEncoder.default(self, o)
```

encode(*o*)

Return a JSON string representation of a Python data structure, *o*. For example:

```
>>> json.JSONEncoder().encode({"foo": ["bar", "baz"]})
'{"foo": ["bar", "baz"]}'
```

iterencode(*o*)

Encode the given object, *o*, and yield each string representation as available. For example:

```
for chunk in json.JSONEncoder().iterencode(bigobject):
    mysocket.write(chunk)
```

20.2.3 Exceptions

exception json.**JSONDecodeError**(*msg*, *doc*, *pos*)
Subclass of *ValueError* with the following additional attributes:

msg
The unformatted error message.

doc
The JSON document being parsed.

pos
The start index of *doc* where parsing failed.

lineno
The line corresponding to *pos*.

colno
The column corresponding to *pos*.

New in version 3.5.

20.2.4 Standard Compliance and Interoperability

The JSON format is specified by **RFC 7159** and by ECMA-404. This section details this module's level of compliance with the RFC. For simplicity, *JSONEncoder* and *JSONDecoder* subclasses, and parameters other than those explicitly mentioned, are not considered.

This module does not comply with the RFC in a strict fashion, implementing some extensions that are valid JavaScript but not valid JSON. In particular:

- Infinite and NaN number values are accepted and output;
- Repeated names within an object are accepted, and only the value of the last name-value pair is used.

Since the RFC permits RFC-compliant parsers to accept input texts that are not RFC-compliant, this module's deserializer is technically RFC-compliant under default settings.

Character Encodings

The RFC requires that JSON be represented using either UTF-8, UTF-16, or UTF-32, with UTF-8 being the recommended default for maximum interoperability.

As permitted, though not required, by the RFC, this module's serializer sets *ensure_ascii=True* by default, thus escaping the output so that the resulting strings only contain ASCII characters.

Other than the *ensure_ascii* parameter, this module is defined strictly in terms of conversion between Python objects and *Unicode strings*, and thus does not otherwise directly address the issue of character encodings.

The RFC prohibits adding a byte order mark (BOM) to the start of a JSON text, and this module's serializer does not add a BOM to its output. The RFC permits, but does not require, JSON deserializers to ignore an initial BOM in their input. This module's deserializer raises a *ValueError* when an initial BOM is present.

The RFC does not explicitly forbid JSON strings which contain byte sequences that don't correspond to valid Unicode characters (e.g. unpaired UTF-16 surrogates), but it does note that they may cause interoperability problems. By default, this module accepts and outputs (when present in the original *str*) code points for such sequences.

Infinite and NaN Number Values

The RFC does not permit the representation of infinite or NaN number values. Despite that, by default, this module accepts and outputs `Infinity`, `-Infinity`, and `NaN` as if they were valid JSON number literal values:

```
>>> # Neither of these calls raises an exception, but the results are not valid JSON
>>> json.dumps(float('-inf'))
'-Infinity'
>>> json.dumps(float('nan'))
'NaN'
>>> # Same when deserializing
>>> json.loads('-Infinity')
-inf
>>> json.loads('NaN')
nan
```

In the serializer, the *allow_nan* parameter can be used to alter this behavior. In the deserializer, the *parse_constant* parameter can be used to alter this behavior.

Repeated Names Within an Object

The RFC specifies that the names within a JSON object should be unique, but does not mandate how repeated names in JSON objects should be handled. By default, this module does not raise an exception; instead, it ignores all but the last name-value pair for a given name:

```
>>> weird_json = '{"x": 1, "x": 2, "x": 3}'
>>> json.loads(weird_json)
{'x': 3}
```

The *object_pairs_hook* parameter can be used to alter this behavior.

Top-level Non-Object, Non-Array Values

The old version of JSON specified by the obsolete **RFC 4627** required that the top-level value of a JSON text must be either a JSON object or array (Python *dict* or *list*), and could not be a JSON null, boolean, number, or string value. **RFC 7159** removed that restriction, and this module does not and has never implemented that restriction in either its serializer or its deserializer.

Regardless, for maximum interoperability, you may wish to voluntarily adhere to the restriction yourself.

Implementation Limitations

Some JSON deserializer implementations may set limits on:

- the size of accepted JSON texts
- the maximum level of nesting of JSON objects and arrays
- the range and precision of JSON numbers
- the content and maximum length of JSON strings

This module does not impose any such limits beyond those of the relevant Python datatypes themselves or the Python interpreter itself.

When serializing to JSON, beware any such limitations in applications that may consume your JSON. In particular, it is common for JSON numbers to be deserialized into IEEE 754 double precision numbers and

thus subject to that representation's range and precision limitations. This is especially relevant when serializing Python *int* values of extremely large magnitude, or when serializing instances of "exotic" numerical types such as *decimal.Decimal*.

20.2.5 Command Line Interface

Source code: Lib/json/tool.py

The *json.tool* module provides a simple command line interface to validate and pretty-print JSON objects.

If the optional `infile` and `outfile` arguments are not specified, *sys.stdin* and *sys.stdout* will be used respectively:

```
$ echo '{"json": "obj"}' | python -m json.tool
{
    "json": "obj"
}
$ echo '{1.2:3.4}' | python -m json.tool
Expecting property name enclosed in double quotes: line 1 column 2 (char 1)
```

Changed in version 3.5: The output is now in the same order as the input. Use the *--sort-keys* option to sort the output of dictionaries alphabetically by key.

Command line options

infile
The JSON file to be validated or pretty-printed:

```
$ python -m json.tool mp_films.json
[
    {
        "title": "And Now for Something Completely Different",
        "year": 1971
    },
    {
        "title": "Monty Python and the Holy Grail",
        "year": 1975
    }
]
```

If *infile* is not specified, read from *sys.stdin*.

outfile
Write the output of the *infile* to the given *outfile*. Otherwise, write it to *sys.stdout*.

--sort-keys
Sort the output of dictionaries alphabetically by key.

New in version 3.5.

-h, --help
Show the help message.

20.3 mailcap — Mailcap file handling

Source code: Lib/mailcap.py

Mailcap files are used to configure how MIME-aware applications such as mail readers and Web browsers react to files with different MIME types. (The name "mailcap" is derived from the phrase "mail capability".) For example, a mailcap file might contain a line like `video/mpeg; xmpeg %s`. Then, if the user encounters an email message or Web document with the MIME type *video/mpeg*, `%s` will be replaced by a filename (usually one belonging to a temporary file) and the **xmpeg** program can be automatically started to view the file.

The mailcap format is documented in **RFC 1524**, "A User Agent Configuration Mechanism For Multimedia Mail Format Information," but is not an Internet standard. However, mailcap files are supported on most Unix systems.

`mailcap.findmatch`(*caps*, *MIMEtype*, *key='view'*, *filename='/dev/null'*, *plist=[]*)

Return a 2-tuple; the first element is a string containing the command line to be executed (which can be passed to *os.system()*), and the second element is the mailcap entry for a given MIME type. If no matching MIME type can be found, `(None, None)` is returned.

key is the name of the field desired, which represents the type of activity to be performed; the default value is 'view', since in the most common case you simply want to view the body of the MIME-typed data. Other possible values might be 'compose' and 'edit', if you wanted to create a new body of the given MIME type or alter the existing body data. See **RFC 1524** for a complete list of these fields.

filename is the filename to be substituted for `%s` in the command line; the default value is `'/dev/null'` which is almost certainly not what you want, so usually you'll override it by specifying a filename.

plist can be a list containing named parameters; the default value is simply an empty list. Each entry in the list must be a string containing the parameter name, an equals sign (`'='`), and the parameter's value. Mailcap entries can contain named parameters like `%{foo}`, which will be replaced by the value of the parameter named 'foo'. For example, if the command line `showpartial %{id} %{number} %{total}` was in a mailcap file, and *plist* was set to `['id=1', 'number=2', 'total=3']`, the resulting command line would be `'showpartial 1 2 3'`.

In a mailcap file, the "test" field can optionally be specified to test some external condition (such as the machine architecture, or the window system in use) to determine whether or not the mailcap line applies. *findmatch()* will automatically check such conditions and skip the entry if the check fails.

`mailcap.getcaps`()

Returns a dictionary mapping MIME types to a list of mailcap file entries. This dictionary must be passed to the *findmatch()* function. An entry is stored as a list of dictionaries, but it shouldn't be necessary to know the details of this representation.

The information is derived from all of the mailcap files found on the system. Settings in the user's mailcap file `$HOME/.mailcap` will override settings in the system mailcap files `/etc/mailcap`, `/usr/etc/mailcap`, and `/usr/local/etc/mailcap`.

An example usage:

```
>>> import mailcap
>>> d = mailcap.getcaps()
>>> mailcap.findmatch(d, 'video/mpeg', filename='tmp1223')
('xmpeg tmp1223', {'view': 'xmpeg %s'})
```

20.4 mailbox — Manipulate mailboxes in various formats

Source code: Lib/mailbox.py

This module defines two classes, *Mailbox* and *Message*, for accessing and manipulating on-disk mailboxes and the messages they contain. *Mailbox* offers a dictionary-like mapping from keys to messages. *Message* extends the *email.message* module's *Message* class with format-specific state and behavior. Supported mailbox formats are Maildir, mbox, MH, Babyl, and MMDF.

See also:

Module *email* Represent and manipulate messages.

20.4.1 Mailbox objects

class mailbox.Mailbox

A mailbox, which may be inspected and modified.

The *Mailbox* class defines an interface and is not intended to be instantiated. Instead, format-specific subclasses should inherit from *Mailbox* and your code should instantiate a particular subclass.

The *Mailbox* interface is dictionary-like, with small keys corresponding to messages. Keys are issued by the *Mailbox* instance with which they will be used and are only meaningful to that *Mailbox* instance. A key continues to identify a message even if the corresponding message is modified, such as by replacing it with another message.

Messages may be added to a *Mailbox* instance using the set-like method *add()* and removed using a `del` statement or the set-like methods *remove()* and *discard()*.

Mailbox interface semantics differ from dictionary semantics in some noteworthy ways. Each time a message is requested, a new representation (typically a *Message* instance) is generated based upon the current state of the mailbox. Similarly, when a message is added to a *Mailbox* instance, the provided message representation's contents are copied. In neither case is a reference to the message representation kept by the *Mailbox* instance.

The default *Mailbox* iterator iterates over message representations, not keys as the default dictionary iterator does. Moreover, modification of a mailbox during iteration is safe and well-defined. Messages added to the mailbox after an iterator is created will not be seen by the iterator. Messages removed from the mailbox before the iterator yields them will be silently skipped, though using a key from an iterator may result in a *KeyError* exception if the corresponding message is subsequently removed.

> **Warning:** Be very cautious when modifying mailboxes that might be simultaneously changed by some other process. The safest mailbox format to use for such tasks is Maildir; try to avoid using single-file formats such as mbox for concurrent writing. If you're modifying a mailbox, you *must* lock it by calling the *lock()* and *unlock()* methods *before* reading any messages in the file or making any changes by adding or deleting a message. Failing to lock the mailbox runs the risk of losing messages or corrupting the entire mailbox.

Mailbox instances have the following methods:

add(*message*)

Add *message* to the mailbox and return the key that has been assigned to it.

Parameter *message* may be a *Message* instance, an *email.message.Message* instance, a string, a byte string, or a file-like object (which should be open in binary mode). If *message* is an instance of the appropriate format-specific *Message* subclass (e.g., if it's an *mboxMessage* instance and this

is an *mbox* instance), its format-specific information is used. Otherwise, reasonable defaults for format-specific information are used.

Changed in version 3.2: Support for binary input was added.

remove(*key*)
__delitem__(*key*)
discard(*key*)
Delete the message corresponding to *key* from the mailbox.

If no such message exists, a *KeyError* exception is raised if the method was called as *remove()* or *__delitem__()* but no exception is raised if the method was called as *discard()*. The behavior of *discard()* may be preferred if the underlying mailbox format supports concurrent modification by other processes.

__setitem__(*key*, *message*)
Replace the message corresponding to *key* with *message*. Raise a *KeyError* exception if no message already corresponds to *key*.

As with *add()*, parameter *message* may be a *Message* instance, an *email.message.Message* instance, a string, a byte string, or a file-like object (which should be open in binary mode). If *message* is an instance of the appropriate format-specific *Message* subclass (e.g., if it's an *mboxMessage* instance and this is an *mbox* instance), its format-specific information is used. Otherwise, the format-specific information of the message that currently corresponds to *key* is left unchanged.

iterkeys()
keys()
Return an iterator over all keys if called as *iterkeys()* or return a list of keys if called as *keys()*.

itervalues()
__iter__()
values()
Return an iterator over representations of all messages if called as *itervalues()* or *__iter__()* or return a list of such representations if called as *values()*. The messages are represented as instances of the appropriate format-specific *Message* subclass unless a custom message factory was specified when the *Mailbox* instance was initialized.

Note: The behavior of *__iter__()* is unlike that of dictionaries, which iterate over keys.

---

iteritems()
items()
Return an iterator over (*key*, *message*) pairs, where *key* is a key and *message* is a message representation, if called as *iteritems()* or return a list of such pairs if called as *items()*. The messages are represented as instances of the appropriate format-specific *Message* subclass unless a custom message factory was specified when the *Mailbox* instance was initialized.

get(*key*, *default=None*)
__getitem__(*key*)
Return a representation of the message corresponding to *key*. If no such message exists, *default* is returned if the method was called as *get()* and a *KeyError* exception is raised if the method was called as *__getitem__()*. The message is represented as an instance of the appropriate format-specific *Message* subclass unless a custom message factory was specified when the *Mailbox* instance was initialized.

get_message(*key*)
Return a representation of the message corresponding to *key* as an instance of the appropriate format-specific *Message* subclass, or raise a *KeyError* exception if no such message exists.

get_bytes(*key*)
Return a byte representation of the message corresponding to *key*, or raise a *KeyError* exception if no such message exists.

New in version 3.2.

get_string(*key*)
Return a string representation of the message corresponding to *key*, or raise a *KeyError* exception if no such message exists. The message is processed through *email.message.Message* to convert it to a 7bit clean representation.

get_file(*key*)
Return a file-like representation of the message corresponding to *key*, or raise a *KeyError* exception if no such message exists. The file-like object behaves as if open in binary mode. This file should be closed once it is no longer needed.

Changed in version 3.2: The file object really is a binary file; previously it was incorrectly returned in text mode. Also, the file-like object now supports the context management protocol: you can use a **with** statement to automatically close it.

Note: Unlike other representations of messages, file-like representations are not necessarily independent of the *Mailbox* instance that created them or of the underlying mailbox. More specific documentation is provided by each subclass.

__contains__(*key*)
Return **True** if *key* corresponds to a message, **False** otherwise.

__len__()
Return a count of messages in the mailbox.

clear()
Delete all messages from the mailbox.

pop(*key*, *default=None*)
Return a representation of the message corresponding to *key* and delete the message. If no such message exists, return *default*. The message is represented as an instance of the appropriate format-specific *Message* subclass unless a custom message factory was specified when the *Mailbox* instance was initialized.

popitem()
Return an arbitrary (*key*, *message*) pair, where *key* is a key and *message* is a message representation, and delete the corresponding message. If the mailbox is empty, raise a *KeyError* exception. The message is represented as an instance of the appropriate format-specific *Message* subclass unless a custom message factory was specified when the *Mailbox* instance was initialized.

update(*arg*)
Parameter *arg* should be a *key*-to-*message* mapping or an iterable of (*key*, *message*) pairs. Updates the mailbox so that, for each given *key* and *message*, the message corresponding to *key* is set to *message* as if by using *__setitem__()*. As with *__setitem__()*, each *key* must already correspond to a message in the mailbox or else a *KeyError* exception will be raised, so in general it is incorrect for *arg* to be a *Mailbox* instance.

Note: Unlike with dictionaries, keyword arguments are not supported.

---

flush()
Write any pending changes to the filesystem. For some *Mailbox* subclasses, changes are always

written immediately and *flush()* does nothing, but you should still make a habit of calling this method.

lock()
Acquire an exclusive advisory lock on the mailbox so that other processes know not to modify it. An *ExternalClashError* is raised if the lock is not available. The particular locking mechanisms used depend upon the mailbox format. You should *always* lock the mailbox before making any modifications to its contents.

unlock()
Release the lock on the mailbox, if any.

close()
Flush the mailbox, unlock it if necessary, and close any open files. For some *Mailbox* subclasses, this method does nothing.

Maildir

class mailbox.Maildir(*dirname*, *factory=None*, *create=True*)
A subclass of *Mailbox* for mailboxes in Maildir format. Parameter *factory* is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If *factory* is `None`, *MaildirMessage* is used as the default message representation. If *create* is `True`, the mailbox is created if it does not exist.

It is for historical reasons that *dirname* is named as such rather than *path*.

Maildir is a directory-based mailbox format invented for the qmail mail transfer agent and now widely supported by other programs. Messages in a Maildir mailbox are stored in separate files within a common directory structure. This design allows Maildir mailboxes to be accessed and modified by multiple unrelated programs without data corruption, so file locking is unnecessary.

Maildir mailboxes contain three subdirectories, namely: `tmp`, `new`, and `cur`. Messages are created momentarily in the `tmp` subdirectory and then moved to the `new` subdirectory to finalize delivery. A mail user agent may subsequently move the message to the `cur` subdirectory and store information about the state of the message in a special "info" section appended to its file name.

Folders of the style introduced by the Courier mail transfer agent are also supported. Any subdirectory of the main mailbox is considered a folder if `'.'` is the first character in its name. Folder names are represented by *Maildir* without the leading `'.'`. Each folder is itself a Maildir mailbox but should not contain other folders. Instead, a logical nesting is indicated using `'.'` to delimit levels, e.g., "Archived.2005.07".

Note: The Maildir specification requires the use of a colon (`':'`) in certain message file names. However, some operating systems do not permit this character in file names, If you wish to use a Maildir-like format on such an operating system, you should specify another character to use instead. The exclamation point (`'!'`) is a popular choice. For example:

```
import mailbox
mailbox.Maildir.colon = '!'
```

The `colon` attribute may also be set on a per-instance basis.

Maildir instances have all of the methods of *Mailbox* in addition to the following:

list_folders()
Return a list of the names of all folders.

`get_folder`(*folder*)
Return a *Maildir* instance representing the folder whose name is *folder*. A *NoSuchMailboxError* exception is raised if the folder does not exist.

`add_folder`(*folder*)
Create a folder whose name is *folder* and return a *Maildir* instance representing it.

`remove_folder`(*folder*)
Delete the folder whose name is *folder*. If the folder contains any messages, a *NotEmptyError* exception will be raised and the folder will not be deleted.

`clean`()
Delete temporary files from the mailbox that have not been accessed in the last 36 hours. The Maildir specification says that mail-reading programs should do this occasionally.

Some *Mailbox* methods implemented by *Maildir* deserve special remarks:

`add`(*message*)
`__setitem__`(*key*, *message*)
`update`(*arg*)

> **Warning:** These methods generate unique file names based upon the current process ID. When using multiple threads, undetected name clashes may occur and cause corruption of the mailbox unless threads are coordinated to avoid using these methods to manipulate the same mailbox simultaneously.

`flush`()
All changes to Maildir mailboxes are immediately applied, so this method does nothing.

`lock`()
`unlock`()
Maildir mailboxes do not support (or require) locking, so these methods do nothing.

`close`()
Maildir instances do not keep any open files and the underlying mailboxes do not support locking, so this method does nothing.

`get_file`(*key*)
Depending upon the host platform, it may not be possible to modify or remove the underlying message while the returned file remains open.

See also:

maildir man page from qmail The original specification of the format.

Using maildir format Notes on Maildir by its inventor. Includes an updated name-creation scheme and details on "info" semantics.

maildir man page from Courier Another specification of the format. Describes a common extension for supporting folders.

mbox

`class mailbox.mbox`(*path*, *factory=None*, *create=True*)
A subclass of *Mailbox* for mailboxes in mbox format. Parameter *factory* is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If *factory* is `None`, *mboxMessage* is used as the default message representation. If *create* is `True`, the mailbox is created if it does not exist.

The mbox format is the classic format for storing mail on Unix systems. All messages in an mbox mailbox are stored in a single file with the beginning of each message indicated by a line whose first five characters are "From ".

Several variations of the mbox format exist to address perceived shortcomings in the original. In the interest of compatibility, *mbox* implements the original format, which is sometimes referred to as *mboxo*. This means that the *Content-Length* header, if present, is ignored and that any occurrences of "From " at the beginning of a line in a message body are transformed to ">From " when storing the message, although occurrences of ">From " are not transformed to "From " when reading the message.

Some *Mailbox* methods implemented by *mbox* deserve special remarks:

`get_file(`*key*`)`
: Using the file after calling `flush()` or `close()` on the *mbox* instance may yield unpredictable results or raise an exception.

`lock()`
`unlock()`
: Three locking mechanisms are used—dot locking and, if available, the `flock()` and `lockf()` system calls.

See also:

mbox man page from qmail A specification of the format and its variations.

mbox man page from tin Another specification of the format, with details on locking.

Configuring Netscape Mail on Unix: Why The Content-Length Format is Bad An argument for using the original mbox format rather than a variation.

"mbox" is a family of several mutually incompatible mailbox formats A history of mbox variations.

MH

`class mailbox.MH(`*path*, *factory=None*, *create=True*`)`
: A subclass of *Mailbox* for mailboxes in MH format. Parameter *factory* is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If *factory* is `None`, *MHMessage* is used as the default message representation. If *create* is `True`, the mailbox is created if it does not exist.

MH is a directory-based mailbox format invented for the MH Message Handling System, a mail user agent. Each message in an MH mailbox resides in its own file. An MH mailbox may contain other MH mailboxes (called *folders*) in addition to messages. Folders may be nested indefinitely. MH mailboxes also support *sequences*, which are named lists used to logically group messages without moving them to sub-folders. Sequences are defined in a file called `.mh_sequences` in each folder.

The *MH* class manipulates MH mailboxes, but it does not attempt to emulate all of **mh**'s behaviors. In particular, it does not modify and is not affected by the `context` or `.mh_profile` files that are used by **mh** to store its state and configuration.

MH instances have all of the methods of *Mailbox* in addition to the following:

`list_folders()`
: Return a list of the names of all folders.

`get_folder(`*folder*`)`
: Return an *MH* instance representing the folder whose name is *folder*. A *NoSuchMailboxError* exception is raised if the folder does not exist.

`add_folder(`*folder*`)`
: Create a folder whose name is *folder* and return an *MH* instance representing it.

remove_folder(*folder*)
Delete the folder whose name is *folder*. If the folder contains any messages, a *NotEmptyError* exception will be raised and the folder will not be deleted.

get_sequences()
Return a dictionary of sequence names mapped to key lists. If there are no sequences, the empty dictionary is returned.

set_sequences(*sequences*)
Re-define the sequences that exist in the mailbox based upon *sequences*, a dictionary of names mapped to key lists, like returned by *get_sequences()*.

pack()
Rename messages in the mailbox as necessary to eliminate gaps in numbering. Entries in the sequences list are updated correspondingly.

Note: Already-issued keys are invalidated by this operation and should not be subsequently used.

Some *Mailbox* methods implemented by *MH* deserve special remarks:

remove(*key*)
__delitem__(*key*)
discard(*key*)
These methods immediately delete the message. The MH convention of marking a message for deletion by prepending a comma to its name is not used.

lock()
unlock()
Three locking mechanisms are used—dot locking and, if available, the `flock()` and `lockf()` system calls. For MH mailboxes, locking the mailbox means locking the `.mh_sequences` file and, only for the duration of any operations that affect them, locking individual message files.

get_file(*key*)
Depending upon the host platform, it may not be possible to remove the underlying message while the returned file remains open.

flush()
All changes to MH mailboxes are immediately applied, so this method does nothing.

close()
MH instances do not keep any open files, so this method is equivalent to *unlock()*.

See also:

nmh - Message Handling System Home page of **nmh**, an updated version of the original **mh**.

MH & nmh: Email for Users & Programmers A GPL-licensed book on **mh** and **nmh**, with some information on the mailbox format.

Babyl

class mailbox.Babyl(*path*, *factory=None*, *create=True*)
A subclass of *Mailbox* for mailboxes in Babyl format. Parameter *factory* is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If *factory* is `None`, *BabylMessage* is used as the default message representation. If *create* is `True`, the mailbox is created if it does not exist.

Babyl is a single-file mailbox format used by the Rmail mail user agent included with Emacs. The beginning of a message is indicated by a line containing the two characters Control-Underscore (`'\037'`)

and Control-L (`'\014'`). The end of a message is indicated by the start of the next message or, in the case of the last message, a line containing a Control-Underscore (`'\037'`) character.

Messages in a Babyl mailbox have two sets of headers, original headers and so-called visible headers. Visible headers are typically a subset of the original headers that have been reformatted or abridged to be more attractive. Each message in a Babyl mailbox also has an accompanying list of *labels*, or short strings that record extra information about the message, and a list of all user-defined labels found in the mailbox is kept in the Babyl options section.

Babyl instances have all of the methods of *Mailbox* in addition to the following:

get_labels()
Return a list of the names of all user-defined labels used in the mailbox.

Note: The actual messages are inspected to determine which labels exist in the mailbox rather than consulting the list of labels in the Babyl options section, but the Babyl section is updated whenever the mailbox is modified.

Some *Mailbox* methods implemented by *Babyl* deserve special remarks:

get_file(*key*)
In Babyl mailboxes, the headers of a message are not stored contiguously with the body of the message. To generate a file-like representation, the headers and body are copied together into an *io.BytesIO* instance, which has an API identical to that of a file. As a result, the file-like object is truly independent of the underlying mailbox but does not save memory compared to a string representation.

lock()
unlock()
Three locking mechanisms are used—dot locking and, if available, the `flock()` and `lockf()` system calls.

See also:

Format of Version 5 Babyl Files A specification of the Babyl format.

Reading Mail with Rmail The Rmail manual, with some information on Babyl semantics.

MMDF

class mailbox.MMDF(*path*, *factory=None*, *create=True*)
A subclass of *Mailbox* for mailboxes in MMDF format. Parameter *factory* is a callable object that accepts a file-like message representation (which behaves as if opened in binary mode) and returns a custom representation. If *factory* is `None`, *MMDFMessage* is used as the default message representation. If *create* is `True`, the mailbox is created if it does not exist.

MMDF is a single-file mailbox format invented for the Multichannel Memorandum Distribution Facility, a mail transfer agent. Each message is in the same form as an mbox message but is bracketed before and after by lines containing four Control-A (`'\001'`) characters. As with the mbox format, the beginning of each message is indicated by a line whose first five characters are "From ", but additional occurrences of "From " are not transformed to ">From " when storing messages because the extra message separator lines prevent mistaking such occurrences for the starts of subsequent messages.

Some *Mailbox* methods implemented by *MMDF* deserve special remarks:

get_file(*key*)
Using the file after calling `flush()` or `close()` on the *MMDF* instance may yield unpredictable results or raise an exception.

lock()

`unlock()`
Three locking mechanisms are used—dot locking and, if available, the `flock()` and `lockf()` system calls.

See also:

mmdf man page from tin A specification of MMDF format from the documentation of tin, a newsreader.

MMDF A Wikipedia article describing the Multichannel Memorandum Distribution Facility.

20.4.2 `Message` objects

`class mailbox.Message(`*message=None*`)`
A subclass of the *email.message* module's *Message*. Subclasses of *mailbox.Message* add mailbox-format-specific state and behavior.

If *message* is omitted, the new instance is created in a default, empty state. If *message* is an *email.message.Message* instance, its contents are copied; furthermore, any format-specific information is converted insofar as possible if *message* is a *Message* instance. If *message* is a string, a byte string, or a file, it should contain an **RFC 2822**-compliant message, which is read and parsed. Files should be open in binary mode, but text mode files are accepted for backward compatibility.

The format-specific state and behaviors offered by subclasses vary, but in general it is only the properties that are not specific to a particular mailbox that are supported (although presumably the properties are specific to a particular mailbox format). For example, file offsets for single-file mailbox formats and file names for directory-based mailbox formats are not retained, because they are only applicable to the original mailbox. But state such as whether a message has been read by the user or marked as important is retained, because it applies to the message itself.

There is no requirement that *Message* instances be used to represent messages retrieved using *Mailbox* instances. In some situations, the time and memory required to generate *Message* representations might not be acceptable. For such situations, *Mailbox* instances also offer string and file-like representations, and a custom message factory may be specified when a *Mailbox* instance is initialized.

`MaildirMessage`

`class mailbox.MaildirMessage(`*message=None*`)`
A message with Maildir-specific behaviors. Parameter *message* has the same meaning as with the *Message* constructor.

Typically, a mail user agent application moves all of the messages in the `new` subdirectory to the `cur` subdirectory after the first time the user opens and closes the mailbox, recording that the messages are old whether or not they've actually been read. Each message in `cur` has an "info" section added to its file name to store information about its state. (Some mail readers may also add an "info" section to messages in `new`.) The "info" section may take one of two forms: it may contain "2," followed by a list of standardized flags (e.g., "2,FR") or it may contain "1," followed by so-called experimental information. Standard flags for Maildir messages are as follows:

Flag	Meaning	Explanation
D	Draft	Under composition
F	Flagged	Marked as important
P	Passed	Forwarded, resent, or bounced
R	Replied	Replied to
S	Seen	Read
T	Trashed	Marked for subsequent deletion

MaildirMessage instances offer the following methods:

get_subdir()
Return either "new" (if the message should be stored in the **new** subdirectory) or "cur" (if the message should be stored in the **cur** subdirectory).

Note: A message is typically moved from **new** to **cur** after its mailbox has been accessed, whether or not the message is has been read. A message **msg** has been read if **"S" in msg.get_flags()** is **True**.

---

set_subdir(*subdir*)
Set the subdirectory the message should be stored in. Parameter *subdir* must be either "new" or "cur".

get_flags()
Return a string specifying the flags that are currently set. If the message complies with the standard Maildir format, the result is the concatenation in alphabetical order of zero or one occurrence of each of **'D'**, **'F'**, **'P'**, **'R'**, **'S'**, and **'T'**. The empty string is returned if no flags are set or if "info" contains experimental semantics.

set_flags(*flags*)
Set the flags specified by *flags* and unset all others.

add_flag(*flag*)
Set the flag(s) specified by *flag* without changing other flags. To add more than one flag at a time, *flag* may be a string of more than one character. The current "info" is overwritten whether or not it contains experimental information rather than flags.

remove_flag(*flag*)
Unset the flag(s) specified by *flag* without changing other flags. To remove more than one flag at a time, *flag* maybe a string of more than one character. If "info" contains experimental information rather than flags, the current "info" is not modified.

get_date()
Return the delivery date of the message as a floating-point number representing seconds since the epoch.

set_date(*date*)
Set the delivery date of the message to *date*, a floating-point number representing seconds since the epoch.

get_info()
Return a string containing the "info" for a message. This is useful for accessing and modifying "info" that is experimental (i.e., not a list of flags).

set_info(*info*)
Set "info" to *info*, which should be a string.

When a *MaildirMessage* instance is created based upon an *mboxMessage* or *MMDFMessage* instance, the *Status* and *X-Status* headers are omitted and the following conversions take place:

Resulting state	*mboxMessage* or *MMDFMessage* state
"cur" subdirectory	O flag
F flag	F flag
R flag	A flag
S flag	R flag
T flag	D flag

When a *MaildirMessage* instance is created based upon an *MHMessage* instance, the following conversions take place:

Resulting state	*MHMessage* state
"cur" subdirectory	"unseen" sequence
"cur" subdirectory and S flag	no "unseen" sequence
F flag	"flagged" sequence
R flag	"replied" sequence

When a *MaildirMessage* instance is created based upon a *BabylMessage* instance, the following conversions take place:

Resulting state	*BabylMessage* state
"cur" subdirectory	"unseen" label
"cur" subdirectory and S flag	no "unseen" label
P flag	"forwarded" or "resent" label
R flag	"answered" label
T flag	"deleted" label

mboxMessage

class mailbox.**mboxMessage**(*message=None*)

A message with mbox-specific behaviors. Parameter *message* has the same meaning as with the *Message* constructor.

Messages in an mbox mailbox are stored together in a single file. The sender's envelope address and the time of delivery are typically stored in a line beginning with "From " that is used to indicate the start of a message, though there is considerable variation in the exact format of this data among mbox implementations. Flags that indicate the state of the message, such as whether it has been read or marked as important, are typically stored in ***Status*** and ***X-Status*** headers.

Conventional flags for mbox messages are as follows:

Flag	Meaning	Explanation
R	Read	Read
O	Old	Previously detected by MUA
D	Deleted	Marked for subsequent deletion
F	Flagged	Marked as important
A	Answered	Replied to

The "R" and "O" flags are stored in the ***Status*** header, and the "D", "F", and "A" flags are stored in the ***X-Status*** header. The flags and headers typically appear in the order mentioned.

mboxMessage instances offer the following methods:

get_from()

Return a string representing the "From " line that marks the start of the message in an mbox mailbox. The leading "From " and the trailing newline are excluded.

set_from(*from_*, *time_=None*)

Set the "From " line to *from_*, which should be specified without a leading "From " or trailing newline. For convenience, *time_* may be specified and will be formatted appropriately and appended to *from_*. If *time_* is specified, it should be a *time.struct_time* instance, a tuple suitable for passing to *time.strftime()*, or `True` (to use *time.gmtime()*).

`get_flags()`
Return a string specifying the flags that are currently set. If the message complies with the conventional format, the result is the concatenation in the following order of zero or one occurrence of each of `'R'`, `'O'`, `'D'`, `'F'`, and `'A'`.

`set_flags(`*flags*`)`
Set the flags specified by *flags* and unset all others. Parameter *flags* should be the concatenation in any order of zero or more occurrences of each of `'R'`, `'O'`, `'D'`, `'F'`, and `'A'`.

`add_flag(`*flag*`)`
Set the flag(s) specified by *flag* without changing other flags. To add more than one flag at a time, *flag* may be a string of more than one character.

`remove_flag(`*flag*`)`
Unset the flag(s) specified by *flag* without changing other flags. To remove more than one flag at a time, *flag* maybe a string of more than one character.

When an *mboxMessage* instance is created based upon a *MaildirMessage* instance, a "From " line is generated based upon the *MaildirMessage* instance's delivery date, and the following conversions take place:

Resulting state	*MaildirMessage* state
R flag	S flag
O flag	"cur" subdirectory
D flag	T flag
F flag	F flag
A flag	R flag

When an *mboxMessage* instance is created based upon an *MHMessage* instance, the following conversions take place:

Resulting state	*MHMessage* state
R flag and O flag	no "unseen" sequence
O flag	"unseen" sequence
F flag	"flagged" sequence
A flag	"replied" sequence

When an *mboxMessage* instance is created based upon a *BabylMessage* instance, the following conversions take place:

Resulting state	*BabylMessage* state
R flag and O flag	no "unseen" label
O flag	"unseen" label
D flag	"deleted" label
A flag	"answered" label

When a *Message* instance is created based upon an *MMDFMessage* instance, the "From " line is copied and all flags directly correspond:

Resulting state	*MMDFMessage* state
R flag	R flag
O flag	O flag
D flag	D flag
F flag	F flag
A flag	A flag

MHMessage

class mailbox.**MHMessage**(*message=None*)

A message with MH-specific behaviors. Parameter *message* has the same meaning as with the *Message* constructor.

MH messages do not support marks or flags in the traditional sense, but they do support sequences, which are logical groupings of arbitrary messages. Some mail reading programs (although not the standard **mh** and **nmh**) use sequences in much the same way flags are used with other formats, as follows:

Sequence	Explanation
unseen	Not read, but previously detected by MUA
replied	Replied to
flagged	Marked as important

MHMessage instances offer the following methods:

get_sequences()

Return a list of the names of sequences that include this message.

set_sequences(*sequences*)

Set the list of sequences that include this message.

add_sequence(*sequence*)

Add *sequence* to the list of sequences that include this message.

remove_sequence(*sequence*)

Remove *sequence* from the list of sequences that include this message.

When an *MHMessage* instance is created based upon a *MaildirMessage* instance, the following conversions take place:

Resulting state	*MaildirMessage* state
“unseen” sequence	no S flag
“replied” sequence	R flag
“flagged” sequence	F flag

When an *MHMessage* instance is created based upon an *mboxMessage* or *MMDFMessage* instance, the ***Status*** and ***X-Status*** headers are omitted and the following conversions take place:

Resulting state	*mboxMessage* or *MMDFMessage* state
“unseen” sequence	no R flag
“replied” sequence	A flag
“flagged” sequence	F flag

When an *MHMessage* instance is created based upon a *BabylMessage* instance, the following conversions take place:

Resulting state	*BabylMessage* state
“unseen” sequence	“unseen” label
“replied” sequence	“answered” label

BabylMessage

class mailbox.BabylMessage(*message=None*)

A message with Babyl-specific behaviors. Parameter *message* has the same meaning as with the *Message* constructor.

Certain message labels, called *attributes*, are defined by convention to have special meanings. The attributes are as follows:

Label	Explanation
unseen	Not read, but previously detected by MUA
deleted	Marked for subsequent deletion
filed	Copied to another file or mailbox
answered	Replied to
forwarded	Forwarded
edited	Modified by the user
resent	Resent

By default, Rmail displays only visible headers. The *BabylMessage* class, though, uses the original headers because they are more complete. Visible headers may be accessed explicitly if desired.

BabylMessage instances offer the following methods:

get_labels()

Return a list of labels on the message.

set_labels(*labels*)

Set the list of labels on the message to *labels*.

add_label(*label*)

Add *label* to the list of labels on the message.

remove_label(*label*)

Remove *label* from the list of labels on the message.

get_visible()

Return an *Message* instance whose headers are the message's visible headers and whose body is empty.

set_visible(*visible*)

Set the message's visible headers to be the same as the headers in *message*. Parameter *visible* should be a *Message* instance, an *email.message.Message* instance, a string, or a file-like object (which should be open in text mode).

update_visible()

When a *BabylMessage* instance's original headers are modified, the visible headers are not automatically modified to correspond. This method updates the visible headers as follows: each visible header with a corresponding original header is set to the value of the original header, each visible header without a corresponding original header is removed, and any of *Date*, *From*, *Reply-To*, *To*, *CC*, and *Subject* that are present in the original headers but not the visible headers are added to the visible headers.

When a *BabylMessage* instance is created based upon a *MaildirMessage* instance, the following conversions take place:

Resulting state	*MaildirMessage* state
“unseen” label	no S flag
“deleted” label	T flag
“answered” label	R flag
“forwarded” label	P flag

When a *BabylMessage* instance is created based upon an *mboxMessage* or *MMDFMessage* instance, the ***Status*** and ***X-Status*** headers are omitted and the following conversions take place:

Resulting state	*mboxMessage* or *MMDFMessage* state
“unseen” label	no R flag
“deleted” label	D flag
“answered” label	A flag

When a *BabylMessage* instance is created based upon an *MHMessage* instance, the following conversions take place:

Resulting state	*MHMessage* state
“unseen” label	“unseen” sequence
“answered” label	“replied” sequence

MMDFMessage

class mailbox.**MMDFMessage**(*message=None*)

A message with MMDF-specific behaviors. Parameter *message* has the same meaning as with the *Message* constructor.

As with message in an mbox mailbox, MMDF messages are stored with the sender’s address and the delivery date in an initial line beginning with “From “. Likewise, flags that indicate the state of the message are typically stored in ***Status*** and ***X-Status*** headers.

Conventional flags for MMDF messages are identical to those of mbox message and are as follows:

Flag	Meaning	Explanation
R	Read	Read
O	Old	Previously detected by MUA
D	Deleted	Marked for subsequent deletion
F	Flagged	Marked as important
A	Answered	Replied to

The “R” and “O” flags are stored in the ***Status*** header, and the “D”, “F”, and “A” flags are stored in the ***X-Status*** header. The flags and headers typically appear in the order mentioned.

MMDFMessage instances offer the following methods, which are identical to those offered by *mboxMessage*:

get_from()

Return a string representing the “From ” line that marks the start of the message in an mbox mailbox. The leading “From ” and the trailing newline are excluded.

set_from(*from_*, *time_=None*)

Set the “From ” line to *from_*, which should be specified without a leading “From ” or trailing newline. For convenience, *time_* may be specified and will be formatted appropriately and

appended to *from_*. If *time_* is specified, it should be a *time.struct_time* instance, a tuple suitable for passing to *time.strftime()*, or `True` (to use *time.gmtime()*).

get_flags()
Return a string specifying the flags that are currently set. If the message complies with the conventional format, the result is the concatenation in the following order of zero or one occurrence of each of `'R'`, `'O'`, `'D'`, `'F'`, and `'A'`.

set_flags(*flags***)**
Set the flags specified by *flags* and unset all others. Parameter *flags* should be the concatenation in any order of zero or more occurrences of each of `'R'`, `'O'`, `'D'`, `'F'`, and `'A'`.

add_flag(*flag***)**
Set the flag(s) specified by *flag* without changing other flags. To add more than one flag at a time, *flag* may be a string of more than one character.

remove_flag(*flag***)**
Unset the flag(s) specified by *flag* without changing other flags. To remove more than one flag at a time, *flag* maybe a string of more than one character.

When an *MMDFMessage* instance is created based upon a *MaildirMessage* instance, a "From " line is generated based upon the *MaildirMessage* instance's delivery date, and the following conversions take place:

Resulting state	*MaildirMessage* state
R flag	S flag
O flag	"cur" subdirectory
D flag	T flag
F flag	F flag
A flag	R flag

When an *MMDFMessage* instance is created based upon an *MHMessage* instance, the following conversions take place:

Resulting state	*MHMessage* state
R flag and O flag	no "unseen" sequence
O flag	"unseen" sequence
F flag	"flagged" sequence
A flag	"replied" sequence

When an *MMDFMessage* instance is created based upon a *BabylMessage* instance, the following conversions take place:

Resulting state	*BabylMessage* state
R flag and O flag	no "unseen" label
O flag	"unseen" label
D flag	"deleted" label
A flag	"answered" label

When an *MMDFMessage* instance is created based upon an *mboxMessage* instance, the "From " line is copied and all flags directly correspond:

Resulting state	*mboxMessage* state
R flag	R flag
O flag	O flag
D flag	D flag
F flag	F flag
A flag	A flag

20.4.3 Exceptions

The following exception classes are defined in the *mailbox* module:

exception mailbox.**Error**
The based class for all other module-specific exceptions.

exception mailbox.**NoSuchMailboxError**
Raised when a mailbox is expected but is not found, such as when instantiating a *Mailbox* subclass with a path that does not exist (and with the *create* parameter set to `False`), or when opening a folder that does not exist.

exception mailbox.**NotEmptyError**
Raised when a mailbox is not empty but is expected to be, such as when deleting a folder that contains messages.

exception mailbox.**ExternalClashError**
Raised when some mailbox-related condition beyond the control of the program causes it to be unable to proceed, such as when failing to acquire a lock that another program already holds a lock, or when a uniquely-generated file name already exists.

exception mailbox.**FormatError**
Raised when the data in a file cannot be parsed, such as when an *MH* instance attempts to read a corrupted `.mh_sequences` file.

20.4.4 Examples

A simple example of printing the subjects of all messages in a mailbox that seem interesting:

```
import mailbox
for message in mailbox.mbox('~/mbox'):
    subject = message['subject']       # Could possibly be None.
    if subject and 'python' in subject.lower():
        print(subject)
```

To copy all mail from a Babyl mailbox to an MH mailbox, converting all of the format-specific information that can be converted:

```
import mailbox
destination = mailbox.MH('~/Mail')
destination.lock()
for message in mailbox.Babyl('~/RMAIL'):
    destination.add(mailbox.MHMessage(message))
destination.flush()
destination.unlock()
```

This example sorts mail from several mailing lists into different mailboxes, being careful to avoid mail corruption due to concurrent modification by other programs, mail loss due to interruption of the program, or premature termination due to malformed messages in the mailbox:

```
import mailbox
import email.errors

list_names = ('python-list', 'python-dev', 'python-bugs')

boxes = {name: mailbox.mbox('~/email/%s' % name) for name in list_names}
inbox = mailbox.Maildir('~/Maildir', factory=None)

for key in inbox.iterkeys():
    try:
        message = inbox[key]
    except email.errors.MessageParseError:
        continue                # The message is malformed. Just leave it.

    for name in list_names:
        list_id = message['list-id']
        if list_id and name in list_id:
            # Get mailbox to use
            box = boxes[name]

            # Write copy to disk before removing original.
            # If there's a crash, you might duplicate a message, but
            # that's better than losing a message completely.
            box.lock()
            box.add(message)
            box.flush()
            box.unlock()

            # Remove original message
            inbox.lock()
            inbox.discard(key)
            inbox.flush()
            inbox.unlock()
            break               # Found destination, so stop looking.

for box in boxes.itervalues():
    box.close()
```

20.5 mimetypes — Map filenames to MIME types

Source code: Lib/mimetypes.py

The *mimetypes* module converts between a filename or URL and the MIME type associated with the filename extension. Conversions are provided from filename to MIME type and from MIME type to filename extension; encodings are not supported for the latter conversion.

The module provides one class and a number of convenience functions. The functions are the normal interface to this module, but some applications may be interested in the class as well.

The functions described below provide the primary interface for this module. If the module has not been initialized, they will call *init()* if they rely on the information *init()* sets up.

mimetypes.**guess_type**(*url*, *strict=True*)

Guess the type of a file based on its filename or URL, given by *url*. The return value is a tuple `(type,`

encoding) where *type* is None if the type can't be guessed (missing or unknown suffix) or a string of the form 'type/subtype', usable for a MIME *content-type* header.

encoding is None for no encoding or the name of the program used to encode (e.g. **compress** or **gzip**). The encoding is suitable for use as a *Content-Encoding* header, **not** as a *Content-Transfer-Encoding* header. The mappings are table driven. Encoding suffixes are case sensitive; type suffixes are first tried case sensitively, then case insensitively.

The optional *strict* argument is a flag specifying whether the list of known MIME types is limited to only the official types registered with IANA. When *strict* is True (the default), only the IANA types are supported; when *strict* is False, some additional non-standard but commonly used MIME types are also recognized.

mimetypes.**guess_all_extensions**(*type*, *strict=True*)
Guess the extensions for a file based on its MIME type, given by *type*. The return value is a list of strings giving all possible filename extensions, including the leading dot ('.'). The extensions are not guaranteed to have been associated with any particular data stream, but would be mapped to the MIME type *type* by *guess_type()*.

The optional *strict* argument has the same meaning as with the *guess_type()* function.

mimetypes.**guess_extension**(*type*, *strict=True*)
Guess the extension for a file based on its MIME type, given by *type*. The return value is a string giving a filename extension, including the leading dot ('.'). The extension is not guaranteed to have been associated with any particular data stream, but would be mapped to the MIME type *type* by *guess_type()*. If no extension can be guessed for *type*, None is returned.

The optional *strict* argument has the same meaning as with the *guess_type()* function.

Some additional functions and data items are available for controlling the behavior of the module.

mimetypes.**init**(*files=None*)
Initialize the internal data structures. If given, *files* must be a sequence of file names which should be used to augment the default type map. If omitted, the file names to use are taken from *knownfiles*; on Windows, the current registry settings are loaded. Each file named in *files* or *knownfiles* takes precedence over those named before it. Calling *init()* repeatedly is allowed.

Specifying an empty list for *files* will prevent the system defaults from being applied: only the well-known values will be present from a built-in list.

Changed in version 3.2: Previously, Windows registry settings were ignored.

mimetypes.**read_mime_types**(*filename*)
Load the type map given in the file *filename*, if it exists. The type map is returned as a dictionary mapping filename extensions, including the leading dot ('.'), to strings of the form 'type/subtype'. If the file *filename* does not exist or cannot be read, None is returned.

mimetypes.**add_type**(*type*, *ext*, *strict=True*)
Add a mapping from the MIME type *type* to the extension *ext*. When the extension is already known, the new type will replace the old one. When the type is already known the extension will be added to the list of known extensions.

When *strict* is True (the default), the mapping will be added to the official MIME types, otherwise to the non-standard ones.

mimetypes.**inited**
Flag indicating whether or not the global data structures have been initialized. This is set to True by *init()*.

mimetypes.**knownfiles**
List of type map file names commonly installed. These files are typically named mime.types and are installed in different locations by different packages.

mimetypes.suffix_map
Dictionary mapping suffixes to suffixes. This is used to allow recognition of encoded files for which the encoding and the type are indicated by the same extension. For example, the `.tgz` extension is mapped to `.tar.gz` to allow the encoding and type to be recognized separately.

mimetypes.encodings_map
Dictionary mapping filename extensions to encoding types.

mimetypes.types_map
Dictionary mapping filename extensions to MIME types.

mimetypes.common_types
Dictionary mapping filename extensions to non-standard, but commonly found MIME types.

An example usage of the module:

```
>>> import mimetypes
>>> mimetypes.init()
>>> mimetypes.knownfiles
['/etc/mime.types', '/etc/httpd/mime.types', ... ]
>>> mimetypes.suffix_map['.tgz']
'.tar.gz'
>>> mimetypes.encodings_map['.gz']
'gzip'
>>> mimetypes.types_map['.tgz']
'application/x-tar-gz'
```

20.5.1 MimeTypes Objects

The *MimeTypes* class may be useful for applications which may want more than one MIME-type database; it provides an interface similar to the one of the *mimetypes* module.

class mimetypes.MimeTypes(*filenames=()*, *strict=True*)
This class represents a MIME-types database. By default, it provides access to the same database as the rest of this module. The initial database is a copy of that provided by the module, and may be extended by loading additional `mime.types`-style files into the database using the *read()* or *readfp()* methods. The mapping dictionaries may also be cleared before loading additional data if the default data is not desired.

The optional *filenames* parameter can be used to cause additional files to be loaded "on top" of the default database.

suffix_map
Dictionary mapping suffixes to suffixes. This is used to allow recognition of encoded files for which the encoding and the type are indicated by the same extension. For example, the `.tgz` extension is mapped to `.tar.gz` to allow the encoding and type to be recognized separately. This is initially a copy of the global *suffix_map* defined in the module.

encodings_map
Dictionary mapping filename extensions to encoding types. This is initially a copy of the global *encodings_map* defined in the module.

types_map
Tuple containing two dictionaries, mapping filename extensions to MIME types: the first dictionary is for the non-standards types and the second one is for the standard types. They are initialized by *common_types* and *types_map*.

types_map_inv
Tuple containing two dictionaries, mapping MIME types to a list of filename extensions: the first

dictionary is for the non-standards types and the second one is for the standard types. They are initialized by *common_types* and *types_map*.

guess_extension(*type*, *strict=True*)
Similar to the *guess_extension()* function, using the tables stored as part of the object.

guess_type(*url*, *strict=True*)
Similar to the *guess_type()* function, using the tables stored as part of the object.

guess_all_extensions(*type*, *strict=True*)
Similar to the *guess_all_extensions()* function, using the tables stored as part of the object.

read(*filename*, *strict=True*)
Load MIME information from a file named *filename*. This uses *readfp()* to parse the file.

If *strict* is `True`, information will be added to list of standard types, else to the list of non-standard types.

readfp(*fp*, *strict=True*)
Load MIME type information from an open file *fp*. The file must have the format of the standard `mime.types` files.

If *strict* is `True`, information will be added to the list of standard types, else to the list of non-standard types.

read_windows_registry(*strict=True*)
Load MIME type information from the Windows registry. Availability: Windows.

If *strict* is `True`, information will be added to the list of standard types, else to the list of non-standard types.

New in version 3.2.

20.6 base64 — Base16, Base32, Base64, Base85 Data Encodings

Source code: Lib/base64.py

This module provides functions for encoding binary data to printable ASCII characters and decoding such encodings back to binary data. It provides encoding and decoding functions for the encodings specified in **RFC 3548**, which defines the Base16, Base32, and Base64 algorithms, and for the de-facto standard Ascii85 and Base85 encodings.

The **RFC 3548** encodings are suitable for encoding binary data so that it can safely sent by email, used as parts of URLs, or included as part of an HTTP POST request. The encoding algorithm is not the same as the **uuencode** program.

There are two interfaces provided by this module. The modern interface supports encoding *bytes-like objects* to ASCII *bytes*, and decoding *bytes-like objects* or strings containing ASCII to *bytes*. Both base-64 alphabets defined in **RFC 3548** (normal, and URL- and filesystem-safe) are supported.

The legacy interface does not support decoding from strings, but it does provide functions for encoding and decoding to and from *file objects*. It only supports the Base64 standard alphabet, and it adds newlines every 76 characters as per **RFC 2045**. Note that if you are looking for **RFC 2045** support you probably want to be looking at the *email* package instead.

Changed in version 3.3: ASCII-only Unicode strings are now accepted by the decoding functions of the modern interface.

Changed in version 3.4: Any *bytes-like objects* are now accepted by all encoding and decoding functions in this module. Ascii85/Base85 support added.

The modern interface provides:

base64.b64encode(*s*, *altchars=None*)
Encode the *bytes-like object* *s* using Base64 and return the encoded *bytes*.

Optional *altchars* must be a *bytes-like object* of at least length 2 (additional characters are ignored) which specifies an alternative alphabet for the `+` and `/` characters. This allows an application to e.g. generate URL or filesystem safe Base64 strings. The default is `None`, for which the standard Base64 alphabet is used.

base64.b64decode(*s*, *altchars=None*, *validate=False*)
Decode the Base64 encoded *bytes-like object* or ASCII string *s* and return the decoded *bytes*.

Optional *altchars* must be a *bytes-like object* or ASCII string of at least length 2 (additional characters are ignored) which specifies the alternative alphabet used instead of the `+` and `/` characters.

A *binascii.Error* exception is raised if *s* is incorrectly padded.

If *validate* is `False` (the default), characters that are neither in the normal base-64 alphabet nor the alternative alphabet are discarded prior to the padding check. If *validate* is `True`, these non-alphabet characters in the input result in a *binascii.Error*.

base64.standard_b64encode(*s*)
Encode *bytes-like object* *s* using the standard Base64 alphabet and return the encoded *bytes*.

base64.standard_b64decode(*s*)
Decode *bytes-like object* or ASCII string *s* using the standard Base64 alphabet and return the decoded *bytes*.

base64.urlsafe_b64encode(*s*)
Encode *bytes-like object* *s* using the URL- and filesystem-safe alphabet, which substitutes `-` instead of `+` and `_` instead of `/` in the standard Base64 alphabet, and return the encoded *bytes*. The result can still contain `=`.

base64.urlsafe_b64decode(*s*)
Decode *bytes-like object* or ASCII string *s* using the URL- and filesystem-safe alphabet, which substitutes `-` instead of `+` and `_` instead of `/` in the standard Base64 alphabet, and return the decoded *bytes*.

base64.b32encode(*s*)
Encode the *bytes-like object* *s* using Base32 and return the encoded *bytes*.

base64.b32decode(*s*, *casefold=False*, *map01=None*)
Decode the Base32 encoded *bytes-like object* or ASCII string *s* and return the decoded *bytes*.

Optional *casefold* is a flag specifying whether a lowercase alphabet is acceptable as input. For security purposes, the default is `False`.

RFC 3548 allows for optional mapping of the digit 0 (zero) to the letter O (oh), and for optional mapping of the digit 1 (one) to either the letter I (eye) or letter L (el). The optional argument *map01* when not `None`, specifies which letter the digit 1 should be mapped to (when *map01* is not `None`, the digit 0 is always mapped to the letter O). For security purposes the default is `None`, so that 0 and 1 are not allowed in the input.

A *binascii.Error* is raised if *s* is incorrectly padded or if there are non-alphabet characters present in the input.

base64.b16encode(*s*)
Encode the *bytes-like object* *s* using Base16 and return the encoded *bytes*.

base64.b16decode(*s*, *casefold=False*)
Decode the Base16 encoded *bytes-like object* or ASCII string *s* and return the decoded *bytes*.

Optional *casefold* is a flag specifying whether a lowercase alphabet is acceptable as input. For security purposes, the default is `False`.

A *binascii.Error* is raised if *s* is incorrectly padded or if there are non-alphabet characters present in the input.

`base64.a85encode`(*b*, ***, *foldspaces=False*, *wrapcol=0*, *pad=False*, *adobe=False*)
Encode the *bytes-like object* *b* using Ascii85 and return the encoded *bytes*.

foldspaces is an optional flag that uses the special short sequence 'y' instead of 4 consecutive spaces (ASCII 0x20) as supported by 'btoa'. This feature is not supported by the "standard" Ascii85 encoding.

wrapcol controls whether the output should have newline (`b'\n'`) characters added to it. If this is non-zero, each output line will be at most this many characters long.

pad controls whether the input is padded to a multiple of 4 before encoding. Note that the `btoa` implementation always pads.

adobe controls whether the encoded byte sequence is framed with `<~` and `~>`, which is used by the Adobe implementation.

New in version 3.4.

`base64.a85decode`(*b*, ***, *foldspaces=False*, *adobe=False*, *ignorechars=b' \t\n\r\v'*)
Decode the Ascii85 encoded *bytes-like object* or ASCII string *b* and return the decoded *bytes*.

foldspaces is a flag that specifies whether the 'y' short sequence should be accepted as shorthand for 4 consecutive spaces (ASCII 0x20). This feature is not supported by the "standard" Ascii85 encoding.

adobe controls whether the input sequence is in Adobe Ascii85 format (i.e. is framed with <~ and ~>).

ignorechars should be a *bytes-like object* or ASCII string containing characters to ignore from the input. This should only contain whitespace characters, and by default contains all whitespace characters in ASCII.

New in version 3.4.

`base64.b85encode`(*b*, *pad=False*)
Encode the *bytes-like object* *b* using base85 (as used in e.g. git-style binary diffs) and return the encoded *bytes*.

If *pad* is true, the input is padded with `b'\0'` so its length is a multiple of 4 bytes before encoding.

New in version 3.4.

`base64.b85decode`(*b*)
Decode the base85-encoded *bytes-like object* or ASCII string *b* and return the decoded *bytes*. Padding is implicitly removed, if necessary.

New in version 3.4.

The legacy interface:

`base64.decode`(*input*, *output*)
Decode the contents of the binary *input* file and write the resulting binary data to the *output* file. *input* and *output* must be *file objects*. *input* will be read until `input.readline()` returns an empty bytes object.

`base64.decodebytes`(*s*)
Decode the *bytes-like object* *s*, which must contain one or more lines of base64 encoded data, and return the decoded *bytes*.

New in version 3.1.

`base64.decodestring`(*s*)
Deprecated alias of *decodebytes()*.

Deprecated since version 3.1.

base64.encode(*input*, *output*)
Encode the contents of the binary *input* file and write the resulting base64 encoded data to the *output* file. *input* and *output* must be *file objects*. *input* will be read until `input.read()` returns an empty bytes object. *encode()* inserts a newline character (`b'\n'`) after every 76 bytes of the output, as well as ensuring that the output always ends with a newline, as per **RFC 2045** (MIME).

base64.encodebytes(*s*)
Encode the *bytes-like object* *s*, which can contain arbitrary binary data, and return *bytes* containing the base64-encoded data, with newlines (`b'\n'`) inserted after every 76 bytes of output, and ensuring that there is a trailing newline, as per **RFC 2045** (MIME).

New in version 3.1.

base64.encodestring(*s*)
Deprecated alias of *encodebytes()*.

Deprecated since version 3.1.

An example usage of the module:

```
>>> import base64
>>> encoded = base64.b64encode(b'data to be encoded')
>>> encoded
b'ZGF0YSBOYyBiZSBlbmNvZGVk'
>>> data = base64.b64decode(encoded)
>>> data
b'data to be encoded'
```

See also:

Module *binascii* Support module containing ASCII-to-binary and binary-to-ASCII conversions.

RFC 1521 - MIME (Multipurpose Internet Mail Extensions) Part One: Mechanisms for Specifying and Des
Section 5.2, "Base64 Content-Transfer-Encoding," provides the definition of the base64 encoding.

20.7 binhex — Encode and decode binhex4 files

Source code: Lib/binhex.py

This module encodes and decodes files in binhex4 format, a format allowing representation of Macintosh files in ASCII. Only the data fork is handled.

The *binhex* module defines the following functions:

binhex.binhex(*input*, *output*)
Convert a binary file with filename *input* to binhex file *output*. The *output* parameter can either be a filename or a file-like object (any object supporting a `write()` and `close()` method).

binhex.hexbin(*input*, *output*)
Decode a binhex file *input*. *input* may be a filename or a file-like object supporting `read()` and `close()` methods. The resulting file is written to a file named *output*, unless the argument is `None` in which case the output filename is read from the binhex file.

The following exception is also defined:

exception binhex.Error
Exception raised when something can't be encoded using the binhex format (for example, a filename is too long to fit in the filename field), or when input is not properly encoded binhex data.

See also:

Module *binascii* Support module containing ASCII-to-binary and binary-to-ASCII conversions.

20.7.1 Notes

There is an alternative, more powerful interface to the coder and decoder, see the source for details.

If you code or decode textfiles on non-Macintosh platforms they will still use the old Macintosh newline convention (carriage-return as end of line).

20.8 binascii — Convert between binary and ASCII

The *binascii* module contains a number of methods to convert between binary and various ASCII-encoded binary representations. Normally, you will not use these functions directly but use wrapper modules like *uu*, *base64*, or *binhex* instead. The *binascii* module contains low-level functions written in C for greater speed that are used by the higher-level modules.

Note: `a2b_*` functions accept Unicode strings containing only ASCII characters. Other functions only accept *bytes-like objects* (such as *bytes*, *bytearray* and other objects that support the buffer protocol).

Changed in version 3.3: ASCII-only unicode strings are now accepted by the `a2b_*` functions.

The *binascii* module defines the following functions:

`binascii.a2b_uu(`*string*`)`
: Convert a single line of uuencoded data back to binary and return the binary data. Lines normally contain 45 (binary) bytes, except for the last line. Line data may be followed by whitespace.

`binascii.b2a_uu(`*data*, ***, *backtick=False*`)`
: Convert binary data to a line of ASCII characters, the return value is the converted line, including a newline char. The length of *data* should be at most 45. If *backtick* is true, zeros are represented by `'`'` instead of spaces.

  Changed in version 3.7: Added the *backtick* parameter.

`binascii.a2b_base64(`*string*`)`
: Convert a block of base64 data back to binary and return the binary data. More than one line may be passed at a time.

`binascii.b2a_base64(`*data*, ***, *newline=True*`)`
: Convert binary data to a line of ASCII characters in base64 coding. The return value is the converted line, including a newline char if *newline* is true. The output of this function conforms to **RFC 3548**.

  Changed in version 3.6: Added the *newline* parameter.

`binascii.a2b_qp(`*data*, *header=False*`)`
: Convert a block of quoted-printable data back to binary and return the binary data. More than one line may be passed at a time. If the optional argument *header* is present and true, underscores will be decoded as spaces.

`binascii.b2a_qp(`*data*, *quotetabs=False*, *istext=True*, *header=False*`)`
: Convert binary data to a line(s) of ASCII characters in quoted-printable encoding. The return value is the converted line(s). If the optional argument *quotetabs* is present and true, all tabs and spaces will be encoded. If the optional argument *istext* is present and true, newlines are not encoded but

trailing whitespace will be encoded. If the optional argument *header* is present and true, spaces will be encoded as underscores per **RFC 1522**. If the optional argument *header* is present and false, newline characters will be encoded as well; otherwise linefeed conversion might corrupt the binary data stream.

binascii.a2b_hqx(*string*)
Convert binhex4 formatted ASCII data to binary, without doing RLE-decompression. The string should contain a complete number of binary bytes, or (in case of the last portion of the binhex4 data) have the remaining bits zero.

binascii.rledecode_hqx(*data*)
Perform RLE-decompression on the data, as per the binhex4 standard. The algorithm uses `0x90` after a byte as a repeat indicator, followed by a count. A count of `0` specifies a byte value of `0x90`. The routine returns the decompressed data, unless data input data ends in an orphaned repeat indicator, in which case the *Incomplete* exception is raised.

Changed in version 3.2: Accept only bytestring or bytearray objects as input.

binascii.rlecode_hqx(*data*)
Perform binhex4 style RLE-compression on *data* and return the result.

binascii.b2a_hqx(*data*)
Perform hexbin4 binary-to-ASCII translation and return the resulting string. The argument should already be RLE-coded, and have a length divisible by 3 (except possibly the last fragment).

binascii.crc_hqx(*data*, *value*)
Compute a 16-bit CRC value of *data*, starting with *value* as the initial CRC, and return the result. This uses the CRC-CCITT polynomial $x^{16} + x^{12} + x^5 + 1$, often represented as 0x1021. This CRC is used in the binhex4 format.

binascii.crc32(*data*[, *value*])
Compute CRC-32, the 32-bit checksum of *data*, starting with an initial CRC of *value*. The default initial CRC is zero. The algorithm is consistent with the ZIP file checksum. Since the algorithm is designed for use as a checksum algorithm, it is not suitable for use as a general hash algorithm. Use as follows:

```
print(binascii.crc32(b"hello world"))
# Or, in two pieces:
crc = binascii.crc32(b"hello")
crc = binascii.crc32(b" world", crc)
print('crc32 = {:#010x}'.format(crc))
```

Changed in version 3.0: The result is always unsigned. To generate the same numeric value across all Python versions and platforms, use `crc32(data) & 0xffffffff`.

binascii.b2a_hex(*data*)
binascii.hexlify(*data*)
Return the hexadecimal representation of the binary *data*. Every byte of *data* is converted into the corresponding 2-digit hex representation. The returned bytes object is therefore twice as long as the length of *data*.

binascii.a2b_hex(*hexstr*)
binascii.unhexlify(*hexstr*)
Return the binary data represented by the hexadecimal string *hexstr*. This function is the inverse of *b2a_hex()*. *hexstr* must contain an even number of hexadecimal digits (which can be upper or lower case), otherwise an *Error* exception is raised.

exception binascii.Error
Exception raised on errors. These are usually programming errors.

exception binascii.Incomplete
Exception raised on incomplete data. These are usually not programming errors, but may be handled

by reading a little more data and trying again.

See also:

Module *base64* Support for RFC compliant base64-style encoding in base 16, 32, 64, and 85.

Module *binhex* Support for the binhex format used on the Macintosh.

Module *uu* Support for UU encoding used on Unix.

Module *quopri* Support for quoted-printable encoding used in MIME email messages.

20.9 quopri — Encode and decode MIME quoted-printable data

Source code: Lib/quopri.py

This module performs quoted-printable transport encoding and decoding, as defined in **RFC 1521**: "MIME (Multipurpose Internet Mail Extensions) Part One: Mechanisms for Specifying and Describing the Format of Internet Message Bodies". The quoted-printable encoding is designed for data where there are relatively few nonprintable characters; the base64 encoding scheme available via the *base64* module is more compact if there are many such characters, as when sending a graphics file.

`quopri.decode`(*input*, *output*, *header=False*)
Decode the contents of the *input* file and write the resulting decoded binary data to the *output* file. *input* and *output* must be *binary file objects*. If the optional argument *header* is present and true, underscore will be decoded as space. This is used to decode "Q"-encoded headers as described in **RFC 1522**: "MIME (Multipurpose Internet Mail Extensions) Part Two: Message Header Extensions for Non-ASCII Text".

`quopri.encode`(*input*, *output*, *quotetabs*, *header=False*)
Encode the contents of the *input* file and write the resulting quoted-printable data to the *output* file. *input* and *output* must be *binary file objects*. *quotetabs*, a non-optional flag which controls whether to encode embedded spaces and tabs; when true it encodes such embedded whitespace, and when false it leaves them unencoded. Note that spaces and tabs appearing at the end of lines are always encoded, as per **RFC 1521**. *header* is a flag which controls if spaces are encoded as underscores as per **RFC 1522**.

`quopri.decodestring`(*s*, *header=False*)
Like *decode()*, except that it accepts a source *bytes* and returns the corresponding decoded *bytes*.

`quopri.encodestring`(*s*, *quotetabs=False*, *header=False*)
Like *encode()*, except that it accepts a source *bytes* and returns the corresponding encoded *bytes*. By default, it sends a `False` value to *quotetabs* parameter of the *encode()* function.

See also:

Module *base64* Encode and decode MIME base64 data

20.10 uu — Encode and decode uuencode files

Source code: Lib/uu.py

This module encodes and decodes files in uuencode format, allowing arbitrary binary data to be transferred over ASCII-only connections. Wherever a file argument is expected, the methods accept a file-like object. For backwards compatibility, a string containing a pathname is also accepted, and the corresponding file will

be opened for reading and writing; the pathname `'-'` is understood to mean the standard input or output. However, this interface is deprecated; it's better for the caller to open the file itself, and be sure that, when required, the mode is `'rb'` or `'wb'` on Windows.

This code was contributed by Lance Ellinghouse, and modified by Jack Jansen.

The *uu* module defines the following functions:

uu.encode(*in_file*, *out_file*, *name=None*, *mode=None*, ***, *backtick=False*)
Uuencode file *in_file* into file *out_file*. The uuencoded file will have the header specifying *name* and *mode* as the defaults for the results of decoding the file. The default defaults are taken from *in_file*, or `'-'` and `0o666` respectively. If *backtick* is true, zeros are represented by `'`'` instead of spaces.

Changed in version 3.7: Added the *backtick* parameter.

uu.decode(*in_file*, *out_file=None*, *mode=None*, *quiet=False*)
This call decodes uuencoded file *in_file* placing the result on file *out_file*. If *out_file* is a pathname, *mode* is used to set the permission bits if the file must be created. Defaults for *out_file* and *mode* are taken from the uuencode header. However, if the file specified in the header already exists, a *uu.Error* is raised.

decode() may print a warning to standard error if the input was produced by an incorrect uuencoder and Python could recover from that error. Setting *quiet* to a true value silences this warning.

exception uu.Error
Subclass of *Exception*, this can be raised by *uu.decode()* under various situations, such as described above, but also including a badly formatted header, or truncated input file.

See also:

Module *binascii* Support module containing ASCII-to-binary and binary-to-ASCII conversions.

CHAPTER

TWENTYONE

STRUCTURED MARKUP PROCESSING TOOLS

Python supports a variety of modules to work with various forms of structured data markup. This includes modules to work with the Standard Generalized Markup Language (SGML) and the Hypertext Markup Language (HTML), and several interfaces for working with the Extensible Markup Language (XML).

21.1 `html` — HyperText Markup Language support

Source code: Lib/html/__init__.py

This module defines utilities to manipulate HTML.

`html.escape`(*s*, *quote=True*)
Convert the characters `&`, `<` and `>` in string *s* to HTML-safe sequences. Use this if you need to display text that might contain such characters in HTML. If the optional flag *quote* is true, the characters (`"`) and (`'`) are also translated; this helps for inclusion in an HTML attribute value delimited by quotes, as in `<a href="...">`.

New in version 3.2.

`html.unescape`(*s*)
Convert all named and numeric character references (e.g. `>`, `&#62;`, `&x3e;`) in the string *s* to the corresponding unicode characters. This function uses the rules defined by the HTML 5 standard for both valid and invalid character references, and the *list of HTML 5 named character references*.

New in version 3.4.

Submodules in the `html` package are:

- *`html.parser`* – HTML/XHTML parser with lenient parsing mode
- *`html.entities`* – HTML entity definitions

21.2 `html.parser` — Simple HTML and XHTML parser

Source code: Lib/html/parser.py

This module defines a class *`HTMLParser`* which serves as the basis for parsing text files formatted in HTML (HyperText Mark-up Language) and XHTML.

class html.parser.HTMLParser(*, *convert_charrefs=True*)

Create a parser instance able to parse invalid markup.

If *convert_charrefs* is `True` (the default), all character references (except the ones in `script`/`style` elements) are automatically converted to the corresponding Unicode characters.

An *HTMLParser* instance is fed HTML data and calls handler methods when start tags, end tags, text, comments, and other markup elements are encountered. The user should subclass *HTMLParser* and override its methods to implement the desired behavior.

This parser does not check that end tags match start tags or call the end-tag handler for elements which are closed implicitly by closing an outer element.

Changed in version 3.4: *convert_charrefs* keyword argument added.

Changed in version 3.5: The default value for argument *convert_charrefs* is now `True`.

21.2.1 Example HTML Parser Application

As a basic example, below is a simple HTML parser that uses the *HTMLParser* class to print out start tags, end tags, and data as they are encountered:

```
from html.parser import HTMLParser

class MyHTMLParser(HTMLParser):
    def handle_starttag(self, tag, attrs):
        print("Encountered a start tag:", tag)

    def handle_endtag(self, tag):
        print("Encountered an end tag :", tag)

    def handle_data(self, data):
        print("Encountered some data  :", data)

parser = MyHTMLParser()
parser.feed('<html><head><title>Test</title></head>'
            '<body><h1>Parse me!</h1></body></html>')
```

The output will then be:

```
Encountered a start tag: html
Encountered a start tag: head
Encountered a start tag: title
Encountered some data  : Test
Encountered an end tag : title
Encountered an end tag : head
Encountered a start tag: body
Encountered a start tag: h1
Encountered some data  : Parse me!
Encountered an end tag : h1
Encountered an end tag : body
Encountered an end tag : html
```

21.2.2 `HTMLParser` Methods

HTMLParser instances have the following methods:

HTMLParser.**feed**(*data*)
Feed some text to the parser. It is processed insofar as it consists of complete elements; incomplete data is buffered until more data is fed or *close()* is called. *data* must be *str*.

HTMLParser.**close**()
Force processing of all buffered data as if it were followed by an end-of-file mark. This method may be redefined by a derived class to define additional processing at the end of the input, but the redefined version should always call the *HTMLParser* base class method *close()*.

HTMLParser.**reset**()
Reset the instance. Loses all unprocessed data. This is called implicitly at instantiation time.

HTMLParser.**getpos**()
Return current line number and offset.

HTMLParser.**get_starttag_text**()
Return the text of the most recently opened start tag. This should not normally be needed for structured processing, but may be useful in dealing with HTML "as deployed" or for re-generating input with minimal changes (whitespace between attributes can be preserved, etc.).

The following methods are called when data or markup elements are encountered and they are meant to be overridden in a subclass. The base class implementations do nothing (except for *handle_startendtag()*):

HTMLParser.**handle_starttag**(*tag*, *attrs*)
This method is called to handle the start of a tag (e.g. `<div id="main">`).

The *tag* argument is the name of the tag converted to lower case. The *attrs* argument is a list of `(name, value)` pairs containing the attributes found inside the tag's `<>` brackets. The *name* will be translated to lower case, and quotes in the *value* have been removed, and character and entity references have been replaced.

For instance, for the tag `<A HREF="https://www.cwi.nl/">`, this method would be called as `handle_starttag('a', [('href', 'https://www.cwi.nl/')])`.

All entity references from *html.entities* are replaced in the attribute values.

HTMLParser.**handle_endtag**(*tag*)
This method is called to handle the end tag of an element (e.g. `</div>`).

The *tag* argument is the name of the tag converted to lower case.

HTMLParser.**handle_startendtag**(*tag*, *attrs*)
Similar to *handle_starttag()*, but called when the parser encounters an XHTML-style empty tag (`<img ... />`). This method may be overridden by subclasses which require this particular lexical information; the default implementation simply calls *handle_starttag()* and *handle_endtag()*.

HTMLParser.**handle_data**(*data*)
This method is called to process arbitrary data (e.g. text nodes and the content of `<script>...</script>` and `<style>...</style>`).

HTMLParser.**handle_entityref**(*name*)
This method is called to process a named character reference of the form `&name;` (e.g. `&gt;`), where *name* is a general entity reference (e.g. `'gt'`). This method is never called if *convert_charrefs* is `True`.

HTMLParser.**handle_charref**(*name*)
This method is called to process decimal and hexadecimal numeric character references of the form `&#NNN;` and `&#xNNN;`. For example, the decimal equivalent for `&gt;` is `&#62;`, whereas the hexadecimal is `&#x3E;`; in this case the method will receive `'62'` or `'x3E'`. This method is never called if *convert_charrefs* is `True`.

HTMLParser.**handle_comment**(*data*)
This method is called when a comment is encountered (e.g. `<!--comment-->`).

For example, the comment `<!-- comment -->` will cause this method to be called with the argument `' comment '`.

The content of Internet Explorer conditional comments (condcoms) will also be sent to this method, so, for `<!--[if IE 9]>IE9-specific content<![endif]-->`, this method will receive `'[if IE 9]>IE9-specific content<![endif]'`.

`HTMLParser.handle_decl(`*decl*`)`
This method is called to handle an HTML doctype declaration (e.g. `<!DOCTYPE html>`).

The *decl* parameter will be the entire contents of the declaration inside the `<!...>` markup (e.g. `'DOCTYPE html'`).

`HTMLParser.handle_pi(`*data*`)`
Method called when a processing instruction is encountered. The *data* parameter will contain the entire processing instruction. For example, for the processing instruction `<?proc color='red'>`, this method would be called as `handle_pi("proc color='red'")`. It is intended to be overridden by a derived class; the base class implementation does nothing.

Note: The *HTMLParser* class uses the SGML syntactic rules for processing instructions. An XHTML processing instruction using the trailing `'?'` will cause the `'?'` to be included in *data*.

`HTMLParser.unknown_decl(`*data*`)`
This method is called when an unrecognized declaration is read by the parser.

The *data* parameter will be the entire contents of the declaration inside the `<![...]>` markup. It is sometimes useful to be overridden by a derived class. The base class implementation does nothing.

21.2.3 Examples

The following class implements a parser that will be used to illustrate more examples:

```
from html.parser import HTMLParser
from html.entities import name2codepoint

class MyHTMLParser(HTMLParser):
    def handle_starttag(self, tag, attrs):
        print("Start tag:", tag)
        for attr in attrs:
            print("     attr:", attr)

    def handle_endtag(self, tag):
        print("End tag  :", tag)

    def handle_data(self, data):
        print("Data     :", data)

    def handle_comment(self, data):
        print("Comment  :", data)

    def handle_entityref(self, name):
        c = chr(name2codepoint[name])
        print("Named ent:", c)

    def handle_charref(self, name):
        if name.startswith('x'):
            c = chr(int(name[1:], 16))
```

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```
        else:
            c = chr(int(name))
        print("Num ent  :", c)

    def handle_decl(self, data):
        print("Decl     :", data)

parser = MyHTMLParser()
```

Parsing a doctype:

```
>>> parser.feed('<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01//EN" '
...             '"http://www.w3.org/TR/html4/strict.dtd">')
Decl     : DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01//EN" "http://www.w3.org/TR/html4/strict.dtd"
```

Parsing an element with a few attributes and a title:

```
>>> parser.feed('<img src="python-logo.png" alt="The Python logo">')
Start tag: img
     attr: ('src', 'python-logo.png')
     attr: ('alt', 'The Python logo')
>>>
>>> parser.feed('<h1>Python</h1>')
Start tag: h1
Data     : Python
End tag  : h1
```

The content of `script` and `style` elements is returned as is, without further parsing:

```
>>> parser.feed('<style type="text/css">#python { color: green }</style>')
Start tag: style
     attr: ('type', 'text/css')
Data     : #python { color: green }
End tag  : style

>>> parser.feed('<script type="text/javascript">'
...             'alert("<strong>hello!</strong>");</script>')
Start tag: script
     attr: ('type', 'text/javascript')
Data     : alert("<strong>hello!</strong>");
End tag  : script
```

Parsing comments:

```
>>> parser.feed('<!-- a comment -->'
...             '<!--[if IE 9]>IE-specific content<![endif]-->')
Comment  :  a comment
Comment  : [if IE 9]>IE-specific content<![endif]
```

Parsing named and numeric character references and converting them to the correct char (note: these 3 references are all equivalent to `'>'`):

```
>>> parser.feed('&gt;&#62;&#x3E;')
Named ent: >
Num ent  : >
Num ent  : >
```

Feeding incomplete chunks to *feed()* works, but *handle_data()* might be called more than once (unless *convert_charrefs* is set to `True`):

```
>>> for chunk in ['<sp', 'an>buff', 'ered ', 'text</s', 'pan>']:
...     parser.feed(chunk)
...
Start tag: span
Data     : buff
Data     : ered
Data     : text
End tag  : span
```

Parsing invalid HTML (e.g. unquoted attributes) also works:

```
>>> parser.feed('<p><a class=link href=#main>tag soup</p ></a>')
Start tag: p
Start tag: a
     attr: ('class', 'link')
     attr: ('href', '#main')
Data     : tag soup
End tag  : p
End tag  : a
```

21.3 `html.entities` — Definitions of HTML general entities

Source code: Lib/html/entities.py

This module defines four dictionaries, *html5*, *name2codepoint*, *codepoint2name*, and *entitydefs*.

html.entities.html5
A dictionary that maps HTML5 named character references[1] to the equivalent Unicode character(s), e.g. `html5['gt;'] == '>'`. Note that the trailing semicolon is included in the name (e.g. `'gt;'`), however some of the names are accepted by the standard even without the semicolon: in this case the name is present with and without the `';'`. See also *html.unescape()*.

New in version 3.3.

html.entities.entitydefs
A dictionary mapping XHTML 1.0 entity definitions to their replacement text in ISO Latin-1.

html.entities.name2codepoint
A dictionary that maps HTML entity names to the Unicode code points.

html.entities.codepoint2name
A dictionary that maps Unicode code points to HTML entity names.

21.4 XML Processing Modules

Source code: Lib/xml/

Python's interfaces for processing XML are grouped in the `xml` package.

[1] See https://www.w3.org/TR/html5/syntax.html#named-character-references

Warning: The XML modules are not secure against erroneous or maliciously constructed data. If you need to parse untrusted or unauthenticated data see the *XML vulnerabilities* and *The defusedxml and defusedexpat Packages* sections.

It is important to note that modules in the *xml* package require that there be at least one SAX-compliant XML parser available. The Expat parser is included with Python, so the *xml.parsers.expat* module will always be available.

The documentation for the *xml.dom* and *xml.sax* packages are the definition of the Python bindings for the DOM and SAX interfaces.

The XML handling submodules are:

- *xml.etree.ElementTree*: the ElementTree API, a simple and lightweight XML processor
- *xml.dom*: the DOM API definition
- *xml.dom.minidom*: a minimal DOM implementation
- *xml.dom.pulldom*: support for building partial DOM trees
- *xml.sax*: SAX2 base classes and convenience functions
- *xml.parsers.expat*: the Expat parser binding

21.4.1 XML vulnerabilities

The XML processing modules are not secure against maliciously constructed data. An attacker can abuse XML features to carry out denial of service attacks, access local files, generate network connections to other machines, or circumvent firewalls.

The following table gives an overview of the known attacks and whether the various modules are vulnerable to them.

kind	sax	etree	minidom	pulldom	xmlrpc
billion laughs	**Vulnerable**	**Vulnerable**	**Vulnerable**	**Vulnerable**	**Vulnerable**
quadratic blowup	**Vulnerable**	**Vulnerable**	**Vulnerable**	**Vulnerable**	**Vulnerable**
external entity expansion	**Vulnerable**	Safe (1)	Safe (2)	**Vulnerable**	Safe (3)
DTD retrieval	**Vulnerable**	Safe	Safe	**Vulnerable**	Safe
decompression bomb	Safe	Safe	Safe	Safe	**Vulnerable**

1. *xml.etree.ElementTree* doesn't expand external entities and raises a `ParserError` when an entity occurs.
2. *xml.dom.minidom* doesn't expand external entities and simply returns the unexpanded entity verbatim.
3. `xmlrpclib` doesn't expand external entities and omits them.

billion laughs / exponential entity expansion The Billion Laughs attack – also known as exponential entity expansion – uses multiple levels of nested entities. Each entity refers to another entity several times, and the final entity definition contains a small string. The exponential expansion results in several gigabytes of text and consumes lots of memory and CPU time.

quadratic blowup entity expansion A quadratic blowup attack is similar to a Billion Laughs attack; it abuses entity expansion, too. Instead of nested entities it repeats one large entity with a couple of thousand chars over and over again. The attack isn't as efficient as the exponential case but it avoids triggering parser countermeasures that forbid deeply-nested entities.

external entity expansion Entity declarations can contain more than just text for replacement. They can also point to external resources or local files. The XML parser accesses the resource and embeds the content into the XML document.

DTD retrieval Some XML libraries like Python's *xml.dom.pulldom* retrieve document type definitions from remote or local locations. The feature has similar implications as the external entity expansion issue.

decompression bomb Decompression bombs (aka ZIP bomb) apply to all XML libraries that can parse compressed XML streams such as gzipped HTTP streams or LZMA-compressed files. For an attacker it can reduce the amount of transmitted data by three magnitudes or more.

The documentation for defusedxml on PyPI has further information about all known attack vectors with examples and references.

21.4.2 The `defusedxml` and `defusedexpat` Packages

defusedxml is a pure Python package with modified subclasses of all stdlib XML parsers that prevent any potentially malicious operation. Use of this package is recommended for any server code that parses untrusted XML data. The package also ships with example exploits and extended documentation on more XML exploits such as XPath injection.

defusedexpat provides a modified libexpat and a patched `pyexpat` module that have countermeasures against entity expansion DoS attacks. The `defusedexpat` module still allows a sane and configurable amount of entity expansions. The modifications may be included in some future release of Python, but will not be included in any bugfix releases of Python because they break backward compatibility.

21.5 `xml.etree.ElementTree` — The ElementTree XML API

Source code: Lib/xml/etree/ElementTree.py

The *xml.etree.ElementTree* module implements a simple and efficient API for parsing and creating XML data.

Changed in version 3.3: This module will use a fast implementation whenever available. The `xml.etree.cElementTree` module is deprecated.

> **Warning:** The *xml.etree.ElementTree* module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see *XML vulnerabilities*.

21.5.1 Tutorial

This is a short tutorial for using *xml.etree.ElementTree* (`ET` in short). The goal is to demonstrate some of the building blocks and basic concepts of the module.

XML tree and elements

XML is an inherently hierarchical data format, and the most natural way to represent it is with a tree. `ET` has two classes for this purpose - *ElementTree* represents the whole XML document as a tree, and *Element* represents a single node in this tree. Interactions with the whole document (reading and writing to/from files) are usually done on the *ElementTree* level. Interactions with a single XML element and its sub-elements are done on the *Element* level.

Parsing XML

We'll be using the following XML document as the sample data for this section:

```
<?xml version="1.0"?>
<data>
    <country name="Liechtenstein">
        <rank>1</rank>
        <year>2008</year>
        <gdppc>141100</gdppc>
        <neighbor name="Austria" direction="E"/>
        <neighbor name="Switzerland" direction="W"/>
    </country>
    <country name="Singapore">
        <rank>4</rank>
        <year>2011</year>
        <gdppc>59900</gdppc>
        <neighbor name="Malaysia" direction="N"/>
    </country>
    <country name="Panama">
        <rank>68</rank>
        <year>2011</year>
        <gdppc>13600</gdppc>
        <neighbor name="Costa Rica" direction="W"/>
        <neighbor name="Colombia" direction="E"/>
    </country>
</data>
```

We can import this data by reading from a file:

```
import xml.etree.ElementTree as ET
tree = ET.parse('country_data.xml')
root = tree.getroot()
```

Or directly from a string:

```
root = ET.fromstring(country_data_as_string)
```

fromstring() parses XML from a string directly into an *Element*, which is the root element of the parsed tree. Other parsing functions may create an *ElementTree*. Check the documentation to be sure.

As an *Element*, `root` has a tag and a dictionary of attributes:

```
>>> root.tag
'data'
>>> root.attrib
{}
```

It also has children nodes over which we can iterate:

```
>>> for child in root:
...     print(child.tag, child.attrib)
...
country {'name': 'Liechtenstein'}
country {'name': 'Singapore'}
country {'name': 'Panama'}
```

Children are nested, and we can access specific child nodes by index:

```
>>> root[0][1].text
'2008'
```

Note: Not all elements of the XML input will end up as elements of the parsed tree. Currently, this module skips over any XML comments, processing instructions, and document type declarations in the input. Nevertheless, trees built using this module's API rather than parsing from XML text can have comments and processing instructions in them; they will be included when generating XML output. A document type declaration may be accessed by passing a custom *TreeBuilder* instance to the *XMLParser* constructor.

Pull API for non-blocking parsing

Most parsing functions provided by this module require the whole document to be read at once before returning any result. It is possible to use an *XMLParser* and feed data into it incrementally, but it is a push API that calls methods on a callback target, which is too low-level and inconvenient for most needs. Sometimes what the user really wants is to be able to parse XML incrementally, without blocking operations, while enjoying the convenience of fully constructed *Element* objects.

The most powerful tool for doing this is *XMLPullParser*. It does not require a blocking read to obtain the XML data, and is instead fed with data incrementally with *XMLPullParser.feed()* calls. To get the parsed XML elements, call *XMLPullParser.read_events()*. Here is an example:

```
>>> parser = ET.XMLPullParser(['start', 'end'])
>>> parser.feed('<mytag>sometext')
>>> list(parser.read_events())
[('start', <Element 'mytag' at 0x7fa66db2be58>)]
>>> parser.feed(' more text</mytag>')
>>> for event, elem in parser.read_events():
...     print(event)
...     print(elem.tag, 'text=', elem.text)
...
end
```

The obvious use case is applications that operate in a non-blocking fashion where the XML data is being received from a socket or read incrementally from some storage device. In such cases, blocking reads are unacceptable.

Because it's so flexible, *XMLPullParser* can be inconvenient to use for simpler use-cases. If you don't mind your application blocking on reading XML data but would still like to have incremental parsing capabilities, take a look at *iterparse()*. It can be useful when you're reading a large XML document and don't want to hold it wholly in memory.

Finding interesting elements

Element has some useful methods that help iterate recursively over all the sub-tree below it (its children, their children, and so on). For example, *Element.iter()*:

```
>>> for neighbor in root.iter('neighbor'):
...     print(neighbor.attrib)
...
{'name': 'Austria', 'direction': 'E'}
{'name': 'Switzerland', 'direction': 'W'}
{'name': 'Malaysia', 'direction': 'N'}
```

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```
{'name': 'Costa Rica', 'direction': 'W'}
{'name': 'Colombia', 'direction': 'E'}
```

Element.findall() finds only elements with a tag which are direct children of the current element. *Element.find()* finds the *first* child with a particular tag, and *Element.text* accesses the element's text content. *Element.get()* accesses the element's attributes:

```
>>> for country in root.findall('country'):
...     rank = country.find('rank').text
...     name = country.get('name')
...     print(name, rank)
...
Liechtenstein 1
Singapore 4
Panama 68
```

More sophisticated specification of which elements to look for is possible by using *XPath*.

Modifying an XML File

ElementTree provides a simple way to build XML documents and write them to files. The *ElementTree.write()* method serves this purpose.

Once created, an *Element* object may be manipulated by directly changing its fields (such as *Element.text*), adding and modifying attributes (*Element.set()* method), as well as adding new children (for example with *Element.append()*).

Let's say we want to add one to each country's rank, and add an `updated` attribute to the rank element:

```
>>> for rank in root.iter('rank'):
...     new_rank = int(rank.text) + 1
...     rank.text = str(new_rank)
...     rank.set('updated', 'yes')
...
>>> tree.write('output.xml')
```

Our XML now looks like this:

```
<?xml version="1.0"?>
<data>
    <country name="Liechtenstein">
        <rank updated="yes">2</rank>
        <year>2008</year>
        <gdppc>141100</gdppc>
        <neighbor name="Austria" direction="E"/>
        <neighbor name="Switzerland" direction="W"/>
    </country>
    <country name="Singapore">
        <rank updated="yes">5</rank>
        <year>2011</year>
        <gdppc>59900</gdppc>
        <neighbor name="Malaysia" direction="N"/>
    </country>
    <country name="Panama">
        <rank updated="yes">69</rank>
        <year>2011</year>
```

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```
        <gdppc>13600</gdppc>
        <neighbor name="Costa Rica" direction="W"/>
        <neighbor name="Colombia" direction="E"/>
    </country>
</data>
```

We can remove elements using *Element.remove()*. Let's say we want to remove all countries with a rank higher than 50:

```
>>> for country in root.findall('country'):
...     rank = int(country.find('rank').text)
...     if rank > 50:
...         root.remove(country)
...
>>> tree.write('output.xml')
```

Our XML now looks like this:

```
<?xml version="1.0"?>
<data>
    <country name="Liechtenstein">
        <rank updated="yes">2</rank>
        <year>2008</year>
        <gdppc>141100</gdppc>
        <neighbor name="Austria" direction="E"/>
        <neighbor name="Switzerland" direction="W"/>
    </country>
    <country name="Singapore">
        <rank updated="yes">5</rank>
        <year>2011</year>
        <gdppc>59900</gdppc>
        <neighbor name="Malaysia" direction="N"/>
    </country>
</data>
```

Building XML documents

The *SubElement()* function also provides a convenient way to create new sub-elements for a given element:

```
>>> a = ET.Element('a')
>>> b = ET.SubElement(a, 'b')
>>> c = ET.SubElement(a, 'c')
>>> d = ET.SubElement(c, 'd')
>>> ET.dump(a)
<a><b /><c><d /></c></a>
```

Parsing XML with Namespaces

If the XML input has namespaces, tags and attributes with prefixes in the form `prefix:sometag` get expanded to `{uri}sometag` where the *prefix* is replaced by the full *URI*. Also, if there is a default namespace, that full URI gets prepended to all of the non-prefixed tags.

Here is an XML example that incorporates two namespaces, one with the prefix "fictional" and the other serving as the default namespace:

```
<?xml version="1.0"?>
<actors xmlns:fictional="http://characters.example.com"
        xmlns="http://people.example.com">
    <actor>
        <name>John Cleese</name>
        <fictional:character>Lancelot</fictional:character>
        <fictional:character>Archie Leach</fictional:character>
    </actor>
    <actor>
        <name>Eric Idle</name>
        <fictional:character>Sir Robin</fictional:character>
        <fictional:character>Gunther</fictional:character>
        <fictional:character>Commander Clement</fictional:character>
    </actor>
</actors>
```

One way to search and explore this XML example is to manually add the URI to every tag or attribute in the xpath of a *find()* or *findall()*:

```
root = fromstring(xml_text)
for actor in root.findall('{http://people.example.com}actor'):
    name = actor.find('{http://people.example.com}name')
    print(name.text)
    for char in actor.findall('{http://characters.example.com}character'):
        print(' |-->', char.text)
```

A better way to search the namespaced XML example is to create a dictionary with your own prefixes and use those in the search functions:

```
ns = {'real_person': 'http://people.example.com',
      'role': 'http://characters.example.com'}

for actor in root.findall('real_person:actor', ns):
    name = actor.find('real_person:name', ns)
    print(name.text)
    for char in actor.findall('role:character', ns):
        print(' |-->', char.text)
```

These two approaches both output:

```
John Cleese
 |--> Lancelot
 |--> Archie Leach
Eric Idle
 |--> Sir Robin
 |--> Gunther
 |--> Commander Clement
```

Additional resources

See http://effbot.org/zone/element-index.htm for tutorials and links to other docs.

21.5.2 XPath support

This module provides limited support for XPath expressions for locating elements in a tree. The goal is to support a small subset of the abbreviated syntax; a full XPath engine is outside the scope of the module.

Example

Here's an example that demonstrates some of the XPath capabilities of the module. We'll be using the `countrydata` XML document from the *Parsing XML* section:

```
import xml.etree.ElementTree as ET

root = ET.fromstring(countrydata)

# Top-level elements
root.findall(".")

# All 'neighbor' grand-children of 'country' children of the top-level
# elements
root.findall("./country/neighbor")

# Nodes with name='Singapore' that have a 'year' child
root.findall(".//year/..[@name='Singapore']")

# 'year' nodes that are children of nodes with name='Singapore'
root.findall(".//*[@name='Singapore']/year")

# All 'neighbor' nodes that are the second child of their parent
root.findall(".//neighbor[2]")
```

Supported XPath syntax

Syntax	Meaning
`tag`	Selects all child elements with the given tag. For example, `spam` selects all child elements named `spam`, and `spam/egg` selects all grandchildren named `egg` in all children named `spam`.
`*`	Selects all child elements. For example, `*/egg` selects all grandchildren named `egg`.
`.`	Selects the current node. This is mostly useful at the beginning of the path, to indicate that it's a relative path.
`//`	Selects all subelements, on all levels beneath the current element. For example, `.//egg` selects all `egg` elements in the entire tree.
`..`	Selects the parent element. Returns `None` if the path attempts to reach the ancestors of the start element (the element `find` was called on).
`[@attrib]`	Selects all elements that have the given attribute.
`[@attrib='value']`	Selects all elements for which the given attribute has the given value. The value cannot contain quotes.
`[tag]`	Selects all elements that have a child named `tag`. Only immediate children are supported.
`[.='text']`	Selects all elements whose complete text content, including descendants, equals the given `text`. New in version 3.7.
`[tag='text']`	Selects all elements that have a child named `tag` whose complete text content, including descendants, equals the given `text`.
`[position]`	Selects all elements that are located at the given position. The position can be either an integer (1 is the first position), the expression `last()` (for the last position), or a position relative to the last position (e.g. `last()-1`).

Predicates (expressions within square brackets) must be preceded by a tag name, an asterisk, or another

predicate. `position` predicates must be preceded by a tag name.

21.5.3 Reference

Functions

`xml.etree.ElementTree.Comment`(*text=None*)
Comment element factory. This factory function creates a special element that will be serialized as an XML comment by the standard serializer. The comment string can be either a bytestring or a Unicode string. *text* is a string containing the comment string. Returns an element instance representing a comment.

Note that *XMLParser* skips over comments in the input instead of creating comment objects for them. An *ElementTree* will only contain comment nodes if they have been inserted into to the tree using one of the *Element* methods.

`xml.etree.ElementTree.dump`(*elem*)
Writes an element tree or element structure to sys.stdout. This function should be used for debugging only.

The exact output format is implementation dependent. In this version, it's written as an ordinary XML file.

elem is an element tree or an individual element.

`xml.etree.ElementTree.fromstring`(*text*)
Parses an XML section from a string constant. Same as *XML()*. *text* is a string containing XML data. Returns an *Element* instance.

`xml.etree.ElementTree.fromstringlist`(*sequence*, *parser=None*)
Parses an XML document from a sequence of string fragments. *sequence* is a list or other sequence containing XML data fragments. *parser* is an optional parser instance. If not given, the standard *XMLParser* parser is used. Returns an *Element* instance.

New in version 3.2.

`xml.etree.ElementTree.iselement`(*element*)
Checks if an object appears to be a valid element object. *element* is an element instance. Returns a true value if this is an element object.

`xml.etree.ElementTree.iterparse`(*source*, *events=None*, *parser=None*)
Parses an XML section into an element tree incrementally, and reports what's going on to the user. *source* is a filename or *file object* containing XML data. *events* is a sequence of events to report back. The supported events are the strings `"start"`, `"end"`, `"start-ns"` and `"end-ns"` (the "ns" events are used to get detailed namespace information). If *events* is omitted, only `"end"` events are reported. *parser* is an optional parser instance. If not given, the standard *XMLParser* parser is used. *parser* must be a subclass of *XMLParser* and can only use the default *TreeBuilder* as a target. Returns an *iterator* providing `(event, elem)` pairs.

Note that while *iterparse()* builds the tree incrementally, it issues blocking reads on *source* (or the file it names). As such, it's unsuitable for applications where blocking reads can't be made. For fully non-blocking parsing, see *XMLPullParser*.

Note: *iterparse()* only guarantees that it has seen the ">" character of a starting tag when it emits a "start" event, so the attributes are defined, but the contents of the text and tail attributes are undefined at that point. The same applies to the element children; they may or may not be present.

If you need a fully populated element, look for "end" events instead.

Deprecated since version 3.4: The *parser* argument.

xml.etree.ElementTree.**parse**(*source*, *parser=None*)
Parses an XML section into an element tree. *source* is a filename or file object containing XML data. *parser* is an optional parser instance. If not given, the standard *XMLParser* parser is used. Returns an *ElementTree* instance.

xml.etree.ElementTree.**ProcessingInstruction**(*target*, *text=None*)
PI element factory. This factory function creates a special element that will be serialized as an XML processing instruction. *target* is a string containing the PI target. *text* is a string containing the PI contents, if given. Returns an element instance, representing a processing instruction.

Note that *XMLParser* skips over processing instructions in the input instead of creating comment objects for them. An *ElementTree* will only contain processing instruction nodes if they have been inserted into to the tree using one of the *Element* methods.

xml.etree.ElementTree.**register_namespace**(*prefix*, *uri*)
Registers a namespace prefix. The registry is global, and any existing mapping for either the given prefix or the namespace URI will be removed. *prefix* is a namespace prefix. *uri* is a namespace uri. Tags and attributes in this namespace will be serialized with the given prefix, if at all possible.

New in version 3.2.

xml.etree.ElementTree.**SubElement**(*parent*, *tag*, *attrib={}*, ***extra*)
Subelement factory. This function creates an element instance, and appends it to an existing element.

The element name, attribute names, and attribute values can be either bytestrings or Unicode strings. *parent* is the parent element. *tag* is the subelement name. *attrib* is an optional dictionary, containing element attributes. *extra* contains additional attributes, given as keyword arguments. Returns an element instance.

xml.etree.ElementTree.**tostring**(*element*, *encoding="us-ascii"*, *method="xml"*, ***, *short_empty_elements=True*)
Generates a string representation of an XML element, including all subelements. *element* is an *Element* instance. *encoding*[1] is the output encoding (default is US-ASCII). Use `encoding="unicode"` to generate a Unicode string (otherwise, a bytestring is generated). *method* is either `"xml"`, `"html"` or `"text"` (default is `"xml"`). *short_empty_elements* has the same meaning as in *ElementTree.write()*. Returns an (optionally) encoded string containing the XML data.

New in version 3.4: The *short_empty_elements* parameter.

xml.etree.ElementTree.**tostringlist**(*element*, *encoding="us-ascii"*, *method="xml"*, ***, *short_empty_elements=True*)
Generates a string representation of an XML element, including all subelements. *element* is an *Element* instance. *encoding*[1] is the output encoding (default is US-ASCII). Use `encoding="unicode"` to generate a Unicode string (otherwise, a bytestring is generated). *method* is either `"xml"`, `"html"` or `"text"` (default is `"xml"`). *short_empty_elements* has the same meaning as in *ElementTree.write()*. Returns a list of (optionally) encoded strings containing the XML data. It does not guarantee any specific sequence, except that `b"".join(tostringlist(element)) == tostring(element)`.

New in version 3.2.

New in version 3.4: The *short_empty_elements* parameter.

xml.etree.ElementTree.**XML**(*text*, *parser=None*)
Parses an XML section from a string constant. This function can be used to embed "XML literals" in Python code. *text* is a string containing XML data. *parser* is an optional parser instance. If not given, the standard *XMLParser* parser is used. Returns an *Element* instance.

[1] The encoding string included in XML output should conform to the appropriate standards. For example, "UTF-8" is valid, but "UTF8" is not. See https://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl and https://www.iana.org/assignments/character-sets/character-sets.xhtml.

xml.etree.ElementTree.**XMLID**(*text*, *parser=None*)
Parses an XML section from a string constant, and also returns a dictionary which maps from element id:s to elements. *text* is a string containing XML data. *parser* is an optional parser instance. If not given, the standard *XMLParser* parser is used. Returns a tuple containing an *Element* instance and a dictionary.

Element Objects

class xml.etree.ElementTree.**Element**(*tag*, *attrib={}*, ***extra*)
Element class. This class defines the Element interface, and provides a reference implementation of this interface.

The element name, attribute names, and attribute values can be either bytestrings or Unicode strings. *tag* is the element name. *attrib* is an optional dictionary, containing element attributes. *extra* contains additional attributes, given as keyword arguments.

tag
A string identifying what kind of data this element represents (the element type, in other words).

text
tail
These attributes can be used to hold additional data associated with the element. Their values are usually strings but may be any application-specific object. If the element is created from an XML file, the *text* attribute holds either the text between the element's start tag and its first child or end tag, or `None`, and the *tail* attribute holds either the text between the element's end tag and the next tag, or `None`. For the XML data

```
<a><b>1<c>2<d/>3</c></b>4</a>
```

the *a* element has `None` for both *text* and *tail* attributes, the *b* element has *text* `"1"` and *tail* `"4"`, the *c* element has *text* `"2"` and *tail* `None`, and the *d* element has *text* `None` and *tail* `"3"`.

To collect the inner text of an element, see *itertext()*, for example `"".join(element.itertext())`.

Applications may store arbitrary objects in these attributes.

attrib
A dictionary containing the element's attributes. Note that while the *attrib* value is always a real mutable Python dictionary, an ElementTree implementation may choose to use another internal representation, and create the dictionary only if someone asks for it. To take advantage of such implementations, use the dictionary methods below whenever possible.

The following dictionary-like methods work on the element attributes.

clear()
Resets an element. This function removes all subelements, clears all attributes, and sets the text and tail attributes to `None`.

get(*key*, *default=None*)
Gets the element attribute named *key*.

Returns the attribute value, or *default* if the attribute was not found.

items()
Returns the element attributes as a sequence of (name, value) pairs. The attributes are returned in an arbitrary order.

keys()
Returns the elements attribute names as a list. The names are returned in an arbitrary order.

set(*key*, *value*)
Set the attribute *key* on the element to *value*.

The following methods work on the element's children (subelements).

append(*subelement*)
Adds the element *subelement* to the end of this element's internal list of subelements. Raises *TypeError* if *subelement* is not an *Element*.

extend(*subelements*)
Appends *subelements* from a sequence object with zero or more elements. Raises *TypeError* if a subelement is not an *Element*.

New in version 3.2.

find(*match*, *namespaces=None*)
Finds the first subelement matching *match*. *match* may be a tag name or a *path*. Returns an element instance or `None`. *namespaces* is an optional mapping from namespace prefix to full name.

findall(*match*, *namespaces=None*)
Finds all matching subelements, by tag name or *path*. Returns a list containing all matching elements in document order. *namespaces* is an optional mapping from namespace prefix to full name.

findtext(*match*, *default=None*, *namespaces=None*)
Finds text for the first subelement matching *match*. *match* may be a tag name or a *path*. Returns the text content of the first matching element, or *default* if no element was found. Note that if the matching element has no text content an empty string is returned. *namespaces* is an optional mapping from namespace prefix to full name.

getchildren()
Deprecated since version 3.2: Use `list(elem)` or iteration.

getiterator(*tag=None*)
Deprecated since version 3.2: Use method *Element.iter()* instead.

insert(*index*, *subelement*)
Inserts *subelement* at the given position in this element. Raises *TypeError* if *subelement* is not an *Element*.

iter(*tag=None*)
Creates a tree *iterator* with the current element as the root. The iterator iterates over this element and all elements below it, in document (depth first) order. If *tag* is not `None` or `'*'`, only elements whose tag equals *tag* are returned from the iterator. If the tree structure is modified during iteration, the result is undefined.

New in version 3.2.

iterfind(*match*, *namespaces=None*)
Finds all matching subelements, by tag name or *path*. Returns an iterable yielding all matching elements in document order. *namespaces* is an optional mapping from namespace prefix to full name.

New in version 3.2.

itertext()
Creates a text iterator. The iterator loops over this element and all subelements, in document order, and returns all inner text.

New in version 3.2.

makeelement(*tag*, *attrib*)
Creates a new element object of the same type as this element. Do not call this method, use the *SubElement()* factory function instead.

remove(*subelement*)
Removes *subelement* from the element. Unlike the find* methods this method compares elements based on the instance identity, not on tag value or contents.

Element objects also support the following sequence type methods for working with subelements: `__delitem__()`, `__getitem__()`, `__setitem__()`, `__len__()`.

Caution: Elements with no subelements will test as `False`. This behavior will change in future versions. Use specific `len(elem)` or `elem is None` test instead.

```
element = root.find('foo')

if not element:  # careful!
    print("element not found, or element has no subelements")

if element is None:
    print("element not found")
```

ElementTree Objects

class xml.etree.ElementTree.**ElementTree**(*element=None*, *file=None*)
ElementTree wrapper class. This class represents an entire element hierarchy, and adds some extra support for serialization to and from standard XML.

element is the root element. The tree is initialized with the contents of the XML *file* if given.

_setroot(*element*)
Replaces the root element for this tree. This discards the current contents of the tree, and replaces it with the given element. Use with care. *element* is an element instance.

find(*match*, *namespaces=None*)
Same as *Element.find()*, starting at the root of the tree.

findall(*match*, *namespaces=None*)
Same as *Element.findall()*, starting at the root of the tree.

findtext(*match*, *default=None*, *namespaces=None*)
Same as *Element.findtext()*, starting at the root of the tree.

getiterator(*tag=None*)
Deprecated since version 3.2: Use method *ElementTree.iter()* instead.

getroot()
Returns the root element for this tree.

iter(*tag=None*)
Creates and returns a tree iterator for the root element. The iterator loops over all elements in this tree, in section order. *tag* is the tag to look for (default is to return all elements).

iterfind(*match*, *namespaces=None*)
Same as *Element.iterfind()*, starting at the root of the tree.

New in version 3.2.

parse(*source*, *parser=None*)
Loads an external XML section into this element tree. *source* is a file name or *file object*. *parser* is an optional parser instance. If not given, the standard *XMLParser* parser is used. Returns the section root element.

write(*file*, *encoding="us-ascii"*, *xml_declaration=None*, *default_namespace=None*, *method="xml"*, ***, *short_empty_elements=True*)
Writes the element tree to a file, as XML. *file* is a file name, or a *file object* opened for writing.

encoding[1] is the output encoding (default is US-ASCII). *xml_declaration* controls if an XML declaration should be added to the file. Use `False` for never, `True` for always, `None` for only if not US-ASCII or UTF-8 or Unicode (default is `None`). *default_namespace* sets the default XML namespace (for "xmlns"). *method* is either `"xml"`, `"html"` or `"text"` (default is `"xml"`). The keyword-only *short_empty_elements* parameter controls the formatting of elements that contain no content. If `True` (the default), they are emitted as a single self-closed tag, otherwise they are emitted as a pair of start/end tags.

The output is either a string (*str*) or binary (*bytes*). This is controlled by the *encoding* argument. If *encoding* is `"unicode"`, the output is a string; otherwise, it's binary. Note that this may conflict with the type of *file* if it's an open *file object*; make sure you do not try to write a string to a binary stream and vice versa.

New in version 3.4: The *short_empty_elements* parameter.

This is the XML file that is going to be manipulated:

```
<html>
    <head>
        <title>Example page</title>
    </head>
    <body>
        <p>Moved to <a href="http://example.org/">example.org</a>
        or <a href="http://example.com/">example.com</a>.</p>
    </body>
</html>
```

Example of changing the attribute "target" of every link in first paragraph:

```
>>> from xml.etree.ElementTree import ElementTree
>>> tree = ElementTree()
>>> tree.parse("index.xhtml")
<Element 'html' at 0xb77e6fac>
>>> p = tree.find("body/p")     # Finds first occurrence of tag p in body
>>> p
<Element 'p' at 0xb77ec26c>
>>> links = list(p.iter("a"))   # Returns list of all links
>>> links
[<Element 'a' at 0xb77ec2ac>, <Element 'a' at 0xb77ec1cc>]
>>> for i in links:             # Iterates through all found links
...     i.attrib["target"] = "blank"
>>> tree.write("output.xhtml")
```

QName Objects

class xml.etree.ElementTree.**QName**(*text_or_uri*, *tag=None*)

QName wrapper. This can be used to wrap a QName attribute value, in order to get proper namespace handling on output. *text_or_uri* is a string containing the QName value, in the form {uri}local, or, if the tag argument is given, the URI part of a QName. If *tag* is given, the first argument is interpreted as a URI, and this argument is interpreted as a local name. *QName* instances are opaque.

TreeBuilder Objects

class xml.etree.ElementTree.**TreeBuilder**(*element_factory=None*)

Generic element structure builder. This builder converts a sequence of start, data, and end method calls to a well-formed element structure. You can use this class to build an element structure using a

custom XML parser, or a parser for some other XML-like format. *element_factory*, when given, must be a callable accepting two positional arguments: a tag and a dict of attributes. It is expected to return a new element instance.

close()
Flushes the builder buffers, and returns the toplevel document element. Returns an *Element* instance.

data(*data*)
Adds text to the current element. *data* is a string. This should be either a bytestring, or a Unicode string.

end(*tag*)
Closes the current element. *tag* is the element name. Returns the closed element.

start(*tag*, *attrs*)
Opens a new element. *tag* is the element name. *attrs* is a dictionary containing element attributes. Returns the opened element.

In addition, a custom *TreeBuilder* object can provide the following method:

doctype(*name*, *pubid*, *system*)
Handles a doctype declaration. *name* is the doctype name. *pubid* is the public identifier. *system* is the system identifier. This method does not exist on the default *TreeBuilder* class.

New in version 3.2.

XMLParser Objects

class xml.etree.ElementTree.**XMLParser**(*html=0*, *target=None*, *encoding=None*)
This class is the low-level building block of the module. It uses *xml.parsers.expat* for efficient, event-based parsing of XML. It can be fed XML data incrementally with the *feed()* method, and parsing events are translated to a push API - by invoking callbacks on the *target* object. If *target* is omitted, the standard *TreeBuilder* is used. The *html* argument was historically used for backwards compatibility and is now deprecated. If *encoding*[1] is given, the value overrides the encoding specified in the XML file.

Deprecated since version 3.4: The *html* argument. The remaining arguments should be passed via keyword to prepare for the removal of the *html* argument.

close()
Finishes feeding data to the parser. Returns the result of calling the `close()` method of the *target* passed during construction; by default, this is the toplevel document element.

doctype(*name*, *pubid*, *system*)
Deprecated since version 3.2: Define the *TreeBuilder.doctype()* method on a custom TreeBuilder target.

feed(*data*)
Feeds data to the parser. *data* is encoded data.

XMLParser.feed() calls *target*'s `start(tag, attrs_dict)` method for each opening tag, its `end(tag)` method for each closing tag, and data is processed by method `data(data)`. *XMLParser.close()* calls *target*'s method `close()`. *XMLParser* can be used not only for building a tree structure. This is an example of counting the maximum depth of an XML file:

```
>>> from xml.etree.ElementTree import XMLParser
>>> class MaxDepth:                     # The target object of the parser
...     maxDepth = 0
...     depth = 0
```

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```
...     def start(self, tag, attrib):   # Called for each opening tag.
...         self.depth += 1
...         if self.depth > self.maxDepth:
...             self.maxDepth = self.depth
...     def end(self, tag):             # Called for each closing tag.
...         self.depth -= 1
...     def data(self, data):
...         pass            # We do not need to do anything with data.
...     def close(self):    # Called when all data has been parsed.
...         return self.maxDepth
...
>>> target = MaxDepth()
>>> parser = XMLParser(target=target)
>>> exampleXml = """
... <a>
...   <b>
...   </b>
...   <b>
...     <c>
...       <d>
...       </d>
...     </c>
...   </b>
... </a>"""
>>> parser.feed(exampleXml)
>>> parser.close()
4
```

XMLPullParser Objects

class xml.etree.ElementTree.**XMLPullParser**(*events=None*)

A pull parser suitable for non-blocking applications. Its input-side API is similar to that of *XMLParser*, but instead of pushing calls to a callback target, *XMLPullParser* collects an internal list of parsing events and lets the user read from it. *events* is a sequence of events to report back. The supported events are the strings `"start"`, `"end"`, `"start-ns"` and `"end-ns"` (the "ns" events are used to get detailed namespace information). If *events* is omitted, only `"end"` events are reported.

feed(*data*)

Feed the given bytes data to the parser.

close()

Signal the parser that the data stream is terminated. Unlike *XMLParser.close()*, this method always returns *None*. Any events not yet retrieved when the parser is closed can still be read with *read_events()*.

read_events()

Return an iterator over the events which have been encountered in the data fed to the parser. The iterator yields `(event, elem)` pairs, where *event* is a string representing the type of event (e.g. `"end"`) and *elem* is the encountered *Element* object.

Events provided in a previous call to *read_events()* will not be yielded again. Events are consumed from the internal queue only when they are retrieved from the iterator, so multiple readers iterating in parallel over iterators obtained from *read_events()* will have unpredictable results.

Note: *XMLPullParser* only guarantees that it has seen the ">" character of a starting tag when it emits a "start" event, so the attributes are defined, but the contents of the text and tail attributes are undefined at that point. The same applies to the element children; they may or may not be present.

If you need a fully populated element, look for "end" events instead.

New in version 3.4.

Exceptions

`class xml.etree.ElementTree.ParseError`
XML parse error, raised by the various parsing methods in this module when parsing fails. The string representation of an instance of this exception will contain a user-friendly error message. In addition, it will have the following attributes available:

`code`
A numeric error code from the expat parser. See the documentation of *xml.parsers.expat* for the list of error codes and their meanings.

`position`
A tuple of *line*, *column* numbers, specifying where the error occurred.

21.6 `xml.dom` — The Document Object Model API

Source code: Lib/xml/dom/__init__.py

The Document Object Model, or "DOM," is a cross-language API from the World Wide Web Consortium (W3C) for accessing and modifying XML documents. A DOM implementation presents an XML document as a tree structure, or allows client code to build such a structure from scratch. It then gives access to the structure through a set of objects which provided well-known interfaces.

The DOM is extremely useful for random-access applications. SAX only allows you a view of one bit of the document at a time. If you are looking at one SAX element, you have no access to another. If you are looking at a text node, you have no access to a containing element. When you write a SAX application, you need to keep track of your program's position in the document somewhere in your own code. SAX does not do it for you. Also, if you need to look ahead in the XML document, you are just out of luck.

Some applications are simply impossible in an event driven model with no access to a tree. Of course you could build some sort of tree yourself in SAX events, but the DOM allows you to avoid writing that code. The DOM is a standard tree representation for XML data.

The Document Object Model is being defined by the W3C in stages, or "levels" in their terminology. The Python mapping of the API is substantially based on the DOM Level 2 recommendation.

DOM applications typically start by parsing some XML into a DOM. How this is accomplished is not covered at all by DOM Level 1, and Level 2 provides only limited improvements: There is a `DOMImplementation` object class which provides access to `Document` creation methods, but no way to access an XML reader/parser/Document builder in an implementation-independent way. There is also no well-defined way to access these methods without an existing `Document` object. In Python, each DOM implementation will provide a function *getDOMImplementation()*. DOM Level 3 adds a Load/Store specification, which defines an interface to the reader, but this is not yet available in the Python standard library.

Once you have a DOM document object, you can access the parts of your XML document through its properties and methods. These properties are defined in the DOM specification; this portion of the reference manual describes the interpretation of the specification in Python.

The specification provided by the W3C defines the DOM API for Java, ECMAScript, and OMG IDL. The Python mapping defined here is based in large part on the IDL version of the specification, but strict compliance is not required (though implementations are free to support the strict mapping from IDL). See section *Conformance* for a detailed discussion of mapping requirements.

See also:

Document Object Model (DOM) Level 2 Specification The W3C recommendation upon which the Python DOM API is based.

Document Object Model (DOM) Level 1 Specification The W3C recommendation for the DOM supported by *xml.dom.minidom*.

Python Language Mapping Specification This specifies the mapping from OMG IDL to Python.

21.6.1 Module Contents

The *xml.dom* contains the following functions:

`xml.dom.registerDOMImplementation`(*name*, *factory*)
Register the *factory* function with the name *name*. The factory function should return an object which implements the `DOMImplementation` interface. The factory function can return the same object every time, or a new one for each call, as appropriate for the specific implementation (e.g. if that implementation supports some customization).

`xml.dom.getDOMImplementation`(*name=None*, *features=()*)
Return a suitable DOM implementation. The *name* is either well-known, the module name of a DOM implementation, or `None`. If it is not `None`, imports the corresponding module and returns a `DOMImplementation` object if the import succeeds. If no name is given, and if the environment variable `PYTHON_DOM` is set, this variable is used to find the implementation.

If name is not given, this examines the available implementations to find one with the required feature set. If no implementation can be found, raise an *ImportError*. The features list must be a sequence of `(feature, version)` pairs which are passed to the `hasFeature()` method on available `DOMImplementation` objects.

Some convenience constants are also provided:

`xml.dom.EMPTY_NAMESPACE`
The value used to indicate that no namespace is associated with a node in the DOM. This is typically found as the `namespaceURI` of a node, or used as the *namespaceURI* parameter to a namespaces-specific method.

`xml.dom.XML_NAMESPACE`
The namespace URI associated with the reserved prefix `xml`, as defined by Namespaces in XML (section 4).

`xml.dom.XMLNS_NAMESPACE`
The namespace URI for namespace declarations, as defined by Document Object Model (DOM) Level 2 Core Specification (section 1.1.8).

`xml.dom.XHTML_NAMESPACE`
The URI of the XHTML namespace as defined by XHTML 1.0: The Extensible HyperText Markup Language (section 3.1.1).

In addition, *xml.dom* contains a base `Node` class and the DOM exception classes. The `Node` class provided by this module does not implement any of the methods or attributes defined by the DOM specification;

concrete DOM implementations must provide those. The `Node` class provided as part of this module does provide the constants used for the `nodeType` attribute on concrete `Node` objects; they are located within the class rather than at the module level to conform with the DOM specifications.

21.6.2 Objects in the DOM

The definitive documentation for the DOM is the DOM specification from the W3C.

Note that DOM attributes may also be manipulated as nodes instead of as simple strings. It is fairly rare that you must do this, however, so this usage is not yet documented.

Interface	Section	Purpose
`DOMImplementation`	*DOMImplementation Objects*	Interface to the underlying implementation.
`Node`	*Node Objects*	Base interface for most objects in a document.
`NodeList`	*NodeList Objects*	Interface for a sequence of nodes.
`DocumentType`	*DocumentType Objects*	Information about the declarations needed to process a document.
`Document`	*Document Objects*	Object which represents an entire document.
`Element`	*Element Objects*	Element nodes in the document hierarchy.
`Attr`	*Attr Objects*	Attribute value nodes on element nodes.
`Comment`	*Comment Objects*	Representation of comments in the source document.
`Text`	*Text and CDATASection Objects*	Nodes containing textual content from the document.
`ProcessingInstruction`	*ProcessingInstruction Objects*	Processing instruction representation.

An additional section describes the exceptions defined for working with the DOM in Python.

DOMImplementation Objects

The `DOMImplementation` interface provides a way for applications to determine the availability of particular features in the DOM they are using. DOM Level 2 added the ability to create new `Document` and `DocumentType` objects using the `DOMImplementation` as well.

`DOMImplementation.hasFeature(`*feature*, *version*`)`
Return true if the feature identified by the pair of strings *feature* and *version* is implemented.

`DOMImplementation.createDocument(`*namespaceUri*, *qualifiedName*, *doctype*`)`
Return a new `Document` object (the root of the DOM), with a child `Element` object having the given *namespaceUri* and *qualifiedName*. The *doctype* must be a `DocumentType` object created by *createDocumentType()*, or `None`. In the Python DOM API, the first two arguments can also be `None` in order to indicate that no `Element` child is to be created.

`DOMImplementation.createDocumentType(`*qualifiedName*, *publicId*, *systemId*`)`
Return a new `DocumentType` object that encapsulates the given *qualifiedName*, *publicId*, and *systemId* strings, representing the information contained in an XML document type declaration.

Node Objects

All of the components of an XML document are subclasses of `Node`.

`Node.nodeType`
An integer representing the node type. Symbolic constants for the types are on the `Node`

object: ELEMENT_NODE, ATTRIBUTE_NODE, TEXT_NODE, CDATA_SECTION_NODE, ENTITY_NODE, PROCESSING_INSTRUCTION_NODE, COMMENT_NODE, DOCUMENT_NODE, DOCUMENT_TYPE_NODE, NOTATION_NODE. This is a read-only attribute.

Node.**parentNode**
The parent of the current node, or None for the document node. The value is always a Node object or None. For Element nodes, this will be the parent element, except for the root element, in which case it will be the Document object. For Attr nodes, this is always None. This is a read-only attribute.

Node.**attributes**
A NamedNodeMap of attribute objects. Only elements have actual values for this; others provide None for this attribute. This is a read-only attribute.

Node.**previousSibling**
The node that immediately precedes this one with the same parent. For instance the element with an end-tag that comes just before the *self* element's start-tag. Of course, XML documents are made up of more than just elements so the previous sibling could be text, a comment, or something else. If this node is the first child of the parent, this attribute will be None. This is a read-only attribute.

Node.**nextSibling**
The node that immediately follows this one with the same parent. See also *previousSibling*. If this is the last child of the parent, this attribute will be None. This is a read-only attribute.

Node.**childNodes**
A list of nodes contained within this node. This is a read-only attribute.

Node.**firstChild**
The first child of the node, if there are any, or None. This is a read-only attribute.

Node.**lastChild**
The last child of the node, if there are any, or None. This is a read-only attribute.

Node.**localName**
The part of the tagName following the colon if there is one, else the entire tagName. The value is a string.

Node.**prefix**
The part of the tagName preceding the colon if there is one, else the empty string. The value is a string, or None.

Node.**namespaceURI**
The namespace associated with the element name. This will be a string or None. This is a read-only attribute.

Node.**nodeName**
This has a different meaning for each node type; see the DOM specification for details. You can always get the information you would get here from another property such as the tagName property for elements or the name property for attributes. For all node types, the value of this attribute will be either a string or None. This is a read-only attribute.

Node.**nodeValue**
This has a different meaning for each node type; see the DOM specification for details. The situation is similar to that with *nodeName*. The value is a string or None.

Node.**hasAttributes**()
Returns true if the node has any attributes.

Node.**hasChildNodes**()
Returns true if the node has any child nodes.

Node.**isSameNode**(*other*)
Returns true if *other* refers to the same node as this node. This is especially useful for DOM imple-

mentations which use any sort of proxy architecture (because more than one object can refer to the same node).

Note: This is based on a proposed DOM Level 3 API which is still in the "working draft" stage, but this particular interface appears uncontroversial. Changes from the W3C will not necessarily affect this method in the Python DOM interface (though any new W3C API for this would also be supported).

`Node.appendChild(`*newChild*`)`
Add a new child node to this node at the end of the list of children, returning *newChild*. If the node was already in the tree, it is removed first.

`Node.insertBefore(`*newChild*, *refChild*`)`
Insert a new child node before an existing child. It must be the case that *refChild* is a child of this node; if not, *ValueError* is raised. *newChild* is returned. If *refChild* is `None`, it inserts *newChild* at the end of the children's list.

`Node.removeChild(`*oldChild*`)`
Remove a child node. *oldChild* must be a child of this node; if not, *ValueError* is raised. *oldChild* is returned on success. If *oldChild* will not be used further, its `unlink()` method should be called.

`Node.replaceChild(`*newChild*, *oldChild*`)`
Replace an existing node with a new node. It must be the case that *oldChild* is a child of this node; if not, *ValueError* is raised.

`Node.normalize()`
Join adjacent text nodes so that all stretches of text are stored as single `Text` instances. This simplifies processing text from a DOM tree for many applications.

`Node.cloneNode(`*deep*`)`
Clone this node. Setting *deep* means to clone all child nodes as well. This returns the clone.

NodeList Objects

A `NodeList` represents a sequence of nodes. These objects are used in two ways in the DOM Core recommendation: an `Element` object provides one as its list of child nodes, and the `getElementsByTagName()` and `getElementsByTagNameNS()` methods of `Node` return objects with this interface to represent query results.

The DOM Level 2 recommendation defines one method and one attribute for these objects:

`NodeList.item(`*i*`)`
Return the *i*'th item from the sequence, if there is one, or `None`. The index *i* is not allowed to be less than zero or greater than or equal to the length of the sequence.

`NodeList.length`
The number of nodes in the sequence.

In addition, the Python DOM interface requires that some additional support is provided to allow `NodeList` objects to be used as Python sequences. All `NodeList` implementations must include support for `__len__()` and `__getitem__()`; this allows iteration over the `NodeList` in `for` statements and proper support for the *len()* built-in function.

If a DOM implementation supports modification of the document, the `NodeList` implementation must also support the `__setitem__()` and `__delitem__()` methods.

DocumentType Objects

Information about the notations and entities declared by a document (including the external subset if the parser uses it and can provide the information) is available from a `DocumentType` object. The `DocumentType`

for a document is available from the `Document` object's `doctype` attribute; if there is no `DOCTYPE` declaration for the document, the document's `doctype` attribute will be set to `None` instead of an instance of this interface.

`DocumentType` is a specialization of `Node`, and adds the following attributes:

`DocumentType.publicId`
: The public identifier for the external subset of the document type definition. This will be a string or `None`.

`DocumentType.systemId`
: The system identifier for the external subset of the document type definition. This will be a URI as a string, or `None`.

`DocumentType.internalSubset`
: A string giving the complete internal subset from the document. This does not include the brackets which enclose the subset. If the document has no internal subset, this should be `None`.

`DocumentType.name`
: The name of the root element as given in the `DOCTYPE` declaration, if present.

`DocumentType.entities`
: This is a `NamedNodeMap` giving the definitions of external entities. For entity names defined more than once, only the first definition is provided (others are ignored as required by the XML recommendation). This may be `None` if the information is not provided by the parser, or if no entities are defined.

`DocumentType.notations`
: This is a `NamedNodeMap` giving the definitions of notations. For notation names defined more than once, only the first definition is provided (others are ignored as required by the XML recommendation). This may be `None` if the information is not provided by the parser, or if no notations are defined.

Document Objects

A `Document` represents an entire XML document, including its constituent elements, attributes, processing instructions, comments etc. Remember that it inherits properties from `Node`.

`Document.documentElement`
: The one and only root element of the document.

`Document.createElement(`*tagName*`)`
: Create and return a new element node. The element is not inserted into the document when it is created. You need to explicitly insert it with one of the other methods such as `insertBefore()` or `appendChild()`.

`Document.createElementNS(`*namespaceURI*`, `*tagName*`)`
: Create and return a new element with a namespace. The *tagName* may have a prefix. The element is not inserted into the document when it is created. You need to explicitly insert it with one of the other methods such as `insertBefore()` or `appendChild()`.

`Document.createTextNode(`*data*`)`
: Create and return a text node containing the data passed as a parameter. As with the other creation methods, this one does not insert the node into the tree.

`Document.createComment(`*data*`)`
: Create and return a comment node containing the data passed as a parameter. As with the other creation methods, this one does not insert the node into the tree.

`Document.createProcessingInstruction(`*target*`, `*data*`)`
: Create and return a processing instruction node containing the *target* and *data* passed as parameters. As with the other creation methods, this one does not insert the node into the tree.

`Document.createAttribute(`*name*`)`
Create and return an attribute node. This method does not associate the attribute node with any particular element. You must use `setAttributeNode()` on the appropriate `Element` object to use the newly created attribute instance.

`Document.createAttributeNS(`*namespaceURI*, *qualifiedName*`)`
Create and return an attribute node with a namespace. The *tagName* may have a prefix. This method does not associate the attribute node with any particular element. You must use `setAttributeNode()` on the appropriate `Element` object to use the newly created attribute instance.

`Document.getElementsByTagName(`*tagName*`)`
Search for all descendants (direct children, children's children, etc.) with a particular element type name.

`Document.getElementsByTagNameNS(`*namespaceURI*, *localName*`)`
Search for all descendants (direct children, children's children, etc.) with a particular namespace URI and localname. The localname is the part of the namespace after the prefix.

Element Objects

`Element` is a subclass of `Node`, so inherits all the attributes of that class.

`Element.tagName`
The element type name. In a namespace-using document it may have colons in it. The value is a string.

`Element.getElementsByTagName(`*tagName*`)`
Same as equivalent method in the `Document` class.

`Element.getElementsByTagNameNS(`*namespaceURI*, *localName*`)`
Same as equivalent method in the `Document` class.

`Element.hasAttribute(`*name*`)`
Returns true if the element has an attribute named by *name*.

`Element.hasAttributeNS(`*namespaceURI*, *localName*`)`
Returns true if the element has an attribute named by *namespaceURI* and *localName*.

`Element.getAttribute(`*name*`)`
Return the value of the attribute named by *name* as a string. If no such attribute exists, an empty string is returned, as if the attribute had no value.

`Element.getAttributeNode(`*attrname*`)`
Return the `Attr` node for the attribute named by *attrname*.

`Element.getAttributeNS(`*namespaceURI*, *localName*`)`
Return the value of the attribute named by *namespaceURI* and *localName* as a string. If no such attribute exists, an empty string is returned, as if the attribute had no value.

`Element.getAttributeNodeNS(`*namespaceURI*, *localName*`)`
Return an attribute value as a node, given a *namespaceURI* and *localName*.

`Element.removeAttribute(`*name*`)`
Remove an attribute by name. If there is no matching attribute, a *NotFoundErr* is raised.

`Element.removeAttributeNode(`*oldAttr*`)`
Remove and return *oldAttr* from the attribute list, if present. If *oldAttr* is not present, *NotFoundErr* is raised.

`Element.removeAttributeNS(`*namespaceURI*, *localName*`)`
Remove an attribute by name. Note that it uses a localName, not a qname. No exception is raised if there is no matching attribute.

Element.**setAttribute**(*name*, *value*)
Set an attribute value from a string.

Element.**setAttributeNode**(*newAttr*)
Add a new attribute node to the element, replacing an existing attribute if necessary if the `name` attribute matches. If a replacement occurs, the old attribute node will be returned. If *newAttr* is already in use, *InuseAttributeErr* will be raised.

Element.**setAttributeNodeNS**(*newAttr*)
Add a new attribute node to the element, replacing an existing attribute if necessary if the `namespaceURI` and `localName` attributes match. If a replacement occurs, the old attribute node will be returned. If *newAttr* is already in use, *InuseAttributeErr* will be raised.

Element.**setAttributeNS**(*namespaceURI*, *qname*, *value*)
Set an attribute value from a string, given a *namespaceURI* and a *qname*. Note that a qname is the whole attribute name. This is different than above.

Attr Objects

`Attr` inherits from `Node`, so inherits all its attributes.

Attr.**name**
The attribute name. In a namespace-using document it may include a colon.

Attr.**localName**
The part of the name following the colon if there is one, else the entire name. This is a read-only attribute.

Attr.**prefix**
The part of the name preceding the colon if there is one, else the empty string.

Attr.**value**
The text value of the attribute. This is a synonym for the `nodeValue` attribute.

NamedNodeMap Objects

`NamedNodeMap` does *not* inherit from `Node`.

NamedNodeMap.**length**
The length of the attribute list.

NamedNodeMap.**item**(*index*)
Return an attribute with a particular index. The order you get the attributes in is arbitrary but will be consistent for the life of a DOM. Each item is an attribute node. Get its value with the `value` attribute.

There are also experimental methods that give this class more mapping behavior. You can use them or you can use the standardized `getAttribute*()` family of methods on the `Element` objects.

Comment Objects

`Comment` represents a comment in the XML document. It is a subclass of `Node`, but cannot have child nodes.

Comment.**data**
The content of the comment as a string. The attribute contains all characters between the leading `<!--` and trailing `-->`, but does not include them.

Text and CDATASection Objects

The `Text` interface represents text in the XML document. If the parser and DOM implementation support the DOM's XML extension, portions of the text enclosed in CDATA marked sections are stored in `CDATASection` objects. These two interfaces are identical, but provide different values for the `nodeType` attribute.

These interfaces extend the `Node` interface. They cannot have child nodes.

`Text.data`
The content of the text node as a string.

Note: The use of a `CDATASection` node does not indicate that the node represents a complete CDATA marked section, only that the content of the node was part of a CDATA section. A single CDATA section may be represented by more than one node in the document tree. There is no way to determine whether two adjacent `CDATASection` nodes represent different CDATA marked sections.

ProcessingInstruction Objects

Represents a processing instruction in the XML document; this inherits from the `Node` interface and cannot have child nodes.

`ProcessingInstruction.target`
The content of the processing instruction up to the first whitespace character. This is a read-only attribute.

`ProcessingInstruction.data`
The content of the processing instruction following the first whitespace character.

Exceptions

The DOM Level 2 recommendation defines a single exception, *`DOMException`*, and a number of constants that allow applications to determine what sort of error occurred. *`DOMException`* instances carry a *`code`* attribute that provides the appropriate value for the specific exception.

The Python DOM interface provides the constants, but also expands the set of exceptions so that a specific exception exists for each of the exception codes defined by the DOM. The implementations must raise the appropriate specific exception, each of which carries the appropriate value for the *`code`* attribute.

exception `xml.dom.DOMException`
Base exception class used for all specific DOM exceptions. This exception class cannot be directly instantiated.

exception `xml.dom.DomstringSizeErr`
Raised when a specified range of text does not fit into a string. This is not known to be used in the Python DOM implementations, but may be received from DOM implementations not written in Python.

exception `xml.dom.HierarchyRequestErr`
Raised when an attempt is made to insert a node where the node type is not allowed.

exception `xml.dom.IndexSizeErr`
Raised when an index or size parameter to a method is negative or exceeds the allowed values.

exception `xml.dom.InuseAttributeErr`
Raised when an attempt is made to insert an `Attr` node that is already present elsewhere in the document.

exception xml.dom.InvalidAccessErr
Raised if a parameter or an operation is not supported on the underlying object.

exception xml.dom.InvalidCharacterErr
This exception is raised when a string parameter contains a character that is not permitted in the context it's being used in by the XML 1.0 recommendation. For example, attempting to create an `Element` node with a space in the element type name will cause this error to be raised.

exception xml.dom.InvalidModificationErr
Raised when an attempt is made to modify the type of a node.

exception xml.dom.InvalidStateErr
Raised when an attempt is made to use an object that is not defined or is no longer usable.

exception xml.dom.NamespaceErr
If an attempt is made to change any object in a way that is not permitted with regard to the Namespaces in XML recommendation, this exception is raised.

exception xml.dom.NotFoundErr
Exception when a node does not exist in the referenced context. For example, `NamedNodeMap.removeNamedItem()` will raise this if the node passed in does not exist in the map.

exception xml.dom.NotSupportedErr
Raised when the implementation does not support the requested type of object or operation.

exception xml.dom.NoDataAllowedErr
This is raised if data is specified for a node which does not support data.

exception xml.dom.NoModificationAllowedErr
Raised on attempts to modify an object where modifications are not allowed (such as for read-only nodes).

exception xml.dom.SyntaxErr
Raised when an invalid or illegal string is specified.

exception xml.dom.WrongDocumentErr
Raised when a node is inserted in a different document than it currently belongs to, and the implementation does not support migrating the node from one document to the other.

The exception codes defined in the DOM recommendation map to the exceptions described above according to this table:

Constant	Exception
DOMSTRING_SIZE_ERR	*DomstringSizeErr*
HIERARCHY_REQUEST_ERR	*HierarchyRequestErr*
INDEX_SIZE_ERR	*IndexSizeErr*
INUSE_ATTRIBUTE_ERR	*InuseAttributeErr*
INVALID_ACCESS_ERR	*InvalidAccessErr*
INVALID_CHARACTER_ERR	*InvalidCharacterErr*
INVALID_MODIFICATION_ERR	*InvalidModificationErr*
INVALID_STATE_ERR	*InvalidStateErr*
NAMESPACE_ERR	*NamespaceErr*
NOT_FOUND_ERR	*NotFoundErr*
NOT_SUPPORTED_ERR	*NotSupportedErr*
NO_DATA_ALLOWED_ERR	*NoDataAllowedErr*
NO_MODIFICATION_ALLOWED_ERR	*NoModificationAllowedErr*
SYNTAX_ERR	*SyntaxErr*
WRONG_DOCUMENT_ERR	*WrongDocumentErr*

21.6.3 Conformance

This section describes the conformance requirements and relationships between the Python DOM API, the W3C DOM recommendations, and the OMG IDL mapping for Python.

Type Mapping

The IDL types used in the DOM specification are mapped to Python types according to the following table.

IDL Type	Python Type
`boolean`	`bool` or `int`
`int`	`int`
`long int`	`int`
`unsigned int`	`int`
`DOMString`	`str` or `bytes`
`null`	`None`

Accessor Methods

The mapping from OMG IDL to Python defines accessor functions for IDL `attribute` declarations in much the way the Java mapping does. Mapping the IDL declarations

```
readonly attribute string someValue;
         attribute string anotherValue;
```

yields three accessor functions: a "get" method for `someValue` (`_get_someValue()`), and "get" and "set" methods for `anotherValue` (`_get_anotherValue()` and `_set_anotherValue()`). The mapping, in particular, does not require that the IDL attributes are accessible as normal Python attributes: `object.someValue` is *not* required to work, and may raise an *AttributeError*.

The Python DOM API, however, *does* require that normal attribute access work. This means that the typical surrogates generated by Python IDL compilers are not likely to work, and wrapper objects may be needed on the client if the DOM objects are accessed via CORBA. While this does require some additional consideration for CORBA DOM clients, the implementers with experience using DOM over CORBA from Python do not consider this a problem. Attributes that are declared `readonly` may not restrict write access in all DOM implementations.

In the Python DOM API, accessor functions are not required. If provided, they should take the form defined by the Python IDL mapping, but these methods are considered unnecessary since the attributes are accessible directly from Python. "Set" accessors should never be provided for `readonly` attributes.

The IDL definitions do not fully embody the requirements of the W3C DOM API, such as the notion of certain objects, such as the return value of `getElementsByTagName()`, being "live". The Python DOM API does not require implementations to enforce such requirements.

21.7 `xml.dom.minidom` — Minimal DOM implementation

Source code: Lib/xml/dom/minidom.py

---

xml.dom.minidom is a minimal implementation of the Document Object Model interface, with an API similar to that in other languages. It is intended to be simpler than the full DOM and also significantly smaller.

Users who are not already proficient with the DOM should consider using the *xml.etree.ElementTree* module for their XML processing instead.

Warning: The *xml.dom.minidom* module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see *XML vulnerabilities*.

DOM applications typically start by parsing some XML into a DOM. With *xml.dom.minidom*, this is done through the parse functions:

```
from xml.dom.minidom import parse, parseString

dom1 = parse('c:\\temp\\mydata.xml')  # parse an XML file by name

datasource = open('c:\\temp\\mydata.xml')
dom2 = parse(datasource)  # parse an open file

dom3 = parseString('<myxml>Some data<empty/> some more data</myxml>')
```

The *parse()* function can take either a filename or an open file object.

xml.dom.minidom.parse(*filename_or_file*, *parser=None*, *bufsize=None*)
Return a `Document` from the given input. *filename_or_file* may be either a file name, or a file-like object. *parser*, if given, must be a SAX2 parser object. This function will change the document handler of the parser and activate namespace support; other parser configuration (like setting an entity resolver) must have been done in advance.

If you have XML in a string, you can use the *parseString()* function instead:

xml.dom.minidom.parseString(*string*, *parser=None*)
Return a `Document` that represents the *string*. This method creates an *io.StringIO* object for the string and passes that on to *parse()*.

Both functions return a `Document` object representing the content of the document.

What the *parse()* and *parseString()* functions do is connect an XML parser with a "DOM builder" that can accept parse events from any SAX parser and convert them into a DOM tree. The name of the functions are perhaps misleading, but are easy to grasp when learning the interfaces. The parsing of the document will be completed before these functions return; it's simply that these functions do not provide a parser implementation themselves.

You can also create a `Document` by calling a method on a "DOM Implementation" object. You can get this object either by calling the `getDOMImplementation()` function in the *xml.dom* package or the *xml.dom.minidom* module. Once you have a `Document`, you can add child nodes to it to populate the DOM:

```
from xml.dom.minidom import getDOMImplementation

impl = getDOMImplementation()

newdoc = impl.createDocument(None, "some_tag", None)
top_element = newdoc.documentElement
text = newdoc.createTextNode('Some textual content.')
top_element.appendChild(text)
```

Once you have a DOM document object, you can access the parts of your XML document through its properties and methods. These properties are defined in the DOM specification. The main property of the document object is the `documentElement` property. It gives you the main element in the XML document: the one that holds all others. Here is an example program:

```
dom3 = parseString("<myxml>Some data</myxml>")
assert dom3.documentElement.tagName == "myxml"
```

When you are finished with a DOM tree, you may optionally call the `unlink()` method to encourage early cleanup of the now-unneeded objects. `unlink()` is an *xml.dom.minidom*-specific extension to the DOM API that renders the node and its descendants are essentially useless. Otherwise, Python's garbage collector will eventually take care of the objects in the tree.

See also:

Document Object Model (DOM) Level 1 Specification The W3C recommendation for the DOM supported by *xml.dom.minidom*.

21.7.1 DOM Objects

The definition of the DOM API for Python is given as part of the *xml.dom* module documentation. This section lists the differences between the API and *xml.dom.minidom*.

`Node.unlink()`
Break internal references within the DOM so that it will be garbage collected on versions of Python without cyclic GC. Even when cyclic GC is available, using this can make large amounts of memory available sooner, so calling this on DOM objects as soon as they are no longer needed is good practice. This only needs to be called on the `Document` object, but may be called on child nodes to discard children of that node.

You can avoid calling this method explicitly by using the `with` statement. The following code will automatically unlink *dom* when the `with` block is exited:

```
with xml.dom.minidom.parse(datasource) as dom:
    ... # Work with dom.
```

`Node.writexml(`*writer*, *indent=""*, *addindent=""*, *newl=""*`)`
Write XML to the writer object. The writer should have a `write()` method which matches that of the file object interface. The *indent* parameter is the indentation of the current node. The *addindent* parameter is the incremental indentation to use for subnodes of the current one. The *newl* parameter specifies the string to use to terminate newlines.

For the `Document` node, an additional keyword argument *encoding* can be used to specify the encoding field of the XML header.

`Node.toxml(`*encoding=None*`)`
Return a string or byte string containing the XML represented by the DOM node.

With an explicit *encoding*[1] argument, the result is a byte string in the specified encoding. With no *encoding* argument, the result is a Unicode string, and the XML declaration in the resulting string does not specify an encoding. Encoding this string in an encoding other than UTF-8 is likely incorrect, since UTF-8 is the default encoding of XML.

`Node.toprettyxml(`*indent=""*, *newl=""*, *encoding=""*`)`
Return a pretty-printed version of the document. *indent* specifies the indentation string and defaults to a tabulator; *newl* specifies the string emitted at the end of each line and defaults to `\n`.

The *encoding* argument behaves like the corresponding argument of *toxml()*.

[1] The encoding name included in the XML output should conform to the appropriate standards. For example, "UTF-8" is valid, but "UTF8" is not valid in an XML document's declaration, even though Python accepts it as an encoding name. See https://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl and https://www.iana.org/assignments/character-sets/character-sets.xhtml.

21.7.2 DOM Example

This example program is a fairly realistic example of a simple program. In this particular case, we do not take much advantage of the flexibility of the DOM.

```
import xml.dom.minidom

document = """\
<slideshow>
<title>Demo slideshow</title>
<slide><title>Slide title</title>
<point>This is a demo</point>
<point>Of a program for processing slides</point>
</slide>

<slide><title>Another demo slide</title>
<point>It is important</point>
<point>To have more than</point>
<point>one slide</point>
</slide>
</slideshow>
"""

dom = xml.dom.minidom.parseString(document)

def getText(nodelist):
    rc = []
    for node in nodelist:
        if node.nodeType == node.TEXT_NODE:
            rc.append(node.data)
    return ''.join(rc)

def handleSlideshow(slideshow):
    print("<html>")
    handleSlideshowTitle(slideshow.getElementsByTagName("title")[0])
    slides = slideshow.getElementsByTagName("slide")
    handleToc(slides)
    handleSlides(slides)
    print("</html>")

def handleSlides(slides):
    for slide in slides:
        handleSlide(slide)

def handleSlide(slide):
    handleSlideTitle(slide.getElementsByTagName("title")[0])
    handlePoints(slide.getElementsByTagName("point"))

def handleSlideshowTitle(title):
    print("<title>%s</title>" % getText(title.childNodes))

def handleSlideTitle(title):
    print("<h2>%s</h2>" % getText(title.childNodes))

def handlePoints(points):
    print("<ul>")
    for point in points:
        handlePoint(point)
```

(continues on next page)

(continued from previous page)

```
    print("</ul>")

def handlePoint(point):
    print("<li>%s</li>" % getText(point.childNodes))

def handleToc(slides):
    for slide in slides:
        title = slide.getElementsByTagName("title")[0]
        print("<p>%s</p>" % getText(title.childNodes))

handleSlideshow(dom)
```

21.7.3 minidom and the DOM standard

The *xml.dom.minidom* module is essentially a DOM 1.0-compatible DOM with some DOM 2 features (primarily namespace features).

Usage of the DOM interface in Python is straight-forward. The following mapping rules apply:

- Interfaces are accessed through instance objects. Applications should not instantiate the classes themselves; they should use the creator functions available on the `Document` object. Derived interfaces support all operations (and attributes) from the base interfaces, plus any new operations.
- Operations are used as methods. Since the DOM uses only `in` parameters, the arguments are passed in normal order (from left to right). There are no optional arguments. `void` operations return `None`.
- IDL attributes map to instance attributes. For compatibility with the OMG IDL language mapping for Python, an attribute `foo` can also be accessed through accessor methods `_get_foo()` and `_set_foo()`. `readonly` attributes must not be changed; this is not enforced at runtime.
- The types `short int`, `unsigned int`, `unsigned long long`, and `boolean` all map to Python integer objects.
- The type `DOMString` maps to Python strings. *xml.dom.minidom* supports either bytes or strings, but will normally produce strings. Values of type `DOMString` may also be `None` where allowed to have the IDL `null` value by the DOM specification from the W3C.
- `const` declarations map to variables in their respective scope (e.g. `xml.dom.minidom.Node.PROCESSING_INSTRUCTION_NODE`); they must not be changed.
- `DOMException` is currently not supported in *xml.dom.minidom*. Instead, *xml.dom.minidom* uses standard Python exceptions such as *TypeError* and *AttributeError*.
- `NodeList` objects are implemented using Python's built-in list type. These objects provide the interface defined in the DOM specification, but with earlier versions of Python they do not support the official API. They are, however, much more "Pythonic" than the interface defined in the W3C recommendations.

The following interfaces have no implementation in *xml.dom.minidom*:

- `DOMTimeStamp`
- `DocumentType`
- `DOMImplementation`
- `CharacterData`
- `CDATASection`
- `Notation`

- Entity
- EntityReference
- DocumentFragment

Most of these reflect information in the XML document that is not of general utility to most DOM users.

21.8 xml.dom.pulldom — Support for building partial DOM trees

Source code: Lib/xml/dom/pulldom.py

The *xml.dom.pulldom* module provides a "pull parser" which can also be asked to produce DOM-accessible fragments of the document where necessary. The basic concept involves pulling "events" from a stream of incoming XML and processing them. In contrast to SAX which also employs an event-driven processing model together with callbacks, the user of a pull parser is responsible for explicitly pulling events from the stream, looping over those events until either processing is finished or an error condition occurs.

> **Warning:** The *xml.dom.pulldom* module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see *XML vulnerabilities*.

Example:

```
from xml.dom import pulldom

doc = pulldom.parse('sales_items.xml')
for event, node in doc:
    if event == pulldom.START_ELEMENT and node.tagName == 'item':
        if int(node.getAttribute('price')) > 50:
            doc.expandNode(node)
            print(node.toxml())
```

`event` is a constant and can be one of:

- START_ELEMENT
- END_ELEMENT
- COMMENT
- START_DOCUMENT
- END_DOCUMENT
- CHARACTERS
- PROCESSING_INSTRUCTION
- IGNORABLE_WHITESPACE

`node` is an object of type `xml.dom.minidom.Document`, `xml.dom.minidom.Element` or `xml.dom.minidom.Text`.

Since the document is treated as a "flat" stream of events, the document "tree" is implicitly traversed and the desired elements are found regardless of their depth in the tree. In other words, one does not need to consider hierarchical issues such as recursive searching of the document nodes, although if the context of elements were important, one would either need to maintain some context-related state (i.e. remembering where one is in the document at any given point) or to make use of the *DOMEventStream.expandNode()* method and switch to DOM-related processing.

class xml.dom.pulldom.**PullDom**(*documentFactory=None*)
Subclass of *xml.sax.handler.ContentHandler*.

class xml.dom.pulldom.**SAX2DOM**(*documentFactory=None*)
Subclass of *xml.sax.handler.ContentHandler*.

xml.dom.pulldom.**parse**(*stream_or_string*, *parser=None*, *bufsize=None*)
Return a *DOMEventStream* from the given input. *stream_or_string* may be either a file name, or a file-like object. *parser*, if given, must be an *XMLReader* object. This function will change the document handler of the parser and activate namespace support; other parser configuration (like setting an entity resolver) must have been done in advance.

If you have XML in a string, you can use the *parseString()* function instead:

xml.dom.pulldom.**parseString**(*string*, *parser=None*)
Return a *DOMEventStream* that represents the (Unicode) *string*.

xml.dom.pulldom.**default_bufsize**
Default value for the *bufsize* parameter to *parse()*.

The value of this variable can be changed before calling *parse()* and the new value will take effect.

21.8.1 DOMEventStream Objects

class xml.dom.pulldom.**DOMEventStream**(*stream*, *parser*, *bufsize*)

getEvent()
Return a tuple containing *event* and the current *node* as `xml.dom.minidom.Document` if event equals `START_DOCUMENT`, `xml.dom.minidom.Element` if event equals `START_ELEMENT` or `END_ELEMENT` or `xml.dom.minidom.Text` if event equals `CHARACTERS`. The current node does not contain information about its children, unless *expandNode()* is called.

expandNode(*node*)
Expands all children of *node* into *node*. Example:

```
from xml.dom import pulldom

xml = '<html><title>Foo</title> <p>Some text <div>and more</div></p> </html>'
doc = pulldom.parseString(xml)
for event, node in doc:
    if event == pulldom.START_ELEMENT and node.tagName == 'p':
        # Following statement only prints '<p/>'
        print(node.toxml())
        doc.expandNode(node)
        # Following statement prints node with all its children '<p>Some text <div>and␣
↪more</div></p>'
        print(node.toxml())
```

reset()

21.9 xml.sax — Support for SAX2 parsers

Source code: Lib/xml/sax/__init__.py

The *xml.sax* package provides a number of modules which implement the Simple API for XML (SAX) interface for Python. The package itself provides the SAX exceptions and the convenience functions which will be most used by users of the SAX API.

Warning: The *xml.sax* module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see *XML vulnerabilities*.

The convenience functions are:

`xml.sax.make_parser`(*parser_list=[]*)
: Create and return a SAX *XMLReader* object. The first parser found will be used. If *parser_list* is provided, it must be a sequence of strings which name modules that have a function named `create_parser()`. Modules listed in *parser_list* will be used before modules in the default list of parsers.

`xml.sax.parse`(*filename_or_stream*, *handler*, *error_handler=handler.ErrorHandler()*)
: Create a SAX parser and use it to parse a document. The document, passed in as *filename_or_stream*, can be a filename or a file object. The *handler* parameter needs to be a SAX *ContentHandler* instance. If *error_handler* is given, it must be a SAX *ErrorHandler* instance; if omitted, *SAXParseException* will be raised on all errors. There is no return value; all work must be done by the *handler* passed in.

`xml.sax.parseString`(*string*, *handler*, *error_handler=handler.ErrorHandler()*)
: Similar to *parse()*, but parses from a buffer *string* received as a parameter. *string* must be a *str* instance or a *bytes-like object*.

  Changed in version 3.5: Added support of *str* instances.

A typical SAX application uses three kinds of objects: readers, handlers and input sources. "Reader" in this context is another term for parser, i.e. some piece of code that reads the bytes or characters from the input source, and produces a sequence of events. The events then get distributed to the handler objects, i.e. the reader invokes a method on the handler. A SAX application must therefore obtain a reader object, create or open the input sources, create the handlers, and connect these objects all together. As the final step of preparation, the reader is called to parse the input. During parsing, methods on the handler objects are called based on structural and syntactic events from the input data.

For these objects, only the interfaces are relevant; they are normally not instantiated by the application itself. Since Python does not have an explicit notion of interface, they are formally introduced as classes, but applications may use implementations which do not inherit from the provided classes. The *InputSource*, *Locator*, `Attributes`, `AttributesNS`, and *XMLReader* interfaces are defined in the module *xml.sax.xmlreader*. The handler interfaces are defined in *xml.sax.handler*. For convenience, *InputSource* (which is often instantiated directly) and the handler classes are also available from *xml.sax*. These interfaces are described below.

In addition to these classes, *xml.sax* provides the following exception classes.

exception `xml.sax.SAXException`(*msg*, *exception=None*)
: Encapsulate an XML error or warning. This class can contain basic error or warning information from either the XML parser or the application: it can be subclassed to provide additional functionality or to add localization. Note that although the handlers defined in the *ErrorHandler* interface receive instances of this exception, it is not required to actually raise the exception — it is also useful as a container for information.

  When instantiated, *msg* should be a human-readable description of the error. The optional *exception* parameter, if given, should be `None` or an exception that was caught by the parsing code and is being passed along as information.

  This is the base class for the other SAX exception classes.

exception xml.sax.SAXParseException(*msg*, *exception*, *locator*)
Subclass of *SAXException* raised on parse errors. Instances of this class are passed to the methods of the SAX *ErrorHandler* interface to provide information about the parse error. This class supports the SAX *Locator* interface as well as the *SAXException* interface.

exception xml.sax.SAXNotRecognizedException(*msg*, *exception=None*)
Subclass of *SAXException* raised when a SAX *XMLReader* is confronted with an unrecognized feature or property. SAX applications and extensions may use this class for similar purposes.

exception xml.sax.SAXNotSupportedException(*msg*, *exception=None*)
Subclass of *SAXException* raised when a SAX *XMLReader* is asked to enable a feature that is not supported, or to set a property to a value that the implementation does not support. SAX applications and extensions may use this class for similar purposes.

See also:

SAX: The Simple API for XML This site is the focal point for the definition of the SAX API. It provides a Java implementation and online documentation. Links to implementations and historical information are also available.

Module *xml.sax.handler* Definitions of the interfaces for application-provided objects.

Module *xml.sax.saxutils* Convenience functions for use in SAX applications.

Module *xml.sax.xmlreader* Definitions of the interfaces for parser-provided objects.

21.9.1 SAXException Objects

The *SAXException* exception class supports the following methods:

SAXException.getMessage()
Return a human-readable message describing the error condition.

SAXException.getException()
Return an encapsulated exception object, or `None`.

21.10 xml.sax.handler — Base classes for SAX handlers

Source code: Lib/xml/sax/handler.py

The SAX API defines four kinds of handlers: content handlers, DTD handlers, error handlers, and entity resolvers. Applications normally only need to implement those interfaces whose events they are interested in; they can implement the interfaces in a single object or in multiple objects. Handler implementations should inherit from the base classes provided in the module *xml.sax.handler*, so that all methods get default implementations.

class xml.sax.handler.ContentHandler
This is the main callback interface in SAX, and the one most important to applications. The order of events in this interface mirrors the order of the information in the document.

class xml.sax.handler.DTDHandler
Handle DTD events.

This interface specifies only those DTD events required for basic parsing (unparsed entities and attributes).

class xml.sax.handler.EntityResolver
: Basic interface for resolving entities. If you create an object implementing this interface, then register the object with your Parser, the parser will call the method in your object to resolve all external entities.

class xml.sax.handler.ErrorHandler
: Interface used by the parser to present error and warning messages to the application. The methods of this object control whether errors are immediately converted to exceptions or are handled in some other way.

In addition to these classes, *xml.sax.handler* provides symbolic constants for the feature and property names.

xml.sax.handler.feature_namespaces
: value: "http://xml.org/sax/features/namespaces"
true: Perform Namespace processing.
false: Optionally do not perform Namespace processing (implies namespace-prefixes; default).
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.feature_namespace_prefixes
: value: "http://xml.org/sax/features/namespace-prefixes"
true: Report the original prefixed names and attributes used for Namespace declarations.
false: Do not report attributes used for Namespace declarations, and optionally do not report original prefixed names (default).
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.feature_string_interning
: value: "http://xml.org/sax/features/string-interning"
true: All element names, prefixes, attribute names, Namespace URIs, and local names are interned using the built-in intern function.
false: Names are not necessarily interned, although they may be (default).
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.feature_validation
: value: "http://xml.org/sax/features/validation"
true: Report all validation errors (implies external-general-entities and external-parameter-entities).
false: Do not report validation errors.
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.feature_external_ges
: value: "http://xml.org/sax/features/external-general-entities"
true: Include all external general (text) entities.
false: Do not include external general entities.
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.feature_external_pes
: value: "http://xml.org/sax/features/external-parameter-entities"
true: Include all external parameter entities, including the external DTD subset.

false: Do not include any external parameter entities, even the external DTD subset.
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.all_features
List of all features.

xml.sax.handler.property_lexical_handler

value: "http://xml.org/sax/properties/lexical-handler"
data type: xml.sax.sax2lib.LexicalHandler (not supported in Python 2)
description: An optional extension handler for lexical events like comments.
access: read/write

xml.sax.handler.property_declaration_handler

value: "http://xml.org/sax/properties/declaration-handler"
data type: xml.sax.sax2lib.DeclHandler (not supported in Python 2)
description: An optional extension handler for DTD-related events other than notations and unparsed entities.
access: read/write

xml.sax.handler.property_dom_node

value: "http://xml.org/sax/properties/dom-node"
data type: org.w3c.dom.Node (not supported in Python 2)
description: When parsing, the current DOM node being visited if this is a DOM iterator; when not parsing, the root DOM node for iteration.
access: (parsing) read-only; (not parsing) read/write

xml.sax.handler.property_xml_string

value: "http://xml.org/sax/properties/xml-string"
data type: String
description: The literal string of characters that was the source for the current event.
access: read-only

xml.sax.handler.all_properties
List of all known property names.

21.10.1 ContentHandler Objects

Users are expected to subclass *ContentHandler* to support their application. The following methods are called by the parser on the appropriate events in the input document:

ContentHandler.setDocumentLocator(*locator*)
Called by the parser to give the application a locator for locating the origin of document events.

SAX parsers are strongly encouraged (though not absolutely required) to supply a locator: if it does so, it must supply the locator to the application by invoking this method before invoking any of the other methods in the DocumentHandler interface.

The locator allows the application to determine the end position of any document-related event, even if the parser is not reporting an error. Typically, the application will use this information for reporting its own errors (such as character content that does not match an application's business rules). The information returned by the locator is probably not sufficient for use with a search engine.

Note that the locator will return correct information only during the invocation of the events in this interface. The application should not attempt to use it at any other time.

`ContentHandler.startDocument()`
Receive notification of the beginning of a document.

The SAX parser will invoke this method only once, before any other methods in this interface or in DTDHandler (except for *setDocumentLocator()*).

`ContentHandler.endDocument()`
Receive notification of the end of a document.

The SAX parser will invoke this method only once, and it will be the last method invoked during the parse. The parser shall not invoke this method until it has either abandoned parsing (because of an unrecoverable error) or reached the end of input.

`ContentHandler.startPrefixMapping(`*prefix*, *uri*`)`
Begin the scope of a prefix-URI Namespace mapping.

The information from this event is not necessary for normal Namespace processing: the SAX XML reader will automatically replace prefixes for element and attribute names when the `feature_namespaces` feature is enabled (the default).

There are cases, however, when applications need to use prefixes in character data or in attribute values, where they cannot safely be expanded automatically; the *startPrefixMapping()* and *endPrefixMapping()* events supply the information to the application to expand prefixes in those contexts itself, if necessary.

Note that *startPrefixMapping()* and *endPrefixMapping()* events are not guaranteed to be properly nested relative to each-other: all *startPrefixMapping()* events will occur before the corresponding *startElement()* event, and all *endPrefixMapping()* events will occur after the corresponding *endElement()* event, but their order is not guaranteed.

`ContentHandler.endPrefixMapping(`*prefix*`)`
End the scope of a prefix-URI mapping.

See *startPrefixMapping()* for details. This event will always occur after the corresponding *endElement()* event, but the order of *endPrefixMapping()* events is not otherwise guaranteed.

`ContentHandler.startElement(`*name*, *attrs*`)`
Signals the start of an element in non-namespace mode.

The *name* parameter contains the raw XML 1.0 name of the element type as a string and the *attrs* parameter holds an object of the `Attributes` interface (see *The Attributes Interface*) containing the attributes of the element. The object passed as *attrs* may be re-used by the parser; holding on to a reference to it is not a reliable way to keep a copy of the attributes. To keep a copy of the attributes, use the *copy()* method of the *attrs* object.

`ContentHandler.endElement(`*name*`)`
Signals the end of an element in non-namespace mode.

The *name* parameter contains the name of the element type, just as with the *startElement()* event.

`ContentHandler.startElementNS(`*name*, *qname*, *attrs*`)`
Signals the start of an element in namespace mode.

The *name* parameter contains the name of the element type as a `(uri, localname)` tuple, the *qname* parameter contains the raw XML 1.0 name used in the source document, and the *attrs* parameter holds an instance of the `AttributesNS` interface (see *The AttributesNS Interface*) containing the attributes of the element. If no namespace is associated with the element, the *uri* component of *name* will be `None`. The object passed as *attrs* may be re-used by the parser; holding on to a reference to it is not a reliable way to keep a copy of the attributes. To keep a copy of the attributes, use the *copy()* method of the *attrs* object.

Parsers may set the *qname* parameter to `None`, unless the `feature_namespace_prefixes` feature is activated.

`ContentHandler.endElementNS(`*name*, *qname*`)`
Signals the end of an element in namespace mode.

The *name* parameter contains the name of the element type, just as with the *startElementNS()* method, likewise the *qname* parameter.

`ContentHandler.characters(`*content*`)`
Receive notification of character data.

The Parser will call this method to report each chunk of character data. SAX parsers may return all contiguous character data in a single chunk, or they may split it into several chunks; however, all of the characters in any single event must come from the same external entity so that the Locator provides useful information.

content may be a string or bytes instance; the `expat` reader module always produces strings.

Note: The earlier SAX 1 interface provided by the Python XML Special Interest Group used a more Java-like interface for this method. Since most parsers used from Python did not take advantage of the older interface, the simpler signature was chosen to replace it. To convert old code to the new interface, use *content* instead of slicing content with the old *offset* and *length* parameters.

`ContentHandler.ignorableWhitespace(`*whitespace*`)`
Receive notification of ignorable whitespace in element content.

Validating Parsers must use this method to report each chunk of ignorable whitespace (see the W3C XML 1.0 recommendation, section 2.10): non-validating parsers may also use this method if they are capable of parsing and using content models.

SAX parsers may return all contiguous whitespace in a single chunk, or they may split it into several chunks; however, all of the characters in any single event must come from the same external entity, so that the Locator provides useful information.

`ContentHandler.processingInstruction(`*target*, *data*`)`
Receive notification of a processing instruction.

The Parser will invoke this method once for each processing instruction found: note that processing instructions may occur before or after the main document element.

A SAX parser should never report an XML declaration (XML 1.0, section 2.8) or a text declaration (XML 1.0, section 4.3.1) using this method.

`ContentHandler.skippedEntity(`*name*`)`
Receive notification of a skipped entity.

The Parser will invoke this method once for each entity skipped. Non-validating processors may skip entities if they have not seen the declarations (because, for example, the entity was declared in an external DTD subset). All processors may skip external entities, depending on the values of the `feature_external_ges` and the `feature_external_pes` properties.

21.10.2 DTDHandler Objects

DTDHandler instances provide the following methods:

`DTDHandler.notationDecl(`*name*, *publicId*, *systemId*`)`
Handle a notation declaration event.

`DTDHandler.unparsedEntityDecl(`*name*, *publicId*, *systemId*, *ndata*`)`
Handle an unparsed entity declaration event.

21.10.3 EntityResolver Objects

EntityResolver.**resolveEntity**(*publicId*, *systemId*)
Resolve the system identifier of an entity and return either the system identifier to read from as a string, or an InputSource to read from. The default implementation returns *systemId*.

21.10.4 ErrorHandler Objects

Objects with this interface are used to receive error and warning information from the *XMLReader*. If you create an object that implements this interface, then register the object with your *XMLReader*, the parser will call the methods in your object to report all warnings and errors. There are three levels of errors available: warnings, (possibly) recoverable errors, and unrecoverable errors. All methods take a SAXParseException as the only parameter. Errors and warnings may be converted to an exception by raising the passed-in exception object.

ErrorHandler.**error**(*exception*)
Called when the parser encounters a recoverable error. If this method does not raise an exception, parsing may continue, but further document information should not be expected by the application. Allowing the parser to continue may allow additional errors to be discovered in the input document.

ErrorHandler.**fatalError**(*exception*)
Called when the parser encounters an error it cannot recover from; parsing is expected to terminate when this method returns.

ErrorHandler.**warning**(*exception*)
Called when the parser presents minor warning information to the application. Parsing is expected to continue when this method returns, and document information will continue to be passed to the application. Raising an exception in this method will cause parsing to end.

21.11 xml.sax.saxutils — SAX Utilities

Source code: Lib/xml/sax/saxutils.py

The module *xml.sax.saxutils* contains a number of classes and functions that are commonly useful when creating SAX applications, either in direct use, or as base classes.

xml.sax.saxutils.**escape**(*data*, *entities={}*)
Escape '&', '<', and '>' in a string of data.

You can escape other strings of data by passing a dictionary as the optional *entities* parameter. The keys and values must all be strings; each key will be replaced with its corresponding value. The characters '&', '<' and '>' are always escaped, even if *entities* is provided.

xml.sax.saxutils.**unescape**(*data*, *entities={}*)
Unescape '&', '<', and '>' in a string of data.

You can unescape other strings of data by passing a dictionary as the optional *entities* parameter. The keys and values must all be strings; each key will be replaced with its corresponding value. '&', '<', and '>' are always unescaped, even if *entities* is provided.

xml.sax.saxutils.**quoteattr**(*data*, *entities={}*)
Similar to *escape()*, but also prepares *data* to be used as an attribute value. The return value is a quoted version of *data* with any additional required replacements. *quoteattr()* will select a quote character based on the content of *data*, attempting to avoid encoding any quote characters in the string. If both single- and double-quote characters are already in *data*, the double-quote characters

will be encoded and *data* will be wrapped in double-quotes. The resulting string can be used directly as an attribute value:

```
>>> print("<element attr=%s>" % quoteattr("ab ' cd \" ef"))
<element attr="ab ' cd &quot; ef">
```

This function is useful when generating attribute values for HTML or any SGML using the reference concrete syntax.

class xml.sax.saxutils.XMLGenerator(*out=None*, *encoding='iso-8859-1'*, *short_empty_elements=False*)

This class implements the *ContentHandler* interface by writing SAX events back into an XML document. In other words, using an *XMLGenerator* as the content handler will reproduce the original document being parsed. *out* should be a file-like object which will default to *sys.stdout*. *encoding* is the encoding of the output stream which defaults to `'iso-8859-1'`. *short_empty_elements* controls the formatting of elements that contain no content: if `False` (the default) they are emitted as a pair of start/end tags, if set to `True` they are emitted as a single self-closed tag.

New in version 3.2: The *short_empty_elements* parameter.

class xml.sax.saxutils.XMLFilterBase(*base*)

This class is designed to sit between an *XMLReader* and the client application's event handlers. By default, it does nothing but pass requests up to the reader and events on to the handlers unmodified, but subclasses can override specific methods to modify the event stream or the configuration requests as they pass through.

xml.sax.saxutils.prepare_input_source(*source*, *base=''*)

This function takes an input source and an optional base URL and returns a fully resolved *InputSource* object ready for reading. The input source can be given as a string, a file-like object, or an *InputSource* object; parsers will use this function to implement the polymorphic *source* argument to their `parse()` method.

21.12 xml.sax.xmlreader — Interface for XML parsers

Source code: Lib/xml/sax/xmlreader.py

SAX parsers implement the *XMLReader* interface. They are implemented in a Python module, which must provide a function `create_parser()`. This function is invoked by *xml.sax.make_parser()* with no arguments to create a new parser object.

class xml.sax.xmlreader.XMLReader

Base class which can be inherited by SAX parsers.

class xml.sax.xmlreader.IncrementalParser

In some cases, it is desirable not to parse an input source at once, but to feed chunks of the document as they get available. Note that the reader will normally not read the entire file, but read it in chunks as well; still `parse()` won't return until the entire document is processed. So these interfaces should be used if the blocking behaviour of `parse()` is not desirable.

When the parser is instantiated it is ready to begin accepting data from the feed method immediately. After parsing has been finished with a call to close the reset method must be called to make the parser ready to accept new data, either from feed or using the parse method.

Note that these methods must *not* be called during parsing, that is, after parse has been called and before it returns.

By default, the class also implements the parse method of the XMLReader interface using the feed, close and reset methods of the IncrementalParser interface as a convenience to SAX 2.0 driver writers.

class xml.sax.xmlreader.Locator
Interface for associating a SAX event with a document location. A locator object will return valid results only during calls to DocumentHandler methods; at any other time, the results are unpredictable. If information is not available, methods may return `None`.

class xml.sax.xmlreader.InputSource(*system_id=None*)
Encapsulation of the information needed by the *XMLReader* to read entities.

This class may include information about the public identifier, system identifier, byte stream (possibly with character encoding information) and/or the character stream of an entity.

Applications will create objects of this class for use in the *XMLReader.parse()* method and for returning from EntityResolver.resolveEntity.

An *InputSource* belongs to the application, the *XMLReader* is not allowed to modify *InputSource* objects passed to it from the application, although it may make copies and modify those.

class xml.sax.xmlreader.AttributesImpl(*attrs*)
This is an implementation of the `Attributes` interface (see section *The Attributes Interface*). This is a dictionary-like object which represents the element attributes in a `startElement()` call. In addition to the most useful dictionary operations, it supports a number of other methods as described by the interface. Objects of this class should be instantiated by readers; *attrs* must be a dictionary-like object containing a mapping from attribute names to attribute values.

class xml.sax.xmlreader.AttributesNSImpl(*attrs*, *qnames*)
Namespace-aware variant of *AttributesImpl*, which will be passed to `startElementNS()`. It is derived from *AttributesImpl*, but understands attribute names as two-tuples of *namespaceURI* and *localname*. In addition, it provides a number of methods expecting qualified names as they appear in the original document. This class implements the `AttributesNS` interface (see section *The AttributesNS Interface*).

21.12.1 XMLReader Objects

The *XMLReader* interface supports the following methods:

XMLReader.parse(*source*)
Process an input source, producing SAX events. The *source* object can be a system identifier (a string identifying the input source – typically a file name or a URL), a file-like object, or an *InputSource* object. When *parse()* returns, the input is completely processed, and the parser object can be discarded or reset.

Changed in version 3.5: Added support of character streams.

XMLReader.getContentHandler()
Return the current *ContentHandler*.

XMLReader.setContentHandler(*handler*)
Set the current *ContentHandler*. If no *ContentHandler* is set, content events will be discarded.

XMLReader.getDTDHandler()
Return the current *DTDHandler*.

XMLReader.setDTDHandler(*handler*)
Set the current *DTDHandler*. If no *DTDHandler* is set, DTD events will be discarded.

XMLReader.getEntityResolver()
Return the current *EntityResolver*.

XMLReader.setEntityResolver(*handler*)
Set the current *EntityResolver*. If no *EntityResolver* is set, attempts to resolve an external entity will result in opening the system identifier for the entity, and fail if it is not available.

XMLReader.getErrorHandler()
Return the current *ErrorHandler*.

XMLReader.setErrorHandler(*handler*)
Set the current error handler. If no *ErrorHandler* is set, errors will be raised as exceptions, and warnings will be printed.

XMLReader.setLocale(*locale*)
Allow an application to set the locale for errors and warnings.

SAX parsers are not required to provide localization for errors and warnings; if they cannot support the requested locale, however, they must raise a SAX exception. Applications may request a locale change in the middle of a parse.

XMLReader.getFeature(*featurename*)
Return the current setting for feature *featurename*. If the feature is not recognized, SAXNotRecognizedException is raised. The well-known featurenames are listed in the module *xml.sax.handler*.

XMLReader.setFeature(*featurename*, *value*)
Set the *featurename* to *value*. If the feature is not recognized, SAXNotRecognizedException is raised. If the feature or its setting is not supported by the parser, *SAXNotSupportedException* is raised.

XMLReader.getProperty(*propertyname*)
Return the current setting for property *propertyname*. If the property is not recognized, a SAXNotRecognizedException is raised. The well-known propertynames are listed in the module *xml.sax.handler*.

XMLReader.setProperty(*propertyname*, *value*)
Set the *propertyname* to *value*. If the property is not recognized, SAXNotRecognizedException is raised. If the property or its setting is not supported by the parser, *SAXNotSupportedException* is raised.

21.12.2 IncrementalParser Objects

Instances of *IncrementalParser* offer the following additional methods:

IncrementalParser.feed(*data*)
Process a chunk of *data*.

IncrementalParser.close()
Assume the end of the document. That will check well-formedness conditions that can be checked only at the end, invoke handlers, and may clean up resources allocated during parsing.

IncrementalParser.reset()
This method is called after close has been called to reset the parser so that it is ready to parse new documents. The results of calling parse or feed after close without calling reset are undefined.

21.12.3 Locator Objects

Instances of *Locator* provide these methods:

Locator.getColumnNumber()
Return the column number where the current event begins.

Locator.getLineNumber()
Return the line number where the current event begins.

Locator.getPublicId()
Return the public identifier for the current event.

Locator.getSystemId()
Return the system identifier for the current event.

21.12.4 InputSource Objects

InputSource.setPublicId(*id*)
Sets the public identifier of this *InputSource*.

InputSource.getPublicId()
Returns the public identifier of this *InputSource*.

InputSource.setSystemId(*id*)
Sets the system identifier of this *InputSource*.

InputSource.getSystemId()
Returns the system identifier of this *InputSource*.

InputSource.setEncoding(*encoding*)
Sets the character encoding of this *InputSource*.

The encoding must be a string acceptable for an XML encoding declaration (see section 4.3.3 of the XML recommendation).

The encoding attribute of the *InputSource* is ignored if the *InputSource* also contains a character stream.

InputSource.getEncoding()
Get the character encoding of this InputSource.

InputSource.setByteStream(*bytefile*)
Set the byte stream (a *binary file*) for this input source.

The SAX parser will ignore this if there is also a character stream specified, but it will use a byte stream in preference to opening a URI connection itself.

If the application knows the character encoding of the byte stream, it should set it with the setEncoding method.

InputSource.getByteStream()
Get the byte stream for this input source.

The getEncoding method will return the character encoding for this byte stream, or `None` if unknown.

InputSource.setCharacterStream(*charfile*)
Set the character stream (a *text file*) for this input source.

If there is a character stream specified, the SAX parser will ignore any byte stream and will not attempt to open a URI connection to the system identifier.

InputSource.getCharacterStream()
Get the character stream for this input source.

21.12.5 The `Attributes` Interface

`Attributes` objects implement a portion of the *mapping protocol*, including the methods `copy()`, `get()`, `__contains__()`, `items()`, `keys()`, and `values()`. The following methods are also provided:

Attributes.getLength()
Return the number of attributes.

Attributes.getNames()
Return the names of the attributes.

`Attributes.getType(`*name*`)`
Returns the type of the attribute *name*, which is normally `'CDATA'`.

`Attributes.getValue(`*name*`)`
Return the value of attribute *name*.

21.12.6 The `AttributesNS` Interface

This interface is a subtype of the `Attributes` interface (see section *The Attributes Interface*). All methods supported by that interface are also available on `AttributesNS` objects.

The following methods are also available:

`AttributesNS.getValueByQName(`*name*`)`
Return the value for a qualified name.

`AttributesNS.getNameByQName(`*name*`)`
Return the `(namespace, localname)` pair for a qualified *name*.

`AttributesNS.getQNameByName(`*name*`)`
Return the qualified name for a `(namespace, localname)` pair.

`AttributesNS.getQNames()`
Return the qualified names of all attributes.

21.13 `xml.parsers.expat` — Fast XML parsing using Expat

Warning: The `pyexpat` module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see *XML vulnerabilities*.

The *`xml.parsers.expat`* module is a Python interface to the Expat non-validating XML parser. The module provides a single extension type, `xmlparser`, that represents the current state of an XML parser. After an `xmlparser` object has been created, various attributes of the object can be set to handler functions. When an XML document is then fed to the parser, the handler functions are called for the character data and markup in the XML document.

This module uses the `pyexpat` module to provide access to the Expat parser. Direct use of the `pyexpat` module is deprecated.

This module provides one exception and one type object:

`exception xml.parsers.expat.ExpatError`
The exception raised when Expat reports an error. See section *ExpatError Exceptions* for more information on interpreting Expat errors.

`exception xml.parsers.expat.error`
Alias for *`ExpatError`*.

`xml.parsers.expat.XMLParserType`
The type of the return values from the *`ParserCreate()`* function.

The *`xml.parsers.expat`* module contains two functions:

`xml.parsers.expat.ErrorString(`*errno*`)`
Returns an explanatory string for a given error number *errno*.

xml.parsers.expat.ParserCreate(*encoding=None*, *namespace_separator=None*)

Creates and returns a new xmlparser object. *encoding*, if specified, must be a string naming the encoding used by the XML data. Expat doesn't support as many encodings as Python does, and its repertoire of encodings can't be extended; it supports UTF-8, UTF-16, ISO-8859-1 (Latin1), and ASCII. If *encoding*[1] is given it will override the implicit or explicit encoding of the document.

Expat can optionally do XML namespace processing for you, enabled by providing a value for *namespace_separator*. The value must be a one-character string; a *ValueError* will be raised if the string has an illegal length (None is considered the same as omission). When namespace processing is enabled, element type names and attribute names that belong to a namespace will be expanded. The element name passed to the element handlers StartElementHandler and EndElementHandler will be the concatenation of the namespace URI, the namespace separator character, and the local part of the name. If the namespace separator is a zero byte (chr(0)) then the namespace URI and the local part will be concatenated without any separator.

For example, if *namespace_separator* is set to a space character (' ') and the following document is parsed:

```
<?xml version="1.0"?>
<root xmlns    = "http://default-namespace.org/"
      xmlns:py = "http://www.python.org/ns/">
  <py:elem1 />
  <elem2 xmlns="" />
</root>
```

StartElementHandler will receive the following strings for each element:

```
http://default-namespace.org/ root
http://www.python.org/ns/ elem1
elem2
```

Due to limitations in the Expat library used by pyexpat, the xmlparser instance returned can only be used to parse a single XML document. Call ParserCreate for each document to provide unique parser instances.

See also:

The Expat XML Parser Home page of the Expat project.

21.13.1 XMLParser Objects

xmlparser objects have the following methods:

xmlparser.Parse(*data*[, *isfinal*])

Parses the contents of the string *data*, calling the appropriate handler functions to process the parsed data. *isfinal* must be true on the final call to this method; it allows the parsing of a single file in fragments, not the submission of multiple files. *data* can be the empty string at any time.

xmlparser.ParseFile(*file*)

Parse XML data reading from the object *file*. *file* only needs to provide the read(nbytes) method, returning the empty string when there's no more data.

xmlparser.SetBase(*base*)

Sets the base to be used for resolving relative URIs in system identifiers in declarations. Resolving relative identifiers is left to the application: this value will be passed through as the *base* argument

[1] The encoding string included in XML output should conform to the appropriate standards. For example, "UTF-8" is valid, but "UTF8" is not. See https://www.w3.org/TR/2006/REC-xml11-20060816/#NT-EncodingDecl and https://www.iana.org/assignments/character-sets/character-sets.xhtml.

to the *ExternalEntityRefHandler()*, *NotationDeclHandler()*, and *UnparsedEntityDeclHandler()* functions.

xmlparser.GetBase()
Returns a string containing the base set by a previous call to *SetBase()*, or `None` if *SetBase()* hasn't been called.

xmlparser.GetInputContext()
Returns the input data that generated the current event as a string. The data is in the encoding of the entity which contains the text. When called while an event handler is not active, the return value is `None`.

xmlparser.ExternalEntityParserCreate(*context*[, *encoding*])
Create a "child" parser which can be used to parse an external parsed entity referred to by content parsed by the parent parser. The *context* parameter should be the string passed to the *ExternalEntityRefHandler()* handler function, described below. The child parser is created with the *ordered_attributes* and *specified_attributes* set to the values of this parser.

xmlparser.SetParamEntityParsing(*flag*)
Control parsing of parameter entities (including the external DTD subset). Possible *flag* values are `XML_PARAM_ENTITY_PARSING_NEVER`, `XML_PARAM_ENTITY_PARSING_UNLESS_STANDALONE` and `XML_PARAM_ENTITY_PARSING_ALWAYS`. Return true if setting the flag was successful.

xmlparser.UseForeignDTD([*flag*])
Calling this with a true value for *flag* (the default) will cause Expat to call the *ExternalEntityRefHandler* with *None* for all arguments to allow an alternate DTD to be loaded. If the document does not contain a document type declaration, the *ExternalEntityRefHandler* will still be called, but the *StartDoctypeDeclHandler* and *EndDoctypeDeclHandler* will not be called.

Passing a false value for *flag* will cancel a previous call that passed a true value, but otherwise has no effect.

This method can only be called before the *Parse()* or *ParseFile()* methods are called; calling it after either of those have been called causes *ExpatError* to be raised with the *code* attribute set to `errors.codes[errors.XML_ERROR_CANT_CHANGE_FEATURE_ONCE_PARSING]`.

`xmlparser` objects have the following attributes:

xmlparser.buffer_size
The size of the buffer used when *buffer_text* is true. A new buffer size can be set by assigning a new integer value to this attribute. When the size is changed, the buffer will be flushed.

xmlparser.buffer_text
Setting this to true causes the `xmlparser` object to buffer textual content returned by Expat to avoid multiple calls to the *CharacterDataHandler()* callback whenever possible. This can improve performance substantially since Expat normally breaks character data into chunks at every line ending. This attribute is false by default, and may be changed at any time.

xmlparser.buffer_used
If *buffer_text* is enabled, the number of bytes stored in the buffer. These bytes represent UTF-8 encoded text. This attribute has no meaningful interpretation when *buffer_text* is false.

xmlparser.ordered_attributes
Setting this attribute to a non-zero integer causes the attributes to be reported as a list rather than a dictionary. The attributes are presented in the order found in the document text. For each attribute, two list entries are presented: the attribute name and the attribute value. (Older versions of this module also used this format.) By default, this attribute is false; it may be changed at any time.

xmlparser.specified_attributes
If set to a non-zero integer, the parser will report only those attributes which were specified in the document instance and not those which were derived from attribute declarations. Applications which

set this need to be especially careful to use what additional information is available from the declarations as needed to comply with the standards for the behavior of XML processors. By default, this attribute is false; it may be changed at any time.

The following attributes contain values relating to the most recent error encountered by an `xmlparser` object, and will only have correct values once a call to `Parse()` or `ParseFile()` has raised an *xml.parsers.expat.ExpatError* exception.

`xmlparser.ErrorByteIndex`
Byte index at which an error occurred.

`xmlparser.ErrorCode`
Numeric code specifying the problem. This value can be passed to the *ErrorString()* function, or compared to one of the constants defined in the `errors` object.

`xmlparser.ErrorColumnNumber`
Column number at which an error occurred.

`xmlparser.ErrorLineNumber`
Line number at which an error occurred.

The following attributes contain values relating to the current parse location in an `xmlparser` object. During a callback reporting a parse event they indicate the location of the first of the sequence of characters that generated the event. When called outside of a callback, the position indicated will be just past the last parse event (regardless of whether there was an associated callback).

`xmlparser.CurrentByteIndex`
Current byte index in the parser input.

`xmlparser.CurrentColumnNumber`
Current column number in the parser input.

`xmlparser.CurrentLineNumber`
Current line number in the parser input.

Here is the list of handlers that can be set. To set a handler on an `xmlparser` object *o*, use `o.handlername = func`. *handlername* must be taken from the following list, and *func* must be a callable object accepting the correct number of arguments. The arguments are all strings, unless otherwise stated.

`xmlparser.XmlDeclHandler(`*version*, *encoding*, *standalone*`)`
Called when the XML declaration is parsed. The XML declaration is the (optional) declaration of the applicable version of the XML recommendation, the encoding of the document text, and an optional "standalone" declaration. *version* and *encoding* will be strings, and *standalone* will be `1` if the document is declared standalone, `0` if it is declared not to be standalone, or `-1` if the standalone clause was omitted. This is only available with Expat version 1.95.0 or newer.

`xmlparser.StartDoctypeDeclHandler(`*doctypeName*, *systemId*, *publicId*, *has_internal_subset*`)`
Called when Expat begins parsing the document type declaration (`<!DOCTYPE ...`). The *doctypeName* is provided exactly as presented. The *systemId* and *publicId* parameters give the system and public identifiers if specified, or `None` if omitted. *has_internal_subset* will be true if the document contains and internal document declaration subset. This requires Expat version 1.2 or newer.

`xmlparser.EndDoctypeDeclHandler()`
Called when Expat is done parsing the document type declaration. This requires Expat version 1.2 or newer.

`xmlparser.ElementDeclHandler(`*name*, *model*`)`
Called once for each element type declaration. *name* is the name of the element type, and *model* is a representation of the content model.

`xmlparser.AttlistDeclHandler(`*elname*, *attname*, *type*, *default*, *required*`)`
Called for each declared attribute for an element type. If an attribute list declaration declares three attributes, this handler is called three times, once for each attribute. *elname* is the name of the element

to which the declaration applies and *attname* is the name of the attribute declared. The attribute type is a string passed as *type*; the possible values are `'CDATA'`, `'ID'`, `'IDREF'`, ... *default* gives the default value for the attribute used when the attribute is not specified by the document instance, or `None` if there is no default value (`#IMPLIED` values). If the attribute is required to be given in the document instance, *required* will be true. This requires Expat version 1.95.0 or newer.

xmlparser.StartElementHandler(*name*, *attributes*)
Called for the start of every element. *name* is a string containing the element name, and *attributes* is the element attributes. If *ordered_attributes* is true, this is a list (see *ordered_attributes* for a full description). Otherwise it's a dictionary mapping names to values.

xmlparser.EndElementHandler(*name*)
Called for the end of every element.

xmlparser.ProcessingInstructionHandler(*target*, *data*)
Called for every processing instruction.

xmlparser.CharacterDataHandler(*data*)
Called for character data. This will be called for normal character data, CDATA marked content, and ignorable whitespace. Applications which must distinguish these cases can use the *StartCdataSectionHandler*, *EndCdataSectionHandler*, and *ElementDeclHandler* callbacks to collect the required information.

xmlparser.UnparsedEntityDeclHandler(*entityName*, *base*, *systemId*, *publicId*, *notationName*)
Called for unparsed (NDATA) entity declarations. This is only present for version 1.2 of the Expat library; for more recent versions, use *EntityDeclHandler* instead. (The underlying function in the Expat library has been declared obsolete.)

xmlparser.EntityDeclHandler(*entityName*, *is_parameter_entity*, *value*, *base*, *systemId*, *publicId*, *notationName*)
Called for all entity declarations. For parameter and internal entities, *value* will be a string giving the declared contents of the entity; this will be `None` for external entities. The *notationName* parameter will be `None` for parsed entities, and the name of the notation for unparsed entities. *is_parameter_entity* will be true if the entity is a parameter entity or false for general entities (most applications only need to be concerned with general entities). This is only available starting with version 1.95.0 of the Expat library.

xmlparser.NotationDeclHandler(*notationName*, *base*, *systemId*, *publicId*)
Called for notation declarations. *notationName*, *base*, and *systemId*, and *publicId* are strings if given. If the public identifier is omitted, *publicId* will be `None`.

xmlparser.StartNamespaceDeclHandler(*prefix*, *uri*)
Called when an element contains a namespace declaration. Namespace declarations are processed before the *StartElementHandler* is called for the element on which declarations are placed.

xmlparser.EndNamespaceDeclHandler(*prefix*)
Called when the closing tag is reached for an element that contained a namespace declaration. This is called once for each namespace declaration on the element in the reverse of the order for which the *StartNamespaceDeclHandler* was called to indicate the start of each namespace declaration's scope. Calls to this handler are made after the corresponding *EndElementHandler* for the end of the element.

xmlparser.CommentHandler(*data*)
Called for comments. *data* is the text of the comment, excluding the leading `'<!--'` and trailing `'-->'`.

xmlparser.StartCdataSectionHandler()
Called at the start of a CDATA section. This and *EndCdataSectionHandler* are needed to be able to identify the syntactical start and end for CDATA sections.

xmlparser.EndCdataSectionHandler()
Called at the end of a CDATA section.

xmlparser.DefaultHandler(*data*)
: Called for any characters in the XML document for which no applicable handler has been specified. This means characters that are part of a construct which could be reported, but for which no handler has been supplied.

xmlparser.DefaultHandlerExpand(*data*)
: This is the same as the *DefaultHandler()*, but doesn't inhibit expansion of internal entities. The entity reference will not be passed to the default handler.

xmlparser.NotStandaloneHandler()
: Called if the XML document hasn't been declared as being a standalone document. This happens when there is an external subset or a reference to a parameter entity, but the XML declaration does not set standalone to `yes` in an XML declaration. If this handler returns `0`, then the parser will raise an `XML_ERROR_NOT_STANDALONE` error. If this handler is not set, no exception is raised by the parser for this condition.

xmlparser.ExternalEntityRefHandler(*context*, *base*, *systemId*, *publicId*)
: Called for references to external entities. *base* is the current base, as set by a previous call to *SetBase()*. The public and system identifiers, *systemId* and *publicId*, are strings if given; if the public identifier is not given, *publicId* will be `None`. The *context* value is opaque and should only be used as described below.

  For external entities to be parsed, this handler must be implemented. It is responsible for creating the sub-parser using `ExternalEntityParserCreate(context)`, initializing it with the appropriate callbacks, and parsing the entity. This handler should return an integer; if it returns `0`, the parser will raise an `XML_ERROR_EXTERNAL_ENTITY_HANDLING` error, otherwise parsing will continue.

  If this handler is not provided, external entities are reported by the *DefaultHandler* callback, if provided.

21.13.2 ExpatError Exceptions

ExpatError exceptions have a number of interesting attributes:

ExpatError.code
: Expat's internal error number for the specific error. The *errors.messages* dictionary maps these error numbers to Expat's error messages. For example:

```
from xml.parsers.expat import ParserCreate, ExpatError, errors

p = ParserCreate()
try:
    p.Parse(some_xml_document)
except ExpatError as err:
    print("Error:", errors.messages[err.code])
```

  The *errors* module also provides error message constants and a dictionary *codes* mapping these messages back to the error codes, see below.

ExpatError.lineno
: Line number on which the error was detected. The first line is numbered `1`.

ExpatError.offset
: Character offset into the line where the error occurred. The first column is numbered `0`.

21.13.3 Example

The following program defines three handlers that just print out their arguments.

```
import xml.parsers.expat

# 3 handler functions
def start_element(name, attrs):
    print('Start element:', name, attrs)
def end_element(name):
    print('End element:', name)
def char_data(data):
    print('Character data:', repr(data))

p = xml.parsers.expat.ParserCreate()

p.StartElementHandler = start_element
p.EndElementHandler = end_element
p.CharacterDataHandler = char_data

p.Parse("""<?xml version="1.0"?>
<parent id="top"><child1 name="paul">Text goes here</child1>
<child2 name="fred">More text</child2>
</parent>""", 1)
```

The output from this program is:

```
Start element: parent {'id': 'top'}
Start element: child1 {'name': 'paul'}
Character data: 'Text goes here'
End element: child1
Character data: '\n'
Start element: child2 {'name': 'fred'}
Character data: 'More text'
End element: child2
Character data: '\n'
End element: parent
```

21.13.4 Content Model Descriptions

Content models are described using nested tuples. Each tuple contains four values: the type, the quantifier, the name, and a tuple of children. Children are simply additional content model descriptions.

The values of the first two fields are constants defined in the *xml.parsers.expat.model* module. These constants can be collected in two groups: the model type group and the quantifier group.

The constants in the model type group are:

xml.parsers.expat.model.XML_CTYPE_ANY
The element named by the model name was declared to have a content model of `ANY`.

xml.parsers.expat.model.XML_CTYPE_CHOICE
The named element allows a choice from a number of options; this is used for content models such as `(A | B | C)`.

xml.parsers.expat.model.XML_CTYPE_EMPTY
Elements which are declared to be `EMPTY` have this model type.

xml.parsers.expat.model.XML_CTYPE_MIXED

xml.parsers.expat.model.XML_CTYPE_NAME

xml.parsers.expat.model.**XML_CTYPE_SEQ**
: Models which represent a series of models which follow one after the other are indicated with this model type. This is used for models such as `(A, B, C)`.

The constants in the quantifier group are:

xml.parsers.expat.model.**XML_CQUANT_NONE**
: No modifier is given, so it can appear exactly once, as for `A`.

xml.parsers.expat.model.**XML_CQUANT_OPT**
: The model is optional: it can appear once or not at all, as for `A?`.

xml.parsers.expat.model.**XML_CQUANT_PLUS**
: The model must occur one or more times (like `A+`).

xml.parsers.expat.model.**XML_CQUANT_REP**
: The model must occur zero or more times, as for `A*`.

21.13.5 Expat error constants

The following constants are provided in the *xml.parsers.expat.errors* module. These constants are useful in interpreting some of the attributes of the `ExpatError` exception objects raised when an error has occurred. Since for backwards compatibility reasons, the constants' value is the error *message* and not the numeric error *code*, you do this by comparing its *code* attribute with `errors.codes[errors.XML_ERROR_`*CONSTANT_NAME*`]`.

The `errors` module has the following attributes:

xml.parsers.expat.errors.**codes**
: A dictionary mapping numeric error codes to their string descriptions.

  New in version 3.2.

xml.parsers.expat.errors.**messages**
: A dictionary mapping string descriptions to their error codes.

  New in version 3.2.

xml.parsers.expat.errors.**XML_ERROR_ASYNC_ENTITY**

xml.parsers.expat.errors.**XML_ERROR_ATTRIBUTE_EXTERNAL_ENTITY_REF**
: An entity reference in an attribute value referred to an external entity instead of an internal entity.

xml.parsers.expat.errors.**XML_ERROR_BAD_CHAR_REF**
: A character reference referred to a character which is illegal in XML (for example, character `0`, or '`&#0;`').

xml.parsers.expat.errors.**XML_ERROR_BINARY_ENTITY_REF**
: An entity reference referred to an entity which was declared with a notation, so cannot be parsed.

xml.parsers.expat.errors.**XML_ERROR_DUPLICATE_ATTRIBUTE**
: An attribute was used more than once in a start tag.

xml.parsers.expat.errors.**XML_ERROR_INCORRECT_ENCODING**

xml.parsers.expat.errors.**XML_ERROR_INVALID_TOKEN**
: Raised when an input byte could not properly be assigned to a character; for example, a NUL byte (value `0`) in a UTF-8 input stream.

xml.parsers.expat.errors.**XML_ERROR_JUNK_AFTER_DOC_ELEMENT**
: Something other than whitespace occurred after the document element.

xml.parsers.expat.errors.**XML_ERROR_MISPLACED_XML_PI**
: An XML declaration was found somewhere other than the start of the input data.

xml.parsers.expat.errors.XML_ERROR_NO_ELEMENTS
: The document contains no elements (XML requires all documents to contain exactly one top-level element)..

xml.parsers.expat.errors.XML_ERROR_NO_MEMORY
: Expat was not able to allocate memory internally.

xml.parsers.expat.errors.XML_ERROR_PARAM_ENTITY_REF
: A parameter entity reference was found where it was not allowed.

xml.parsers.expat.errors.XML_ERROR_PARTIAL_CHAR
: An incomplete character was found in the input.

xml.parsers.expat.errors.XML_ERROR_RECURSIVE_ENTITY_REF
: An entity reference contained another reference to the same entity; possibly via a different name, and possibly indirectly.

xml.parsers.expat.errors.XML_ERROR_SYNTAX
: Some unspecified syntax error was encountered.

xml.parsers.expat.errors.XML_ERROR_TAG_MISMATCH
: An end tag did not match the innermost open start tag.

xml.parsers.expat.errors.XML_ERROR_UNCLOSED_TOKEN
: Some token (such as a start tag) was not closed before the end of the stream or the next token was encountered.

xml.parsers.expat.errors.XML_ERROR_UNDEFINED_ENTITY
: A reference was made to an entity which was not defined.

xml.parsers.expat.errors.XML_ERROR_UNKNOWN_ENCODING
: The document encoding is not supported by Expat.

xml.parsers.expat.errors.XML_ERROR_UNCLOSED_CDATA_SECTION
: A CDATA marked section was not closed.

xml.parsers.expat.errors.XML_ERROR_EXTERNAL_ENTITY_HANDLING

xml.parsers.expat.errors.XML_ERROR_NOT_STANDALONE
: The parser determined that the document was not "standalone" though it declared itself to be in the XML declaration, and the `NotStandaloneHandler` was set and returned `0`.

xml.parsers.expat.errors.XML_ERROR_UNEXPECTED_STATE

xml.parsers.expat.errors.XML_ERROR_ENTITY_DECLARED_IN_PE

xml.parsers.expat.errors.XML_ERROR_FEATURE_REQUIRES_XML_DTD
: An operation was requested that requires DTD support to be compiled in, but Expat was configured without DTD support. This should never be reported by a standard build of the *xml.parsers.expat* module.

xml.parsers.expat.errors.XML_ERROR_CANT_CHANGE_FEATURE_ONCE_PARSING
: A behavioral change was requested after parsing started that can only be changed before parsing has started. This is (currently) only raised by `UseForeignDTD()`.

xml.parsers.expat.errors.XML_ERROR_UNBOUND_PREFIX
: An undeclared prefix was found when namespace processing was enabled.

xml.parsers.expat.errors.XML_ERROR_UNDECLARING_PREFIX
: The document attempted to remove the namespace declaration associated with a prefix.

xml.parsers.expat.errors.XML_ERROR_INCOMPLETE_PE
: A parameter entity contained incomplete markup.

xml.parsers.expat.errors.XML_ERROR_XML_DECL
: The document contained no document element at all.

xml.parsers.expat.errors.XML_ERROR_TEXT_DECL
: There was an error parsing a text declaration in an external entity.

xml.parsers.expat.errors.XML_ERROR_PUBLICID
: Characters were found in the public id that are not allowed.

xml.parsers.expat.errors.XML_ERROR_SUSPENDED
: The requested operation was made on a suspended parser, but isn't allowed. This includes attempts to provide additional input or to stop the parser.

xml.parsers.expat.errors.XML_ERROR_NOT_SUSPENDED
: An attempt to resume the parser was made when the parser had not been suspended.

xml.parsers.expat.errors.XML_ERROR_ABORTED
: This should not be reported to Python applications.

xml.parsers.expat.errors.XML_ERROR_FINISHED
: The requested operation was made on a parser which was finished parsing input, but isn't allowed. This includes attempts to provide additional input or to stop the parser.

xml.parsers.expat.errors.XML_ERROR_SUSPEND_PE

CHAPTER

TWENTYTWO

INTERNET PROTOCOLS AND SUPPORT

The modules described in this chapter implement Internet protocols and support for related technology. They are all implemented in Python. Most of these modules require the presence of the system-dependent module *socket*, which is currently supported on most popular platforms. Here is an overview:

22.1 webbrowser — Convenient Web-browser controller

Source code: Lib/webbrowser.py

The *webbrowser* module provides a high-level interface to allow displaying Web-based documents to users. Under most circumstances, simply calling the *open()* function from this module will do the right thing.

Under Unix, graphical browsers are preferred under X11, but text-mode browsers will be used if graphical browsers are not available or an X11 display isn't available. If text-mode browsers are used, the calling process will block until the user exits the browser.

If the environment variable BROWSER exists, it is interpreted as the *os.pathsep*-separated list of browsers to try ahead of the platform defaults. When the value of a list part contains the string %s, then it is interpreted as a literal browser command line to be used with the argument URL substituted for %s; if the part does not contain %s, it is simply interpreted as the name of the browser to launch.[1]

For non-Unix platforms, or when a remote browser is available on Unix, the controlling process will not wait for the user to finish with the browser, but allow the remote browser to maintain its own windows on the display. If remote browsers are not available on Unix, the controlling process will launch a new browser and wait.

The script **webbrowser** can be used as a command-line interface for the module. It accepts a URL as the argument. It accepts the following optional parameters: -n opens the URL in a new browser window, if possible; -t opens the URL in a new browser page ("tab"). The options are, naturally, mutually exclusive. Usage example:

```
python -m webbrowser -t "http://www.python.org"
```

The following exception is defined:

exception webbrowser.Error
Exception raised when a browser control error occurs.

The following functions are defined:

webbrowser.open(*url*, *new=0*, *autoraise=True*)
Display *url* using the default browser. If *new* is 0, the *url* is opened in the same browser window if possible. If *new* is 1, a new browser window is opened if possible. If *new* is 2, a new browser page

[1] Executables named here without a full path will be searched in the directories given in the PATH environment variable.

("tab") is opened if possible. If *autoraise* is `True`, the window is raised if possible (note that under many window managers this will occur regardless of the setting of this variable).

Note that on some platforms, trying to open a filename using this function, may work and start the operating system's associated program. However, this is neither supported nor portable.

`webbrowser.open_new(`*url*`)`
Open *url* in a new window of the default browser, if possible, otherwise, open *url* in the only browser window.

`webbrowser.open_new_tab(`*url*`)`
Open *url* in a new page ("tab") of the default browser, if possible, otherwise equivalent to *open_new()*.

`webbrowser.get(`*using=None*`)`
Return a controller object for the browser type *using*. If *using* is `None`, return a controller for a default browser appropriate to the caller's environment.

`webbrowser.register(`*name*, *constructor*, *instance=None*, ***, *preferred=False*`)`
Register the browser type *name*. Once a browser type is registered, the *get()* function can return a controller for that browser type. If *instance* is not provided, or is `None`, *constructor* will be called without parameters to create an instance when needed. If *instance* is provided, *constructor* will never be called, and may be `None`.

Setting *preferred* to `True` makes this browser a preferred result for a *get()* call with no argument. Otherwise, this entry point is only useful if you plan to either set the `BROWSER` variable or call *get()* with a nonempty argument matching the name of a handler you declare.

Changed in version 3.7: *preferred* keyword-only parameter was added.

A number of browser types are predefined. This table gives the type names that may be passed to the *get()* function and the corresponding instantiations for the controller classes, all defined in this module.

Type Name	Class Name	Notes
`'mozilla'`	`Mozilla('mozilla')`	
`'firefox'`	`Mozilla('mozilla')`	
`'netscape'`	`Mozilla('netscape')`	
`'galeon'`	`Galeon('galeon')`	
`'epiphany'`	`Galeon('epiphany')`	
`'skipstone'`	`BackgroundBrowser('skipstone')`	
`'kfmclient'`	`Konqueror()`	(1)
`'konqueror'`	`Konqueror()`	(1)
`'kfm'`	`Konqueror()`	(1)
`'mosaic'`	`BackgroundBrowser('mosaic')`	
`'opera'`	`Opera()`	
`'grail'`	`Grail()`	
`'links'`	`GenericBrowser('links')`	
`'elinks'`	`Elinks('elinks')`	
`'lynx'`	`GenericBrowser('lynx')`	
`'w3m'`	`GenericBrowser('w3m')`	
`'windows-default'`	`WindowsDefault`	(2)
`'macosx'`	`MacOSX('default')`	(3)
`'safari'`	`MacOSX('safari')`	(3)
`'google-chrome'`	`Chrome('google-chrome')`	
`'chrome'`	`Chrome('chrome')`	
`'chromium'`	`Chromium('chromium')`	
`'chromium-browser'`	`Chromium('chromium-browser')`	

Notes:

1. "Konqueror" is the file manager for the KDE desktop environment for Unix, and only makes sense to use if KDE is running. Some way of reliably detecting KDE would be nice; the `KDEDIR` variable is not sufficient. Note also that the name "kfm" is used even when using the **konqueror** command with KDE 2 — the implementation selects the best strategy for running Konqueror.
2. Only on Windows platforms.
3. Only on Mac OS X platform.

New in version 3.3: Support for Chrome/Chromium has been added.

Here are some simple examples:

```
url = 'http://docs.python.org/'

# Open URL in a new tab, if a browser window is already open.
webbrowser.open_new_tab(url)

# Open URL in new window, raising the window if possible.
webbrowser.open_new(url)
```

22.1.1 Browser Controller Objects

Browser controllers provide these methods which parallel three of the module-level convenience functions:

`controller.open(`*url*, *new=0*, *autoraise=True*`)`
Display *url* using the browser handled by this controller. If *new* is 1, a new browser window is opened if possible. If *new* is 2, a new browser page ("tab") is opened if possible.

`controller.open_new(`*url*`)`
Open *url* in a new window of the browser handled by this controller, if possible, otherwise, open *url* in the only browser window. Alias *open_new()*.

`controller.open_new_tab(`*url*`)`
Open *url* in a new page ("tab") of the browser handled by this controller, if possible, otherwise equivalent to *open_new()*.

22.2 cgi — Common Gateway Interface support

Source code: Lib/cgi.py

Support module for Common Gateway Interface (CGI) scripts.

This module defines a number of utilities for use by CGI scripts written in Python.

22.2.1 Introduction

A CGI script is invoked by an HTTP server, usually to process user input submitted through an HTML `<FORM>` or `<ISINDEX>` element.

Most often, CGI scripts live in the server's special `cgi-bin` directory. The HTTP server places all sorts of information about the request (such as the client's hostname, the requested URL, the query string, and lots of other goodies) in the script's shell environment, executes the script, and sends the script's output back to the client.

The script's input is connected to the client too, and sometimes the form data is read this way; at other times the form data is passed via the "query string" part of the URL. This module is intended to take care of the different cases and provide a simpler interface to the Python script. It also provides a number of utilities that help in debugging scripts, and the latest addition is support for file uploads from a form (if your browser supports it).

The output of a CGI script should consist of two sections, separated by a blank line. The first section contains a number of headers, telling the client what kind of data is following. Python code to generate a minimal header section looks like this:

```
print("Content-Type: text/html")    # HTML is following
print()                             # blank line, end of headers
```

The second section is usually HTML, which allows the client software to display nicely formatted text with header, in-line images, etc. Here's Python code that prints a simple piece of HTML:

```
print("<TITLE>CGI script output</TITLE>")
print("<H1>This is my first CGI script</H1>")
print("Hello, world!")
```

22.2.2 Using the cgi module

Begin by writing `import cgi`.

When you write a new script, consider adding these lines:

```
import cgitb
cgitb.enable()
```

This activates a special exception handler that will display detailed reports in the Web browser if any errors occur. If you'd rather not show the guts of your program to users of your script, you can have the reports saved to files instead, with code like this:

```
import cgitb
cgitb.enable(display=0, logdir="/path/to/logdir")
```

It's very helpful to use this feature during script development. The reports produced by *cgitb* provide information that can save you a lot of time in tracking down bugs. You can always remove the `cgitb` line later when you have tested your script and are confident that it works correctly.

To get at submitted form data, use the `FieldStorage` class. If the form contains non-ASCII characters, use the *encoding* keyword parameter set to the value of the encoding defined for the document. It is usually contained in the META tag in the HEAD section of the HTML document or by the *Content-Type* header). This reads the form contents from the standard input or the environment (depending on the value of various environment variables set according to the CGI standard). Since it may consume standard input, it should be instantiated only once.

The `FieldStorage` instance can be indexed like a Python dictionary. It allows membership testing with the `in` operator, and also supports the standard dictionary method *keys()* and the built-in function *len()*. Form fields containing empty strings are ignored and do not appear in the dictionary; to keep such values, provide a true value for the optional *keep_blank_values* keyword parameter when creating the `FieldStorage` instance.

For instance, the following code (which assumes that the *Content-Type* header and blank line have already been printed) checks that the fields `name` and `addr` are both set to a non-empty string:

```
form = cgi.FieldStorage()
if "name" not in form or "addr" not in form:
    print("<H1>Error</H1>")
    print("Please fill in the name and addr fields.")
    return
print("<p>name:", form["name"].value)
print("<p>addr:", form["addr"].value)
...further form processing here...
```

Here the fields, accessed through `form[key]`, are themselves instances of `FieldStorage` (or `MiniFieldStorage`, depending on the form encoding). The `value` attribute of the instance yields the string value of the field. The `getvalue()` method returns this string value directly; it also accepts an optional second argument as a default to return if the requested key is not present.

If the submitted form data contains more than one field with the same name, the object retrieved by `form[key]` is not a `FieldStorage` or `MiniFieldStorage` instance but a list of such instances. Similarly, in this situation, `form.getvalue(key)` would return a list of strings. If you expect this possibility (when your HTML form contains multiple fields with the same name), use the *`getlist()`* method, which always returns a list of values (so that you do not need to special-case the single item case). For example, this code concatenates any number of username fields, separated by commas:

```
value = form.getlist("username")
usernames = ",".join(value)
```

If a field represents an uploaded file, accessing the value via the `value` attribute or the `getvalue()` method reads the entire file in memory as bytes. This may not be what you want. You can test for an uploaded file by testing either the `filename` attribute or the `file` attribute. You can then read the data from the `file` attribute before it is automatically closed as part of the garbage collection of the `FieldStorage` instance (the *`read()`* and *`readline()`* methods will return bytes):

```
fileitem = form["userfile"]
if fileitem.file:
    # It's an uploaded file; count lines
    linecount = 0
    while True:
        line = fileitem.file.readline()
        if not line: break
        linecount = linecount + 1
```

`FieldStorage` objects also support being used in a `with` statement, which will automatically close them when done.

If an error is encountered when obtaining the contents of an uploaded file (for example, when the user interrupts the form submission by clicking on a Back or Cancel button) the `done` attribute of the object for the field will be set to the value -1.

The file upload draft standard entertains the possibility of uploading multiple files from one field (using a recursive *`multipart/*`* encoding). When this occurs, the item will be a dictionary-like `FieldStorage` item. This can be determined by testing its `type` attribute, which should be *`multipart/form-data`* (or perhaps another MIME type matching *`multipart/*`*). In this case, it can be iterated over recursively just like the top-level form object.

When a form is submitted in the "old" format (as the query string or as a single data part of type *`application/x-www-form-urlencoded`*), the items will actually be instances of the class `MiniFieldStorage`. In this case, the `list`, `file`, and `filename` attributes are always `None`.

A form submitted via POST that also has a query string will contain both `FieldStorage` and `MiniFieldStorage` items.

Changed in version 3.4: The `file` attribute is automatically closed upon the garbage collection of the creating `FieldStorage` instance.

Changed in version 3.5: Added support for the context management protocol to the `FieldStorage` class.

22.2.3 Higher Level Interface

The previous section explains how to read CGI form data using the `FieldStorage` class. This section describes a higher level interface which was added to this class to allow one to do it in a more readable and intuitive way. The interface doesn't make the techniques described in previous sections obsolete — they are still useful to process file uploads efficiently, for example.

The interface consists of two simple methods. Using the methods you can process form data in a generic way, without the need to worry whether only one or more values were posted under one name.

In the previous section, you learned to write following code anytime you expected a user to post more than one value under one name:

```
item = form.getvalue("item")
if isinstance(item, list):
    # The user is requesting more than one item.
else:
    # The user is requesting only one item.
```

This situation is common for example when a form contains a group of multiple checkboxes with the same name:

```
<input type="checkbox" name="item" value="1" />
<input type="checkbox" name="item" value="2" />
```

In most situations, however, there's only one form control with a particular name in a form and then you expect and need only one value associated with this name. So you write a script containing for example this code:

```
user = form.getvalue("user").upper()
```

The problem with the code is that you should never expect that a client will provide valid input to your scripts. For example, if a curious user appends another `user=foo` pair to the query string, then the script would crash, because in this situation the `getvalue("user")` method call returns a list instead of a string. Calling the *upper()* method on a list is not valid (since lists do not have a method of this name) and results in an *AttributeError* exception.

Therefore, the appropriate way to read form data values was to always use the code which checks whether the obtained value is a single value or a list of values. That's annoying and leads to less readable scripts.

A more convenient approach is to use the methods *getfirst()* and *getlist()* provided by this higher level interface.

`FieldStorage.getfirst`(*name*, *default=None*)

This method always returns only one value associated with form field *name*. The method returns only the first value in case that more values were posted under such name. Please note that the order in which the values are received may vary from browser to browser and should not be counted on.[1] If no such form field or value exists then the method returns the value specified by the optional parameter *default*. This parameter defaults to `None` if not specified.

[1] Note that some recent versions of the HTML specification do state what order the field values should be supplied in, but knowing whether a request was received from a conforming browser, or even from a browser at all, is tedious and error-prone.

FieldStorage.getlist(*name*)
: This method always returns a list of values associated with form field *name*. The method returns an empty list if no such form field or value exists for *name*. It returns a list consisting of one item if only one such value exists.

Using these methods you can write nice compact code:

```
import cgi
form = cgi.FieldStorage()
user = form.getfirst("user", "").upper()    # This way it's safe.
for item in form.getlist("item"):
    do_something(item)
```

22.2.4 Functions

These are useful if you want more control, or if you want to employ some of the algorithms implemented in this module in other circumstances.

cgi.parse(*fp=None*, *environ=os.environ*, *keep_blank_values=False*, *strict_parsing=False*)
: Parse a query in the environment or from a file (the file defaults to `sys.stdin`). The *keep_blank_values* and *strict_parsing* parameters are passed to *urllib.parse.parse_qs()* unchanged.

cgi.parse_qs(*qs*, *keep_blank_values=False*, *strict_parsing=False*)
: This function is deprecated in this module. Use *urllib.parse.parse_qs()* instead. It is maintained here only for backward compatibility.

cgi.parse_qsl(*qs*, *keep_blank_values=False*, *strict_parsing=False*)
: This function is deprecated in this module. Use *urllib.parse.parse_qsl()* instead. It is maintained here only for backward compatibility.

cgi.parse_multipart(*fp*, *pdict*, *encoding="utf-8"*, *errors="replace"*)
: Parse input of type *multipart/form-data* (for file uploads). Arguments are *fp* for the input file, *pdict* for a dictionary containing other parameters in the *Content-Type* header, and *encoding*, the request encoding.

  Returns a dictionary just like *urllib.parse.parse_qs()*: keys are the field names, each value is a list of values for that field. For non-file fields, the value is a list of strings.

  This is easy to use but not much good if you are expecting megabytes to be uploaded — in that case, use the `FieldStorage` class instead which is much more flexible.

  Changed in version 3.7: Added the *encoding* and *errors* parameters. For non-file fields, the value is now a list of strings, not bytes.

cgi.parse_header(*string*)
: Parse a MIME header (such as *Content-Type*) into a main value and a dictionary of parameters.

cgi.test()
: Robust test CGI script, usable as main program. Writes minimal HTTP headers and formats all information provided to the script in HTML form.

cgi.print_environ()
: Format the shell environment in HTML.

cgi.print_form(*form*)
: Format a form in HTML.

cgi.print_directory()
: Format the current directory in HTML.

cgi.print_environ_usage()
: Print a list of useful (used by CGI) environment variables in HTML.

cgi.escape(*s*, *quote=False*)

Convert the characters '&', '<' and '>' in string *s* to HTML-safe sequences. Use this if you need to display text that might contain such characters in HTML. If the optional flag *quote* is true, the quotation mark character (") is also translated; this helps for inclusion in an HTML attribute value delimited by double quotes, as in <a href="...">. Note that single quotes are never translated.

Deprecated since version 3.2: This function is unsafe because *quote* is false by default, and therefore deprecated. Use *html.escape()* instead.

22.2.5 Caring about security

There's one important rule: if you invoke an external program (via the *os.system()* or *os.popen()* functions. or others with similar functionality), make very sure you don't pass arbitrary strings received from the client to the shell. This is a well-known security hole whereby clever hackers anywhere on the Web can exploit a gullible CGI script to invoke arbitrary shell commands. Even parts of the URL or field names cannot be trusted, since the request doesn't have to come from your form!

To be on the safe side, if you must pass a string gotten from a form to a shell command, you should make sure the string contains only alphanumeric characters, dashes, underscores, and periods.

22.2.6 Installing your CGI script on a Unix system

Read the documentation for your HTTP server and check with your local system administrator to find the directory where CGI scripts should be installed; usually this is in a directory cgi-bin in the server tree.

Make sure that your script is readable and executable by "others"; the Unix file mode should be 0o755 octal (use chmod 0755 filename). Make sure that the first line of the script contains #! starting in column 1 followed by the pathname of the Python interpreter, for instance:

```
#!/usr/local/bin/python
```

Make sure the Python interpreter exists and is executable by "others".

Make sure that any files your script needs to read or write are readable or writable, respectively, by "others" — their mode should be 0o644 for readable and 0o666 for writable. This is because, for security reasons, the HTTP server executes your script as user "nobody", without any special privileges. It can only read (write, execute) files that everybody can read (write, execute). The current directory at execution time is also different (it is usually the server's cgi-bin directory) and the set of environment variables is also different from what you get when you log in. In particular, don't count on the shell's search path for executables (PATH) or the Python module search path (PYTHONPATH) to be set to anything interesting.

If you need to load modules from a directory which is not on Python's default module search path, you can change the path in your script, before importing other modules. For example:

```
import sys
sys.path.insert(0, "/usr/home/joe/lib/python")
sys.path.insert(0, "/usr/local/lib/python")
```

(This way, the directory inserted last will be searched first!)

Instructions for non-Unix systems will vary; check your HTTP server's documentation (it will usually have a section on CGI scripts).

22.2.7 Testing your CGI script

Unfortunately, a CGI script will generally not run when you try it from the command line, and a script that works perfectly from the command line may fail mysteriously when run from the server. There's one reason why you should still test your script from the command line: if it contains a syntax error, the Python interpreter won't execute it at all, and the HTTP server will most likely send a cryptic error to the client.

Assuming your script has no syntax errors, yet it does not work, you have no choice but to read the next section.

22.2.8 Debugging CGI scripts

First of all, check for trivial installation errors — reading the section above on installing your CGI script carefully can save you a lot of time. If you wonder whether you have understood the installation procedure correctly, try installing a copy of this module file (`cgi.py`) as a CGI script. When invoked as a script, the file will dump its environment and the contents of the form in HTML form. Give it the right mode etc, and send it a request. If it's installed in the standard `cgi-bin` directory, it should be possible to send it a request by entering a URL into your browser of the form:

```
http://yourhostname/cgi-bin/cgi.py?name=Joe+Blow&addr=At+Home
```

If this gives an error of type 404, the server cannot find the script – perhaps you need to install it in a different directory. If it gives another error, there's an installation problem that you should fix before trying to go any further. If you get a nicely formatted listing of the environment and form content (in this example, the fields should be listed as "addr" with value "At Home" and "name" with value "Joe Blow"), the `cgi.py` script has been installed correctly. If you follow the same procedure for your own script, you should now be able to debug it.

The next step could be to call the *cgi* module's *test()* function from your script: replace its main code with the single statement

```
cgi.test()
```

This should produce the same results as those gotten from installing the `cgi.py` file itself.

When an ordinary Python script raises an unhandled exception (for whatever reason: of a typo in a module name, a file that can't be opened, etc.), the Python interpreter prints a nice traceback and exits. While the Python interpreter will still do this when your CGI script raises an exception, most likely the traceback will end up in one of the HTTP server's log files, or be discarded altogether.

Fortunately, once you have managed to get your script to execute *some* code, you can easily send tracebacks to the Web browser using the *cgitb* module. If you haven't done so already, just add the lines:

```
import cgitb
cgitb.enable()
```

to the top of your script. Then try running it again; when a problem occurs, you should see a detailed report that will likely make apparent the cause of the crash.

If you suspect that there may be a problem in importing the *cgitb* module, you can use an even more robust approach (which only uses built-in modules):

```
import sys
sys.stderr = sys.stdout
print("Content-Type: text/plain")
print()
...your code here...
```

This relies on the Python interpreter to print the traceback. The content type of the output is set to plain text, which disables all HTML processing. If your script works, the raw HTML will be displayed by your client. If it raises an exception, most likely after the first two lines have been printed, a traceback will be displayed. Because no HTML interpretation is going on, the traceback will be readable.

22.2.9 Common problems and solutions

- Most HTTP servers buffer the output from CGI scripts until the script is completed. This means that it is not possible to display a progress report on the client's display while the script is running.
- Check the installation instructions above.
- Check the HTTP server's log files. (`tail -f logfile` in a separate window may be useful!)
- Always check a script for syntax errors first, by doing something like `python script.py`.
- If your script does not have any syntax errors, try adding `import cgitb; cgitb.enable()` to the top of the script.
- When invoking external programs, make sure they can be found. Usually, this means using absolute path names — `PATH` is usually not set to a very useful value in a CGI script.
- When reading or writing external files, make sure they can be read or written by the userid under which your CGI script will be running: this is typically the userid under which the web server is running, or some explicitly specified userid for a web server's `suexec` feature.
- Don't try to give a CGI script a set-uid mode. This doesn't work on most systems, and is a security liability as well.

22.3 `cgitb` — Traceback manager for CGI scripts

Source code: Lib/cgitb.py

The *cgitb* module provides a special exception handler for Python scripts. (Its name is a bit misleading. It was originally designed to display extensive traceback information in HTML for CGI scripts. It was later generalized to also display this information in plain text.) After this module is activated, if an uncaught exception occurs, a detailed, formatted report will be displayed. The report includes a traceback showing excerpts of the source code for each level, as well as the values of the arguments and local variables to currently running functions, to help you debug the problem. Optionally, you can save this information to a file instead of sending it to the browser.

To enable this feature, simply add this to the top of your CGI script:

```
import cgitb
cgitb.enable()
```

The options to the *enable()* function control whether the report is displayed in the browser and whether the report is logged to a file for later analysis.

`cgitb.enable`(*display=1*, *logdir=None*, *context=5*, *format="html"*)

This function causes the *cgitb* module to take over the interpreter's default handling for exceptions by setting the value of *sys.excepthook*.

The optional argument *display* defaults to `1` and can be set to `0` to suppress sending the traceback to the browser. If the argument *logdir* is present, the traceback reports are written to files. The value of *logdir* should be a directory where these files will be placed. The optional argument *context* is the number of lines of context to display around the current line of source code in the traceback; this

defaults to 5. If the optional argument *format* is "html", the output is formatted as HTML. Any other value forces plain text output. The default value is "html".

cgitb.**text**(*info*, *context=5*)
: This function handles the exception described by *info* (a 3-tuple containing the result of *sys.exc_info()*), formatting its traceback as text and returning the result as a string. The optional argument *context* is the number of lines of context to display around the current line of source code in the traceback; this defaults to 5.

cgitb.**html**(*info*, *context=5*)
: This function handles the exception described by *info* (a 3-tuple containing the result of *sys.exc_info()*), formatting its traceback as HTML and returning the result as a string. The optional argument *context* is the number of lines of context to display around the current line of source code in the traceback; this defaults to 5.

cgitb.**handler**(*info=None*)
: This function handles an exception using the default settings (that is, show a report in the browser, but don't log to a file). This can be used when you've caught an exception and want to report it using *cgitb*. The optional *info* argument should be a 3-tuple containing an exception type, exception value, and traceback object, exactly like the tuple returned by *sys.exc_info()*. If the *info* argument is not supplied, the current exception is obtained from *sys.exc_info()*.

22.4 wsgiref — WSGI Utilities and Reference Implementation

The Web Server Gateway Interface (WSGI) is a standard interface between web server software and web applications written in Python. Having a standard interface makes it easy to use an application that supports WSGI with a number of different web servers.

Only authors of web servers and programming frameworks need to know every detail and corner case of the WSGI design. You don't need to understand every detail of WSGI just to install a WSGI application or to write a web application using an existing framework.

wsgiref is a reference implementation of the WSGI specification that can be used to add WSGI support to a web server or framework. It provides utilities for manipulating WSGI environment variables and response headers, base classes for implementing WSGI servers, a demo HTTP server that serves WSGI applications, and a validation tool that checks WSGI servers and applications for conformance to the WSGI specification (**PEP 3333**).

See wsgi.readthedocs.io for more information about WSGI, and links to tutorials and other resources.

22.4.1 wsgiref.util – WSGI environment utilities

This module provides a variety of utility functions for working with WSGI environments. A WSGI environment is a dictionary containing HTTP request variables as described in **PEP 3333**. All of the functions taking an *environ* parameter expect a WSGI-compliant dictionary to be supplied; please see **PEP 3333** for a detailed specification.

wsgiref.util.**guess_scheme**(*environ*)
: Return a guess for whether wsgi.url_scheme should be "http" or "https", by checking for a HTTPS environment variable in the *environ* dictionary. The return value is a string.

  This function is useful when creating a gateway that wraps CGI or a CGI-like protocol such as FastCGI. Typically, servers providing such protocols will include a HTTPS variable with a value of "1" "yes", or "on" when a request is received via SSL. So, this function returns "https" if such a value is found, and "http" otherwise.

wsgiref.util.request_uri(*environ*, *include_query=True*)
Return the full request URI, optionally including the query string, using the algorithm found in the "URL Reconstruction" section of **PEP 3333**. If *include_query* is false, the query string is not included in the resulting URI.

wsgiref.util.application_uri(*environ*)
Similar to *request_uri()*, except that the PATH_INFO and QUERY_STRING variables are ignored. The result is the base URI of the application object addressed by the request.

wsgiref.util.shift_path_info(*environ*)
Shift a single name from PATH_INFO to SCRIPT_NAME and return the name. The *environ* dictionary is *modified* in-place; use a copy if you need to keep the original PATH_INFO or SCRIPT_NAME intact.

If there are no remaining path segments in PATH_INFO, None is returned.

Typically, this routine is used to process each portion of a request URI path, for example to treat the path as a series of dictionary keys. This routine modifies the passed-in environment to make it suitable for invoking another WSGI application that is located at the target URI. For example, if there is a WSGI application at /foo, and the request URI path is /foo/bar/baz, and the WSGI application at /foo calls *shift_path_info()*, it will receive the string "bar", and the environment will be updated to be suitable for passing to a WSGI application at /foo/bar. That is, SCRIPT_NAME will change from /foo to /foo/bar, and PATH_INFO will change from /bar/baz to /baz.

When PATH_INFO is just a "/", this routine returns an empty string and appends a trailing slash to SCRIPT_NAME, even though empty path segments are normally ignored, and SCRIPT_NAME doesn't normally end in a slash. This is intentional behavior, to ensure that an application can tell the difference between URIs ending in /x from ones ending in /x/ when using this routine to do object traversal.

wsgiref.util.setup_testing_defaults(*environ*)
Update *environ* with trivial defaults for testing purposes.

This routine adds various parameters required for WSGI, including HTTP_HOST, SERVER_NAME, SERVER_PORT, REQUEST_METHOD, SCRIPT_NAME, PATH_INFO, and all of the **PEP 3333**-defined wsgi.* variables. It only supplies default values, and does not replace any existing settings for these variables.

This routine is intended to make it easier for unit tests of WSGI servers and applications to set up dummy environments. It should NOT be used by actual WSGI servers or applications, since the data is fake!

Example usage:

```
from wsgiref.util import setup_testing_defaults
from wsgiref.simple_server import make_server

# A relatively simple WSGI application. It's going to print out the
# environment dictionary after being updated by setup_testing_defaults
def simple_app(environ, start_response):
    setup_testing_defaults(environ)

    status = '200 OK'
    headers = [('Content-type', 'text/plain; charset=utf-8')]

    start_response(status, headers)

    ret = [("%s: %s\n" % (key, value)).encode("utf-8")
           for key, value in environ.items()]
    return ret

with make_server('', 8000, simple_app) as httpd:
    print("Serving on port 8000...")
    httpd.serve_forever()
```

In addition to the environment functions above, the *wsgiref.util* module also provides these miscellaneous utilities:

wsgiref.util.is_hop_by_hop(*header_name*)
Return true if 'header_name' is an HTTP/1.1 "Hop-by-Hop" header, as defined by **RFC 2616**.

class wsgiref.util.FileWrapper(*filelike*, *blksize=8192*)
A wrapper to convert a file-like object to an *iterator*. The resulting objects support both `__getitem__()` and `__iter__()` iteration styles, for compatibility with Python 2.1 and Jython. As the object is iterated over, the optional *blksize* parameter will be repeatedly passed to the *filelike* object's `read()` method to obtain bytestrings to yield. When `read()` returns an empty bytestring, iteration is ended and is not resumable.

If *filelike* has a `close()` method, the returned object will also have a `close()` method, and it will invoke the *filelike* object's `close()` method when called.

Example usage:

```
from io import StringIO
from wsgiref.util import FileWrapper

# We're using a StringIO-buffer for as the file-like object
filelike = StringIO("This is an example file-like object"*10)
wrapper = FileWrapper(filelike, blksize=5)

for chunk in wrapper:
    print(chunk)
```

22.4.2 wsgiref.headers – WSGI response header tools

This module provides a single class, *Headers*, for convenient manipulation of WSGI response headers using a mapping-like interface.

class wsgiref.headers.Headers([*headers*])
Create a mapping-like object wrapping *headers*, which must be a list of header name/value tuples as described in **PEP 3333**. The default value of *headers* is an empty list.

Headers objects support typical mapping operations including `__getitem__()`, `get()`, `__setitem__()`, `setdefault()`, `__delitem__()` and `__contains__()`. For each of these methods, the key is the header name (treated case-insensitively), and the value is the first value associated with that header name. Setting a header deletes any existing values for that header, then adds a new value at the end of the wrapped header list. Headers' existing order is generally maintained, with new headers added to the end of the wrapped list.

Unlike a dictionary, *Headers* objects do not raise an error when you try to get or delete a key that isn't in the wrapped header list. Getting a nonexistent header just returns `None`, and deleting a nonexistent header does nothing.

Headers objects also support `keys()`, `values()`, and `items()` methods. The lists returned by `keys()` and `items()` can include the same key more than once if there is a multi-valued header. The `len()` of a *Headers* object is the same as the length of its `items()`, which is the same as the length of the wrapped header list. In fact, the `items()` method just returns a copy of the wrapped header list.

Calling `bytes()` on a *Headers* object returns a formatted bytestring suitable for transmission as HTTP response headers. Each header is placed on a line with its value, separated by a colon and a space. Each line is terminated by a carriage return and line feed, and the bytestring is terminated with a blank line.

In addition to their mapping interface and formatting features, *Headers* objects also have the following methods for querying and adding multi-valued headers, and for adding headers with MIME parameters:

get_all(*name*)
Return a list of all the values for the named header.

The returned list will be sorted in the order they appeared in the original header list or were added to this instance, and may contain duplicates. Any fields deleted and re-inserted are always appended to the header list. If no fields exist with the given name, returns an empty list.

add_header(*name*, *value*, ***_params*)
Add a (possibly multi-valued) header, with optional MIME parameters specified via keyword arguments.

name is the header field to add. Keyword arguments can be used to set MIME parameters for the header field. Each parameter must be a string or `None`. Underscores in parameter names are converted to dashes, since dashes are illegal in Python identifiers, but many MIME parameter names include dashes. If the parameter value is a string, it is added to the header value parameters in the form `name="value"`. If it is `None`, only the parameter name is added. (This is used for MIME parameters without a value.) Example usage:

```
h.add_header('content-disposition', 'attachment', filename='bud.gif')
```

The above will add a header that looks like this:

```
Content-Disposition: attachment; filename="bud.gif"
```

Changed in version 3.5: *headers* parameter is optional.

22.4.3 wsgiref.simple_server – a simple WSGI HTTP server

This module implements a simple HTTP server (based on *http.server*) that serves WSGI applications. Each server instance serves a single WSGI application on a given host and port. If you want to serve multiple applications on a single host and port, you should create a WSGI application that parses `PATH_INFO` to select which application to invoke for each request. (E.g., using the `shift_path_info()` function from *wsgiref.util*.)

wsgiref.simple_server.make_server(*host*, *port*, *app*, *server_class=WSGIServer*, *handler_class=WSGIRequestHandler*)
Create a new WSGI server listening on *host* and *port*, accepting connections for *app*. The return value is an instance of the supplied *server_class*, and will process requests using the specified *handler_class*. *app* must be a WSGI application object, as defined by **PEP 3333**.

Example usage:

```
from wsgiref.simple_server import make_server, demo_app

with make_server('', 8000, demo_app) as httpd:
    print("Serving HTTP on port 8000...")

    # Respond to requests until process is killed
    httpd.serve_forever()

    # Alternative: serve one request, then exit
    httpd.handle_request()
```

wsgiref.simple_server.demo_app(*environ*, *start_response*)
This function is a small but complete WSGI application that returns a text page containing the

message "Hello world!" and a list of the key/value pairs provided in the *environ* parameter. It's useful for verifying that a WSGI server (such as *wsgiref.simple_server*) is able to run a simple WSGI application correctly.

class wsgiref.simple_server.WSGIServer(*server_address*, *RequestHandlerClass*)
Create a *WSGIServer* instance. *server_address* should be a `(host,port)` tuple, and *RequestHandlerClass* should be the subclass of *http.server.BaseHTTPRequestHandler* that will be used to process requests.

You do not normally need to call this constructor, as the *make_server()* function can handle all the details for you.

WSGIServer is a subclass of *http.server.HTTPServer*, so all of its methods (such as `serve_forever()` and `handle_request()`) are available. *WSGIServer* also provides these WSGI-specific methods:

set_app(*application*)
Sets the callable *application* as the WSGI application that will receive requests.

get_app()
Returns the currently-set application callable.

Normally, however, you do not need to use these additional methods, as *set_app()* is normally called by *make_server()*, and the *get_app()* exists mainly for the benefit of request handler instances.

class wsgiref.simple_server.WSGIRequestHandler(*request*, *client_address*, *server*)
Create an HTTP handler for the given *request* (i.e. a socket), *client_address* (a `(host,port)` tuple), and *server* (*WSGIServer* instance).

You do not need to create instances of this class directly; they are automatically created as needed by *WSGIServer* objects. You can, however, subclass this class and supply it as a *handler_class* to the *make_server()* function. Some possibly relevant methods for overriding in subclasses:

get_environ()
Returns a dictionary containing the WSGI environment for a request. The default implementation copies the contents of the *WSGIServer* object's `base_environ` dictionary attribute and then adds various headers derived from the HTTP request. Each call to this method should return a new dictionary containing all of the relevant CGI environment variables as specified in **PEP 3333**.

get_stderr()
Return the object that should be used as the `wsgi.errors` stream. The default implementation just returns `sys.stderr`.

handle()
Process the HTTP request. The default implementation creates a handler instance using a *wsgiref.handlers* class to implement the actual WSGI application interface.

22.4.4 wsgiref.validate — WSGI conformance checker

When creating new WSGI application objects, frameworks, servers, or middleware, it can be useful to validate the new code's conformance using *wsgiref.validate*. This module provides a function that creates WSGI application objects that validate communications between a WSGI server or gateway and a WSGI application object, to check both sides for protocol conformance.

Note that this utility does not guarantee complete **PEP 3333** compliance; an absence of errors from this module does not necessarily mean that errors do not exist. However, if this module does produce an error, then it is virtually certain that either the server or application is not 100% compliant.

This module is based on the `paste.lint` module from Ian Bicking's "Python Paste" library.

wsgiref.validate.validator(*application*)
Wrap *application* and return a new WSGI application object. The returned application will forward

all requests to the original *application*, and will check that both the *application* and the server invoking it are conforming to the WSGI specification and to **RFC 2616**.

Any detected nonconformance results in an *AssertionError* being raised; note, however, that how these errors are handled is server-dependent. For example, *wsgiref.simple_server* and other servers based on *wsgiref.handlers* (that don't override the error handling methods to do something else) will simply output a message that an error has occurred, and dump the traceback to `sys.stderr` or some other error stream.

This wrapper may also generate output using the *warnings* module to indicate behaviors that are questionable but which may not actually be prohibited by **PEP 3333**. Unless they are suppressed using Python command-line options or the *warnings* API, any such warnings will be written to `sys.stderr` (*not* `wsgi.errors`, unless they happen to be the same object).

Example usage:

```
from wsgiref.validate import validator
from wsgiref.simple_server import make_server

# Our callable object which is intentionally not compliant to the
# standard, so the validator is going to break
def simple_app(environ, start_response):
    status = '200 OK'  # HTTP Status
    headers = [('Content-type', 'text/plain')]  # HTTP Headers
    start_response(status, headers)

    # This is going to break because we need to return a list, and
    # the validator is going to inform us
    return b"Hello World"

# This is the application wrapped in a validator
validator_app = validator(simple_app)

with make_server('', 8000, validator_app) as httpd:
    print("Listening on port 8000....")
    httpd.serve_forever()
```

22.4.5 `wsgiref.handlers` – server/gateway base classes

This module provides base handler classes for implementing WSGI servers and gateways. These base classes handle most of the work of communicating with a WSGI application, as long as they are given a CGI-like environment, along with input, output, and error streams.

`class wsgiref.handlers.CGIHandler`

CGI-based invocation via `sys.stdin`, `sys.stdout`, `sys.stderr` and `os.environ`. This is useful when you have a WSGI application and want to run it as a CGI script. Simply invoke `CGIHandler().run(app)`, where `app` is the WSGI application object you wish to invoke.

This class is a subclass of *BaseCGIHandler* that sets `wsgi.run_once` to true, `wsgi.multithread` to false, and `wsgi.multiprocess` to true, and always uses *sys* and *os* to obtain the necessary CGI streams and environment.

`class wsgiref.handlers.IISCGIHandler`

A specialized alternative to *CGIHandler*, for use when deploying on Microsoft's IIS web server, without having set the config allowPathInfo option (IIS>=7) or metabase allowPathInfoForScriptMappings (IIS<7).

By default, IIS gives a `PATH_INFO` that duplicates the `SCRIPT_NAME` at the front, causing problems for WSGI applications that wish to implement routing. This handler strips any such duplicated path.

IIS can be configured to pass the correct `PATH_INFO`, but this causes another bug where `PATH_TRANSLATED` is wrong. Luckily this variable is rarely used and is not guaranteed by WSGI. On IIS<7, though, the setting can only be made on a vhost level, affecting all other script mappings, many of which break when exposed to the `PATH_TRANSLATED` bug. For this reason IIS<7 is almost never deployed with the fix. (Even IIS7 rarely uses it because there is still no UI for it.)

There is no way for CGI code to tell whether the option was set, so a separate handler class is provided. It is used in the same way as *CGIHandler*, i.e., by calling `IISCGIHandler().run(app)`, where `app` is the WSGI application object you wish to invoke.

New in version 3.2.

class wsgiref.handlers.BaseCGIHandler(*stdin*, *stdout*, *stderr*, *environ*, *multithread=True*, *multiprocess=False*)

Similar to *CGIHandler*, but instead of using the *sys* and *os* modules, the CGI environment and I/O streams are specified explicitly. The *multithread* and *multiprocess* values are used to set the `wsgi.multithread` and `wsgi.multiprocess` flags for any applications run by the handler instance.

This class is a subclass of *SimpleHandler* intended for use with software other than HTTP "origin servers". If you are writing a gateway protocol implementation (such as CGI, FastCGI, SCGI, etc.) that uses a `Status:` header to send an HTTP status, you probably want to subclass this instead of *SimpleHandler*.

class wsgiref.handlers.SimpleHandler(*stdin*, *stdout*, *stderr*, *environ*, *multithread=True*, *multiprocess=False*)

Similar to *BaseCGIHandler*, but designed for use with HTTP origin servers. If you are writing an HTTP server implementation, you will probably want to subclass this instead of *BaseCGIHandler*.

This class is a subclass of *BaseHandler*. It overrides the `__init__()`, `get_stdin()`, `get_stderr()`, `add_cgi_vars()`, `_write()`, and `_flush()` methods to support explicitly setting the environment and streams via the constructor. The supplied environment and streams are stored in the `stdin`, `stdout`, `stderr`, and `environ` attributes.

The *write()* method of *stdout* should write each chunk in full, like *io.BufferedIOBase*.

class wsgiref.handlers.BaseHandler

This is an abstract base class for running WSGI applications. Each instance will handle a single HTTP request, although in principle you could create a subclass that was reusable for multiple requests.

BaseHandler instances have only one method intended for external use:

run(*app*)

Run the specified WSGI application, *app*.

All of the other *BaseHandler* methods are invoked by this method in the process of running the application, and thus exist primarily to allow customizing the process.

The following methods MUST be overridden in a subclass:

_write(*data*)

Buffer the bytes *data* for transmission to the client. It's okay if this method actually transmits the data; *BaseHandler* just separates write and flush operations for greater efficiency when the underlying system actually has such a distinction.

_flush()

Force buffered data to be transmitted to the client. It's okay if this method is a no-op (i.e., if *_write()* actually sends the data).

get_stdin()

Return an input stream object suitable for use as the `wsgi.input` of the request currently being processed.

`get_stderr()`
Return an output stream object suitable for use as the `wsgi.errors` of the request currently being processed.

`add_cgi_vars()`
Insert CGI variables for the current request into the `environ` attribute.

Here are some other methods and attributes you may wish to override. This list is only a summary, however, and does not include every method that can be overridden. You should consult the docstrings and source code for additional information before attempting to create a customized *BaseHandler* subclass.

Attributes and methods for customizing the WSGI environment:

`wsgi_multithread`
The value to be used for the `wsgi.multithread` environment variable. It defaults to true in *BaseHandler*, but may have a different default (or be set by the constructor) in the other subclasses.

`wsgi_multiprocess`
The value to be used for the `wsgi.multiprocess` environment variable. It defaults to true in *BaseHandler*, but may have a different default (or be set by the constructor) in the other subclasses.

`wsgi_run_once`
The value to be used for the `wsgi.run_once` environment variable. It defaults to false in *BaseHandler*, but *CGIHandler* sets it to true by default.

`os_environ`
The default environment variables to be included in every request's WSGI environment. By default, this is a copy of `os.environ` at the time that *wsgiref.handlers* was imported, but subclasses can either create their own at the class or instance level. Note that the dictionary should be considered read-only, since the default value is shared between multiple classes and instances.

`server_software`
If the *origin_server* attribute is set, this attribute's value is used to set the default `SERVER_SOFTWARE` WSGI environment variable, and also to set a default `Server:` header in HTTP responses. It is ignored for handlers (such as *BaseCGIHandler* and *CGIHandler*) that are not HTTP origin servers.

Changed in version 3.3: The term "Python" is replaced with implementation specific term like "CPython", "Jython" etc.

`get_scheme()`
Return the URL scheme being used for the current request. The default implementation uses the `guess_scheme()` function from *wsgiref.util* to guess whether the scheme should be "http" or "https", based on the current request's `environ` variables.

`setup_environ()`
Set the `environ` attribute to a fully-populated WSGI environment. The default implementation uses all of the above methods and attributes, plus the *get_stdin()*, *get_stderr()*, and *add_cgi_vars()* methods and the *wsgi_file_wrapper* attribute. It also inserts a `SERVER_SOFTWARE` key if not present, as long as the *origin_server* attribute is a true value and the *server_software* attribute is set.

Methods and attributes for customizing exception handling:

`log_exception(`*exc_info*`)`
Log the *exc_info* tuple in the server log. *exc_info* is a `(type, value, traceback)` tuple. The default implementation simply writes the traceback to the request's `wsgi.errors` stream and

flushes it. Subclasses can override this method to change the format or retarget the output, mail the traceback to an administrator, or whatever other action may be deemed suitable.

traceback_limit
The maximum number of frames to include in tracebacks output by the default *log_exception()* method. If `None`, all frames are included.

error_output(*environ*, *start_response*)
This method is a WSGI application to generate an error page for the user. It is only invoked if an error occurs before headers are sent to the client.

This method can access the current error information using `sys.exc_info()`, and should pass that information to *start_response* when calling it (as described in the "Error Handling" section of **PEP 3333**).

The default implementation just uses the *error_status*, *error_headers*, and *error_body* attributes to generate an output page. Subclasses can override this to produce more dynamic error output.

Note, however, that it's not recommended from a security perspective to spit out diagnostics to any old user; ideally, you should have to do something special to enable diagnostic output, which is why the default implementation doesn't include any.

error_status
The HTTP status used for error responses. This should be a status string as defined in **PEP 3333**; it defaults to a 500 code and message.

error_headers
The HTTP headers used for error responses. This should be a list of WSGI response headers (`(name, value)` tuples), as described in **PEP 3333**. The default list just sets the content type to `text/plain`.

error_body
The error response body. This should be an HTTP response body bytestring. It defaults to the plain text, "A server error occurred. Please contact the administrator."

Methods and attributes for **PEP 3333**'s "Optional Platform-Specific File Handling" feature:

wsgi_file_wrapper
A `wsgi.file_wrapper` factory, or `None`. The default value of this attribute is the *wsgiref.util.FileWrapper* class.

sendfile()
Override to implement platform-specific file transmission. This method is called only if the application's return value is an instance of the class specified by the *wsgi_file_wrapper* attribute. It should return a true value if it was able to successfully transmit the file, so that the default transmission code will not be executed. The default implementation of this method just returns a false value.

Miscellaneous methods and attributes:

origin_server
This attribute should be set to a true value if the handler's *_write()* and *_flush()* are being used to communicate directly to the client, rather than via a CGI-like gateway protocol that wants the HTTP status in a special `Status:` header.

This attribute's default value is true in *BaseHandler*, but false in *BaseCGIHandler* and *CGIHandler*.

http_version
If *origin_server* is true, this string attribute is used to set the HTTP version of the response set to the client. It defaults to `"1.0"`.

wsgiref.handlers.read_environ()
: Transcode CGI variables from os.environ to PEP 3333 "bytes in unicode" strings, returning a new dictionary. This function is used by *CGIHandler* and *IISCGIHandler* in place of directly using os.environ, which is not necessarily WSGI-compliant on all platforms and web servers using Python 3 – specifically, ones where the OS's actual environment is Unicode (i.e. Windows), or ones where the environment is bytes, but the system encoding used by Python to decode it is anything other than ISO-8859-1 (e.g. Unix systems using UTF-8).

  If you are implementing a CGI-based handler of your own, you probably want to use this routine instead of just copying values out of os.environ directly.

  New in version 3.2.

22.4.6 Examples

This is a working "Hello World" WSGI application:

```
from wsgiref.simple_server import make_server

# Every WSGI application must have an application object - a callable
# object that accepts two arguments. For that purpose, we're going to
# use a function (note that you're not limited to a function, you can
# use a class for example). The first argument passed to the function
# is a dictionary containing CGI-style environment variables and the
# second variable is the callable object (see PEP 333).
def hello_world_app(environ, start_response):
    status = '200 OK'  # HTTP Status
    headers = [('Content-type', 'text/plain; charset=utf-8')]  # HTTP Headers
    start_response(status, headers)

    # The returned object is going to be printed
    return [b"Hello World"]

with make_server('', 8000, hello_world_app) as httpd:
    print("Serving on port 8000...")

    # Serve until process is killed
    httpd.serve_forever()
```

22.5 urllib — URL handling modules

Source code: Lib/urllib/

---

urllib is a package that collects several modules for working with URLs:

- *urllib.request* for opening and reading URLs
- *urllib.error* containing the exceptions raised by *urllib.request*
- *urllib.parse* for parsing URLs
- *urllib.robotparser* for parsing robots.txt files

22.6 urllib.request — Extensible library for opening URLs

Source code: Lib/urllib/request.py

The *urllib.request* module defines functions and classes which help in opening URLs (mostly HTTP) in a complex world — basic and digest authentication, redirections, cookies and more.

See also:

The Requests package is recommended for a higher-level HTTP client interface.

The *urllib.request* module defines the following functions:

urllib.request.urlopen(*url*, *data=None*[, *timeout*], ***, *cafile=None*, *capath=None*, *cadefault=False*, *context=None*)

Open the URL *url*, which can be either a string or a *Request* object.

data must be an object specifying additional data to be sent to the server, or `None` if no such data is needed. See *Request* for details.

urllib.request module uses HTTP/1.1 and includes `Connection:close` header in its HTTP requests.

The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used). This actually only works for HTTP, HTTPS and FTP connections.

If *context* is specified, it must be a *ssl.SSLContext* instance describing the various SSL options. See *HTTPSConnection* for more details.

The optional *cafile* and *capath* parameters specify a set of trusted CA certificates for HTTPS requests. *cafile* should point to a single file containing a bundle of CA certificates, whereas *capath* should point to a directory of hashed certificate files. More information can be found in *ssl.SSLContext.load_verify_locations()*.

The *cadefault* parameter is ignored.

This function always returns an object which can work as a *context manager* and has methods such as

- `geturl()` — return the URL of the resource retrieved, commonly used to determine if a redirect was followed
- `info()` — return the meta-information of the page, such as headers, in the form of an *email.message_from_string()* instance (see Quick Reference to HTTP Headers)
- `getcode()` – return the HTTP status code of the response.

For HTTP and HTTPS URLs, this function returns a *http.client.HTTPResponse* object slightly modified. In addition to the three new methods above, the msg attribute contains the same information as the *reason* attribute — the reason phrase returned by server — instead of the response headers as it is specified in the documentation for *HTTPResponse*.

For FTP, file, and data URLs and requests explicitly handled by legacy *URLopener* and *FancyURLopener* classes, this function returns a `urllib.response.addinfourl` object.

Raises *URLError* on protocol errors.

Note that `None` may be returned if no handler handles the request (though the default installed global *OpenerDirector* uses *UnknownHandler* to ensure this never happens).

In addition, if proxy settings are detected (for example, when a `*_proxy` environment variable like `http_proxy` is set), *ProxyHandler* is default installed and makes sure the requests are handled through the proxy.

The legacy `urllib.urlopen` function from Python 2.6 and earlier has been discontinued; *urllib.request.urlopen()* corresponds to the old `urllib2.urlopen`. Proxy handling, which was done by passing a dictionary parameter to `urllib.urlopen`, can be obtained by using *ProxyHandler* objects.

Changed in version 3.2: *cafile* and *capath* were added.

Changed in version 3.2: HTTPS virtual hosts are now supported if possible (that is, if *ssl.HAS_SNI* is true).

New in version 3.2: *data* can be an iterable object.

Changed in version 3.3: *cadefault* was added.

Changed in version 3.4.3: *context* was added.

Deprecated since version 3.6: *cafile*, *capath* and *cadefault* are deprecated in favor of *context*. Please use *ssl.SSLContext.load_cert_chain()* instead, or let *ssl.create_default_context()* select the system's trusted CA certificates for you.

`urllib.request.install_opener(`*opener*`)`
Install an *OpenerDirector* instance as the default global opener. Installing an opener is only necessary if you want urlopen to use that opener; otherwise, simply call *OpenerDirector.open()* instead of *urlopen()*. The code does not check for a real *OpenerDirector*, and any class with the appropriate interface will work.

`urllib.request.build_opener(`[*handler*, ...]`)`
Return an *OpenerDirector* instance, which chains the handlers in the order given. *handler*s can be either instances of *BaseHandler*, or subclasses of *BaseHandler* (in which case it must be possible to call the constructor without any parameters). Instances of the following classes will be in front of the *handler*s, unless the *handler*s contain them, instances of them or subclasses of them: *ProxyHandler* (if proxy settings are detected), *UnknownHandler*, *HTTPHandler*, *HTTPDefaultErrorHandler*, *HTTPRedirectHandler*, *FTPHandler*, *FileHandler*, *HTTPErrorProcessor*.

If the Python installation has SSL support (i.e., if the *ssl* module can be imported), *HTTPSHandler* will also be added.

A *BaseHandler* subclass may also change its `handler_order` attribute to modify its position in the handlers list.

`urllib.request.pathname2url(`*path*`)`
Convert the pathname *path* from the local syntax for a path to the form used in the path component of a URL. This does not produce a complete URL. The return value will already be quoted using the *quote()* function.

`urllib.request.url2pathname(`*path*`)`
Convert the path component *path* from a percent-encoded URL to the local syntax for a path. This does not accept a complete URL. This function uses *unquote()* to decode *path*.

`urllib.request.getproxies()`
This helper function returns a dictionary of scheme to proxy server URL mappings. It scans the environment for variables named `<scheme>_proxy`, in a case insensitive approach, for all operating systems first, and when it cannot find it, looks for proxy information from Mac OSX System Configuration for Mac OS X and Windows Systems Registry for Windows. If both lowercase and uppercase environment variables exist (and disagree), lowercase is preferred.

Note: If the environment variable `REQUEST_METHOD` is set, which usually indicates your script is running in a CGI environment, the environment variable `HTTP_PROXY` (uppercase `_PROXY`) will be ignored. This is because that variable can be injected by a client using the "Proxy:" HTTP header. If you need to use an HTTP proxy in a CGI environment, either use `ProxyHandler` explicitly, or make sure the variable name is in lowercase (or at least the `_proxy` suffix).

The following classes are provided:

class urllib.request.Request(*url*, *data=None*, *headers={}*, *origin_req_host=None*, *unverifiable=False*, *method=None*)

This class is an abstraction of a URL request.

url should be a string containing a valid URL.

data must be an object specifying additional data to send to the server, or `None` if no such data is needed. Currently HTTP requests are the only ones that use *data*. The supported object types include bytes, file-like objects, and iterables. If no `Content-Length` nor `Transfer-Encoding` header field has been provided, *HTTPHandler* will set these headers according to the type of *data*. `Content-Length` will be used to send bytes objects, while `Transfer-Encoding: chunked` as specified in **RFC 7230**, Section 3.3.1 will be used to send files and other iterables.

For an HTTP POST request method, *data* should be a buffer in the standard *application/x-www-form-urlencoded* format. The *urllib.parse.urlencode()* function takes a mapping or sequence of 2-tuples and returns an ASCII string in this format. It should be encoded to bytes before being used as the *data* parameter.

headers should be a dictionary, and will be treated as if *add_header()* was called with each key and value as arguments. This is often used to "spoof" the `User-Agent` header value, which is used by a browser to identify itself – some HTTP servers only allow requests coming from common browsers as opposed to scripts. For example, Mozilla Firefox may identify itself as `"Mozilla/5.0 (X11; U; Linux i686) Gecko/20071127 Firefox/2.0.0.11"`, while *urllib*'s default user agent string is `"Python-urllib/2.6"` (on Python 2.6).

An appropriate `Content-Type` header should be included if the *data* argument is present. If this header has not been provided and *data* is not None, `Content-Type: application/x-www-form-urlencoded` will be added as a default.

The final two arguments are only of interest for correct handling of third-party HTTP cookies:

origin_req_host should be the request-host of the origin transaction, as defined by **RFC 2965**. It defaults to `http.cookiejar.request_host(self)`. This is the host name or IP address of the original request that was initiated by the user. For example, if the request is for an image in an HTML document, this should be the request-host of the request for the page containing the image.

unverifiable should indicate whether the request is unverifiable, as defined by **RFC 2965**. It defaults to `False`. An unverifiable request is one whose URL the user did not have the option to approve. For example, if the request is for an image in an HTML document, and the user had no option to approve the automatic fetching of the image, this should be true.

method should be a string that indicates the HTTP request method that will be used (e.g. `'HEAD'`). If provided, its value is stored in the *method* attribute and is used by *get_method()*. The default is `'GET'` if *data* is `None` or `'POST'` otherwise. Subclasses may indicate a different default method by setting the *method* attribute in the class itself.

Note: The request will not work as expected if the data object is unable to deliver its content more than once (e.g. a file or an iterable that can produce the content only once) and the request is retried for HTTP redirects or authentication. The *data* is sent to the HTTP server right away after the headers. There is no support for a 100-continue expectation in the library.

Changed in version 3.3: *Request.method* argument is added to the Request class.

Changed in version 3.4: Default *Request.method* may be indicated at the class level.

Changed in version 3.6: Do not raise an error if the `Content-Length` has not been provided and *data* is neither `None` nor a bytes object. Fall back to use chunked transfer encoding instead.

class urllib.request.OpenerDirector
The *OpenerDirector* class opens URLs via *BaseHandler*s chained together. It manages the chaining of handlers, and recovery from errors.

class urllib.request.BaseHandler
This is the base class for all registered handlers — and handles only the simple mechanics of registration.

class urllib.request.HTTPDefaultErrorHandler
A class which defines a default handler for HTTP error responses; all responses are turned into *HTTPError* exceptions.

class urllib.request.HTTPRedirectHandler
A class to handle redirections.

class urllib.request.HTTPCookieProcessor(*cookiejar=None*)
A class to handle HTTP Cookies.

class urllib.request.ProxyHandler(*proxies=None*)
Cause requests to go through a proxy. If *proxies* is given, it must be a dictionary mapping protocol names to URLs of proxies. The default is to read the list of proxies from the environment variables `<protocol>_proxy`. If no proxy environment variables are set, then in a Windows environment proxy settings are obtained from the registry's Internet Settings section, and in a Mac OS X environment proxy information is retrieved from the OS X System Configuration Framework.

To disable autodetected proxy pass an empty dictionary.

The `no_proxy` environment variable can be used to specify hosts which shouldn't be reached via proxy; if set, it should be a comma-separated list of hostname suffixes, optionally with `:port` appended, for example `cern.ch,ncsa.uiuc.edu,some.host:8080`.

> **Note:** `HTTP_PROXY` will be ignored if a variable `REQUEST_METHOD` is set; see the documentation on *getproxies()*.

class urllib.request.HTTPPasswordMgr
Keep a database of `(realm, uri) -> (user, password)` mappings.

class urllib.request.HTTPPasswordMgrWithDefaultRealm
Keep a database of `(realm, uri) -> (user, password)` mappings. A realm of `None` is considered a catch-all realm, which is searched if no other realm fits.

class urllib.request.HTTPPasswordMgrWithPriorAuth
A variant of *HTTPPasswordMgrWithDefaultRealm* that also has a database of `uri -> is_authenticated` mappings. Can be used by a BasicAuth handler to determine when to send authentication credentials immediately instead of waiting for a `401` response first.

New in version 3.5.

class urllib.request.AbstractBasicAuthHandler(*password_mgr=None*)
This is a mixin class that helps with HTTP authentication, both to the remote host and to a proxy. *password_mgr*, if given, should be something that is compatible with *HTTPPasswordMgr*; refer to section *HTTPPasswordMgr Objects* for information on the interface that must be supported. If *passwd_mgr* also provides `is_authenticated` and `update_authenticated` methods (see *HTTPPasswordMgrWithPriorAuth Objects*), then the handler will use the `is_authenticated` result for a given URI to determine whether or not to send authentication credentials with the request. If `is_authenticated` returns `True` for the URI, credentials are sent. If `is_authenticated` is `False`, credentials are not sent, and then if a `401` response is received the request is re-sent with the authentication credentials. If authentication succeeds, `update_authenticated` is called to set `is_authenticated True` for the URI, so that subsequent requests to the URI or any of its super-URIs will automatically include the authentication credentials.

New in version 3.5: Added `is_authenticated` support.

class urllib.request.HTTPBasicAuthHandler(*password_mgr=None*)
Handle authentication with the remote host. *password_mgr*, if given, should be something that is compatible with *HTTPPasswordMgr*; refer to section *HTTPPasswordMgr Objects* for information on the interface that must be supported. HTTPBasicAuthHandler will raise a *ValueError* when presented with a wrong Authentication scheme.

class urllib.request.ProxyBasicAuthHandler(*password_mgr=None*)
Handle authentication with the proxy. *password_mgr*, if given, should be something that is compatible with *HTTPPasswordMgr*; refer to section *HTTPPasswordMgr Objects* for information on the interface that must be supported.

class urllib.request.AbstractDigestAuthHandler(*password_mgr=None*)
This is a mixin class that helps with HTTP authentication, both to the remote host and to a proxy. *password_mgr*, if given, should be something that is compatible with *HTTPPasswordMgr*; refer to section *HTTPPasswordMgr Objects* for information on the interface that must be supported.

class urllib.request.HTTPDigestAuthHandler(*password_mgr=None*)
Handle authentication with the remote host. *password_mgr*, if given, should be something that is compatible with *HTTPPasswordMgr*; refer to section *HTTPPasswordMgr Objects* for information on the interface that must be supported. When both Digest Authentication Handler and Basic Authentication Handler are both added, Digest Authentication is always tried first. If the Digest Authentication returns a 40x response again, it is sent to Basic Authentication handler to Handle. This Handler method will raise a *ValueError* when presented with an authentication scheme other than Digest or Basic.

Changed in version 3.3: Raise *ValueError* on unsupported Authentication Scheme.

class urllib.request.ProxyDigestAuthHandler(*password_mgr=None*)
Handle authentication with the proxy. *password_mgr*, if given, should be something that is compatible with *HTTPPasswordMgr*; refer to section *HTTPPasswordMgr Objects* for information on the interface that must be supported.

class urllib.request.HTTPHandler
A class to handle opening of HTTP URLs.

class urllib.request.HTTPSHandler(*debuglevel=0*, *context=None*, *check_hostname=None*)
A class to handle opening of HTTPS URLs. *context* and *check_hostname* have the same meaning as in *http.client.HTTPSConnection*.

Changed in version 3.2: *context* and *check_hostname* were added.

class urllib.request.FileHandler
Open local files.

class urllib.request.DataHandler
Open data URLs.

New in version 3.4.

class urllib.request.FTPHandler
Open FTP URLs.

class urllib.request.CacheFTPHandler
Open FTP URLs, keeping a cache of open FTP connections to minimize delays.

class urllib.request.UnknownHandler
A catch-all class to handle unknown URLs.

class urllib.request.HTTPErrorProcessor
Process HTTP error responses.

22.6.1 Request Objects

The following methods describe *Request*'s public interface, and so all may be overridden in subclasses. It also defines several public attributes that can be used by clients to inspect the parsed request.

Request.full_url
The original URL passed to the constructor.

Changed in version 3.4.

Request.full_url is a property with setter, getter and a deleter. Getting *full_url* returns the original request URL with the fragment, if it was present.

Request.type
The URI scheme.

Request.host
The URI authority, typically a host, but may also contain a port separated by a colon.

Request.origin_req_host
The original host for the request, without port.

Request.selector
The URI path. If the *Request* uses a proxy, then selector will be the full URL that is passed to the proxy.

Request.data
The entity body for the request, or None if not specified.

Changed in version 3.4: Changing value of *Request.data* now deletes "Content-Length" header if it was previously set or calculated.

Request.unverifiable
boolean, indicates whether the request is unverifiable as defined by **RFC 2965**.

Request.method
The HTTP request method to use. By default its value is *None*, which means that *get_method()* will do its normal computation of the method to be used. Its value can be set (thus overriding the default computation in *get_method()*) either by providing a default value by setting it at the class level in a *Request* subclass, or by passing a value in to the *Request* constructor via the *method* argument.

New in version 3.3.

Changed in version 3.4: A default value can now be set in subclasses; previously it could only be set via the constructor argument.

Request.get_method()
Return a string indicating the HTTP request method. If *Request.method* is not None, return its value, otherwise return 'GET' if *Request.data* is None, or 'POST' if it's not. This is only meaningful for HTTP requests.

Changed in version 3.3: get_method now looks at the value of *Request.method*.

Request.add_header(*key*, *val*)
Add another header to the request. Headers are currently ignored by all handlers except HTTP handlers, where they are added to the list of headers sent to the server. Note that there cannot be more than one header with the same name, and later calls will overwrite previous calls in case the *key* collides. Currently, this is no loss of HTTP functionality, since all headers which have meaning when used more than once have a (header-specific) way of gaining the same functionality using only one header.

Request.add_unredirected_header(*key*, *header*)
Add a header that will not be added to a redirected request.

Request.**has_header**(*header*)
Return whether the instance has the named header (checks both regular and unredirected).

Request.**remove_header**(*header*)
Remove named header from the request instance (both from regular and unredirected headers).

New in version 3.4.

Request.**get_full_url**()
Return the URL given in the constructor.

Changed in version 3.4.

Returns *Request.full_url*

Request.**set_proxy**(*host*, *type*)
Prepare the request by connecting to a proxy server. The *host* and *type* will replace those of the instance, and the instance's selector will be the original URL given in the constructor.

Request.**get_header**(*header_name*, *default=None*)
Return the value of the given header. If the header is not present, return the default value.

Request.**header_items**()
Return a list of tuples (header_name, header_value) of the Request headers.

Changed in version 3.4: The request methods add_data, has_data, get_data, get_type, get_host, get_selector, get_origin_req_host and is_unverifiable that were deprecated since 3.3 have been removed.

22.6.2 OpenerDirector Objects

OpenerDirector instances have the following methods:

OpenerDirector.**add_handler**(*handler*)
handler should be an instance of *BaseHandler*. The following methods are searched, and added to the possible chains (note that HTTP errors are a special case).

- `protocol_open()` — signal that the handler knows how to open *protocol* URLs.
- `http_error_type()` — signal that the handler knows how to handle HTTP errors with HTTP error code *type*.
- `protocol_error()` — signal that the handler knows how to handle errors from (non-`http`) *protocol*.
- `protocol_request()` — signal that the handler knows how to pre-process *protocol* requests.
- `protocol_response()` — signal that the handler knows how to post-process *protocol* responses.

OpenerDirector.**open**(*url*, *data=None*[, *timeout*])
Open the given *url* (which can be a request object or a string), optionally passing the given *data*. Arguments, return values and exceptions raised are the same as those of *urlopen()* (which simply calls the *open()* method on the currently installed global *OpenerDirector*). The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used). The timeout feature actually works only for HTTP, HTTPS and FTP connections).

OpenerDirector.**error**(*proto*, **args*)
Handle an error of the given protocol. This will call the registered error handlers for the given protocol with the given arguments (which are protocol specific). The HTTP protocol is a special case which uses the HTTP response code to determine the specific error handler; refer to the `http_error_*()` methods of the handler classes.

Return values and exceptions raised are the same as those of *urlopen()*.

OpenerDirector objects open URLs in three stages:

The order in which these methods are called within each stage is determined by sorting the handler instances.

1. Every handler with a method named like `protocol_request()` has that method called to pre-process the request.
2. Handlers with a method named like `protocol_open()` are called to handle the request. This stage ends when a handler either returns a non-*None* value (ie. a response), or raises an exception (usually *URLError*). Exceptions are allowed to propagate.

   In fact, the above algorithm is first tried for methods named `default_open()`. If all such methods return *None*, the algorithm is repeated for methods named like `protocol_open()`. If all such methods return *None*, the algorithm is repeated for methods named `unknown_open()`.

   Note that the implementation of these methods may involve calls of the parent *OpenerDirector* instance's *open()* and *error()* methods.
3. Every handler with a method named like `protocol_response()` has that method called to post-process the response.

22.6.3 BaseHandler Objects

BaseHandler objects provide a couple of methods that are directly useful, and others that are meant to be used by derived classes. These are intended for direct use:

`BaseHandler.add_parent(`*director*`)`
Add a director as parent.

`BaseHandler.close()`
Remove any parents.

The following attribute and methods should only be used by classes derived from *BaseHandler*.

Note: The convention has been adopted that subclasses defining `protocol_request()` or `protocol_response()` methods are named `*Processor`; all others are named `*Handler`.

`BaseHandler.parent`
A valid *OpenerDirector*, which can be used to open using a different protocol, or handle errors.

`BaseHandler.default_open(`*req*`)`
This method is *not* defined in *BaseHandler*, but subclasses should define it if they want to catch all URLs.

This method, if implemented, will be called by the parent *OpenerDirector*. It should return a file-like object as described in the return value of the *open()* of *OpenerDirector*, or `None`. It should raise *URLError*, unless a truly exceptional thing happens (for example, *MemoryError* should not be mapped to `URLError`).

This method will be called before any protocol-specific open method.

`BaseHandler.protocol_open(`*req*`)`
This method is *not* defined in *BaseHandler*, but subclasses should define it if they want to handle URLs with the given protocol.

This method, if defined, will be called by the parent *OpenerDirector*. Return values should be the same as for *default_open()*.

`BaseHandler.unknown_open(`*req*`)`
This method is *not* defined in *BaseHandler*, but subclasses should define it if they want to catch all URLs with no specific registered handler to open it.

This method, if implemented, will be called by the *parent* *OpenerDirector*. Return values should be the same as for *default_open()*.

`BaseHandler.http_error_default`(*req*, *fp*, *code*, *msg*, *hdrs*)
This method is *not* defined in *BaseHandler*, but subclasses should override it if they intend to provide a catch-all for otherwise unhandled HTTP errors. It will be called automatically by the *OpenerDirector* getting the error, and should not normally be called in other circumstances.

req will be a *Request* object, *fp* will be a file-like object with the HTTP error body, *code* will be the three-digit code of the error, *msg* will be the user-visible explanation of the code and *hdrs* will be a mapping object with the headers of the error.

Return values and exceptions raised should be the same as those of *urlopen()*.

`BaseHandler.http_error_nnn`(*req*, *fp*, *code*, *msg*, *hdrs*)
nnn should be a three-digit HTTP error code. This method is also not defined in *BaseHandler*, but will be called, if it exists, on an instance of a subclass, when an HTTP error with code *nnn* occurs.

Subclasses should override this method to handle specific HTTP errors.

Arguments, return values and exceptions raised should be the same as for *http_error_default()*.

`BaseHandler.protocol_request`(*req*)
This method is *not* defined in *BaseHandler*, but subclasses should define it if they want to pre-process requests of the given protocol.

This method, if defined, will be called by the parent *OpenerDirector*. *req* will be a *Request* object. The return value should be a *Request* object.

`BaseHandler.protocol_response`(*req*, *response*)
This method is *not* defined in *BaseHandler*, but subclasses should define it if they want to post-process responses of the given protocol.

This method, if defined, will be called by the parent *OpenerDirector*. *req* will be a *Request* object. *response* will be an object implementing the same interface as the return value of *urlopen()*. The return value should implement the same interface as the return value of *urlopen()*.

22.6.4 HTTPRedirectHandler Objects

Note: Some HTTP redirections require action from this module's client code. If this is the case, *HTTPError* is raised. See **RFC 2616** for details of the precise meanings of the various redirection codes.

An `HTTPError` exception raised as a security consideration if the HTTPRedirectHandler is presented with a redirected URL which is not an HTTP, HTTPS or FTP URL.

`HTTPRedirectHandler.redirect_request`(*req*, *fp*, *code*, *msg*, *hdrs*, *newurl*)
Return a *Request* or `None` in response to a redirect. This is called by the default implementations of the `http_error_30*()` methods when a redirection is received from the server. If a redirection should take place, return a new *Request* to allow `http_error_30*()` to perform the redirect to *newurl*. Otherwise, raise *HTTPError* if no other handler should try to handle this URL, or return `None` if you can't but another handler might.

Note: The default implementation of this method does not strictly follow **RFC 2616**, which says that 301 and 302 responses to `POST` requests must not be automatically redirected without confirmation by the user. In reality, browsers do allow automatic redirection of these responses, changing the POST to a `GET`, and the default implementation reproduces this behavior.

HTTPRedirectHandler.**http_error_301**(*req*, *fp*, *code*, *msg*, *hdrs*)
Redirect to the `Location:` or `URI:` URL. This method is called by the parent *OpenerDirector* when getting an HTTP 'moved permanently' response.

HTTPRedirectHandler.**http_error_302**(*req*, *fp*, *code*, *msg*, *hdrs*)
The same as *http_error_301()*, but called for the 'found' response.

HTTPRedirectHandler.**http_error_303**(*req*, *fp*, *code*, *msg*, *hdrs*)
The same as *http_error_301()*, but called for the 'see other' response.

HTTPRedirectHandler.**http_error_307**(*req*, *fp*, *code*, *msg*, *hdrs*)
The same as *http_error_301()*, but called for the 'temporary redirect' response.

22.6.5 HTTPCookieProcessor Objects

HTTPCookieProcessor instances have one attribute:

HTTPCookieProcessor.**cookiejar**
The *http.cookiejar.CookieJar* in which cookies are stored.

22.6.6 ProxyHandler Objects

ProxyHandler.**protocol_open**(*request*)
The *ProxyHandler* will have a method `protocol_open()` for every *protocol* which has a proxy in the *proxies* dictionary given in the constructor. The method will modify requests to go through the proxy, by calling `request.set_proxy()`, and call the next handler in the chain to actually execute the protocol.

22.6.7 HTTPPasswordMgr Objects

These methods are available on *HTTPPasswordMgr* and *HTTPPasswordMgrWithDefaultRealm* objects.

HTTPPasswordMgr.**add_password**(*realm*, *uri*, *user*, *passwd*)
uri can be either a single URI, or a sequence of URIs. *realm*, *user* and *passwd* must be strings. This causes `(user, passwd)` to be used as authentication tokens when authentication for *realm* and a super-URI of any of the given URIs is given.

HTTPPasswordMgr.**find_user_password**(*realm*, *authuri*)
Get user/password for given realm and URI, if any. This method will return `(None, None)` if there is no matching user/password.

For *HTTPPasswordMgrWithDefaultRealm* objects, the realm `None` will be searched if the given *realm* has no matching user/password.

22.6.8 HTTPPasswordMgrWithPriorAuth Objects

This password manager extends *HTTPPasswordMgrWithDefaultRealm* to support tracking URIs for which authentication credentials should always be sent.

HTTPPasswordMgrWithPriorAuth.**add_password**(*realm*, *uri*, *user*, *passwd*, *is_authenticated=False*)
realm, *uri*, *user*, *passwd* are as for *HTTPPasswordMgr.add_password()*. *is_authenticated* sets the initial value of the `is_authenticated` flag for the given URI or list of URIs. If *is_authenticated* is specified as `True`, *realm* is ignored.

HTTPPasswordMgr.**find_user_password**(*realm*, *authuri*)
Same as for *HTTPPasswordMgrWithDefaultRealm* objects

HTTPPasswordMgrWithPriorAuth.**update_authenticated**(*self*, *uri*, *is_authenticated=False*)
Update the `is_authenticated` flag for the given *uri* or list of URIs.

HTTPPasswordMgrWithPriorAuth.**is_authenticated**(*self*, *authuri*)
Returns the current state of the `is_authenticated` flag for the given URI.

22.6.9 AbstractBasicAuthHandler Objects

AbstractBasicAuthHandler.**http_error_auth_reqed**(*authreq*, *host*, *req*, *headers*)
Handle an authentication request by getting a user/password pair, and re-trying the request. *authreq* should be the name of the header where the information about the realm is included in the request, *host* specifies the URL and path to authenticate for, *req* should be the (failed) *Request* object, and *headers* should be the error headers.

host is either an authority (e.g. `"python.org"`) or a URL containing an authority component (e.g. `"http://python.org/"`). In either case, the authority must not contain a userinfo component (so, `"python.org"` and `"python.org:80"` are fine, `"joe:password@python.org"` is not).

22.6.10 HTTPBasicAuthHandler Objects

HTTPBasicAuthHandler.**http_error_401**(*req*, *fp*, *code*, *msg*, *hdrs*)
Retry the request with authentication information, if available.

22.6.11 ProxyBasicAuthHandler Objects

ProxyBasicAuthHandler.**http_error_407**(*req*, *fp*, *code*, *msg*, *hdrs*)
Retry the request with authentication information, if available.

22.6.12 AbstractDigestAuthHandler Objects

AbstractDigestAuthHandler.**http_error_auth_reqed**(*authreq*, *host*, *req*, *headers*)
authreq should be the name of the header where the information about the realm is included in the request, *host* should be the host to authenticate to, *req* should be the (failed) *Request* object, and *headers* should be the error headers.

22.6.13 HTTPDigestAuthHandler Objects

HTTPDigestAuthHandler.**http_error_401**(*req*, *fp*, *code*, *msg*, *hdrs*)
Retry the request with authentication information, if available.

22.6.14 ProxyDigestAuthHandler Objects

ProxyDigestAuthHandler.**http_error_407**(*req*, *fp*, *code*, *msg*, *hdrs*)
Retry the request with authentication information, if available.

22.6.15 HTTPHandler Objects

HTTPHandler.**http_open**(*req*)
Send an HTTP request, which can be either GET or POST, depending on `req.has_data()`.

22.6.16 HTTPSHandler Objects

`HTTPSHandler.https_open(req)`
Send an HTTPS request, which can be either GET or POST, depending on `req.has_data()`.

22.6.17 FileHandler Objects

`FileHandler.file_open(req)`
Open the file locally, if there is no host name, or the host name is `'localhost'`.

Changed in version 3.2: This method is applicable only for local hostnames. When a remote hostname is given, an *URLError* is raised.

22.6.18 DataHandler Objects

`DataHandler.data_open(req)`
Read a data URL. This kind of URL contains the content encoded in the URL itself. The data URL syntax is specified in **RFC 2397**. This implementation ignores white spaces in base64 encoded data URLs so the URL may be wrapped in whatever source file it comes from. But even though some browsers don't mind about a missing padding at the end of a base64 encoded data URL, this implementation will raise an *ValueError* in that case.

22.6.19 FTPHandler Objects

`FTPHandler.ftp_open(req)`
Open the FTP file indicated by *req*. The login is always done with empty username and password.

22.6.20 CacheFTPHandler Objects

CacheFTPHandler objects are *FTPHandler* objects with the following additional methods:

`CacheFTPHandler.setTimeout(t)`
Set timeout of connections to *t* seconds.

`CacheFTPHandler.setMaxConns(m)`
Set maximum number of cached connections to *m*.

22.6.21 UnknownHandler Objects

`UnknownHandler.unknown_open()`
Raise a *URLError* exception.

22.6.22 HTTPErrorProcessor Objects

`HTTPErrorProcessor.http_response()`
Process HTTP error responses.

For 200 error codes, the response object is returned immediately.

For non-200 error codes, this simply passes the job on to the `protocol_error_code()` handler methods, via *OpenerDirector.error()*. Eventually, *HTTPDefaultErrorHandler* will raise an *HTTPError* if no other handler handles the error.

HTTPErrorProcessor.**https_response**()
Process HTTPS error responses.

The behavior is same as *http_response()*.

22.6.23 Examples

In addition to the examples below, more examples are given in urllib-howto.

This example gets the python.org main page and displays the first 300 bytes of it.

```
>>> import urllib.request
>>> with urllib.request.urlopen('http://www.python.org/') as f:
...     print(f.read(300))
...
b'<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">\n\n\n<html
xmlns="http://www.w3.org/1999/xhtml" xml:lang="en" lang="en">\n\n<head>\n
<meta http-equiv="content-type" content="text/html; charset=utf-8" />\n
<title>Python Programming '
```

Note that urlopen returns a bytes object. This is because there is no way for urlopen to automatically determine the encoding of the byte stream it receives from the HTTP server. In general, a program will decode the returned bytes object to string once it determines or guesses the appropriate encoding.

The following W3C document, https://www.w3.org/International/O-charset, lists the various ways in which an (X)HTML or an XML document could have specified its encoding information.

As the python.org website uses *utf-8* encoding as specified in its meta tag, we will use the same for decoding the bytes object.

```
>>> with urllib.request.urlopen('http://www.python.org/') as f:
...     print(f.read(100).decode('utf-8'))
...
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtm
```

It is also possible to achieve the same result without using the *context manager* approach.

```
>>> import urllib.request
>>> f = urllib.request.urlopen('http://www.python.org/')
>>> print(f.read(100).decode('utf-8'))
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtm
```

In the following example, we are sending a data-stream to the stdin of a CGI and reading the data it returns to us. Note that this example will only work when the Python installation supports SSL.

```
>>> import urllib.request
>>> req = urllib.request.Request(url='https://localhost/cgi-bin/test.cgi',
...                       data=b'This data is passed to stdin of the CGI')
>>> with urllib.request.urlopen(req) as f:
...     print(f.read().decode('utf-8'))
...
Got Data: "This data is passed to stdin of the CGI"
```

The code for the sample CGI used in the above example is:

```
#!/usr/bin/env python
import sys
data = sys.stdin.read()
print('Content-type: text/plain\n\nGot Data: "%s"' % data)
```

Here is an example of doing a PUT request using *Request*:

```
import urllib.request
DATA = b'some data'
req = urllib.request.Request(url='http://localhost:8080', data=DATA,method='PUT')
with urllib.request.urlopen(req) as f:
    pass
print(f.status)
print(f.reason)
```

Use of Basic HTTP Authentication:

```
import urllib.request
# Create an OpenerDirector with support for Basic HTTP Authentication...
auth_handler = urllib.request.HTTPBasicAuthHandler()
auth_handler.add_password(realm='PDQ Application',
                          uri='https://mahler:8092/site-updates.py',
                          user='klem',
                          passwd='kadidd!ehopper')
opener = urllib.request.build_opener(auth_handler)
# ...and install it globally so it can be used with urlopen.
urllib.request.install_opener(opener)
urllib.request.urlopen('http://www.example.com/login.html')
```

build_opener() provides many handlers by default, including a *ProxyHandler*. By default, *ProxyHandler* uses the environment variables named <scheme>_proxy, where <scheme> is the URL scheme involved. For example, the http_proxy environment variable is read to obtain the HTTP proxy's URL.

This example replaces the default *ProxyHandler* with one that uses programmatically-supplied proxy URLs, and adds proxy authorization support with *ProxyBasicAuthHandler*.

```
proxy_handler = urllib.request.ProxyHandler({'http': 'http://www.example.com:3128/'})
proxy_auth_handler = urllib.request.ProxyBasicAuthHandler()
proxy_auth_handler.add_password('realm', 'host', 'username', 'password')

opener = urllib.request.build_opener(proxy_handler, proxy_auth_handler)
# This time, rather than install the OpenerDirector, we use it directly:
opener.open('http://www.example.com/login.html')
```

Adding HTTP headers:

Use the *headers* argument to the *Request* constructor, or:

```
import urllib.request
req = urllib.request.Request('http://www.example.com/')
req.add_header('Referer', 'http://www.python.org/')
# Customize the default User-Agent header value:
req.add_header('User-Agent', 'urllib-example/0.1 (Contact: . . .)')
r = urllib.request.urlopen(req)
```

OpenerDirector automatically adds a *User-Agent* header to every *Request*. To change this:

```
import urllib.request
opener = urllib.request.build_opener()
opener.addheaders = [('User-agent', 'Mozilla/5.0')]
opener.open('http://www.example.com/')
```

Also, remember that a few standard headers (*Content-Length*, *Content-Type* and *Host*) are added when the *Request* is passed to *urlopen()* (or *OpenerDirector.open()*).

Here is an example session that uses the `GET` method to retrieve a URL containing parameters:

```
>>> import urllib.request
>>> import urllib.parse
>>> params = urllib.parse.urlencode({'spam': 1, 'eggs': 2, 'bacon': 0})
>>> url = "http://www.musi-cal.com/cgi-bin/query?%s" % params
>>> with urllib.request.urlopen(url) as f:
...     print(f.read().decode('utf-8'))
...
```

The following example uses the `POST` method instead. Note that params output from urlencode is encoded to bytes before it is sent to urlopen as data:

```
>>> import urllib.request
>>> import urllib.parse
>>> data = urllib.parse.urlencode({'spam': 1, 'eggs': 2, 'bacon': 0})
>>> data = data.encode('ascii')
>>> with urllib.request.urlopen("http://requestb.in/xrbl82xr", data) as f:
...     print(f.read().decode('utf-8'))
...
```

The following example uses an explicitly specified HTTP proxy, overriding environment settings:

```
>>> import urllib.request
>>> proxies = {'http': 'http://proxy.example.com:8080/'}
>>> opener = urllib.request.FancyURLopener(proxies)
>>> with opener.open("http://www.python.org") as f:
...     f.read().decode('utf-8')
...
```

The following example uses no proxies at all, overriding environment settings:

```
>>> import urllib.request
>>> opener = urllib.request.FancyURLopener({})
>>> with opener.open("http://www.python.org/") as f:
...     f.read().decode('utf-8')
...
```

22.6.24 Legacy interface

The following functions and classes are ported from the Python 2 module `urllib` (as opposed to `urllib2`). They might become deprecated at some point in the future.

`urllib.request.urlretrieve`(*url*, *filename=None*, *reporthook=None*, *data=None*)

Copy a network object denoted by a URL to a local file. If the URL points to a local file, the object will not be copied unless filename is supplied. Return a tuple `(filename, headers)` where *filename* is the local file name under which the object can be found, and *headers* is whatever the `info()` method of the object returned by *urlopen()* returned (for a remote object). Exceptions are the same as for *urlopen()*.

The second argument, if present, specifies the file location to copy to (if absent, the location will be a tempfile with a generated name). The third argument, if present, is a callable that will be called once on establishment of the network connection and once after each block read thereafter. The callable will be passed three arguments; a count of blocks transferred so far, a block size in bytes, and the total size of the file. The third argument may be `-1` on older FTP servers which do not return a file size in response to a retrieval request.

The following example illustrates the most common usage scenario:

```
>>> import urllib.request
>>> local_filename, headers = urllib.request.urlretrieve('http://python.org/')
>>> html = open(local_filename)
>>> html.close()
```

If the *url* uses the `http:` scheme identifier, the optional *data* argument may be given to specify a `POST` request (normally the request type is `GET`). The *data* argument must be a bytes object in standard *application/x-www-form-urlencoded* format; see the *urllib.parse.urlencode()* function.

urlretrieve() will raise `ContentTooShortError` when it detects that the amount of data available was less than the expected amount (which is the size reported by a *Content-Length* header). This can occur, for example, when the download is interrupted.

The *Content-Length* is treated as a lower bound: if there's more data to read, urlretrieve reads more data, but if less data is available, it raises the exception.

You can still retrieve the downloaded data in this case, it is stored in the `content` attribute of the exception instance.

If no *Content-Length* header was supplied, urlretrieve can not check the size of the data it has downloaded, and just returns it. In this case you just have to assume that the download was successful.

`urllib.request.urlcleanup()`
Cleans up temporary files that may have been left behind by previous calls to *urlretrieve()*.

`class urllib.request.URLopener(`*proxies=None*, ***x509*`)`
Deprecated since version 3.3.

Base class for opening and reading URLs. Unless you need to support opening objects using schemes other than `http:`, `ftp:`, or `file:`, you probably want to use *FancyURLopener*.

By default, the *URLopener* class sends a *User-Agent* header of `urllib/VVV`, where *VVV* is the *urllib* version number. Applications can define their own *User-Agent* header by subclassing *URLopener* or *FancyURLopener* and setting the class attribute *version* to an appropriate string value in the subclass definition.

The optional *proxies* parameter should be a dictionary mapping scheme names to proxy URLs, where an empty dictionary turns proxies off completely. Its default value is `None`, in which case environmental proxy settings will be used if present, as discussed in the definition of *urlopen()*, above.

Additional keyword parameters, collected in *x509*, may be used for authentication of the client when using the `https:` scheme. The keywords *key_file* and *cert_file* are supported to provide an SSL key and certificate; both are needed to support client authentication.

URLopener objects will raise an *OSError* exception if the server returns an error code.

`open(`*fullurl*, *data=None*`)`
Open *fullurl* using the appropriate protocol. This method sets up cache and proxy information, then calls the appropriate open method with its input arguments. If the scheme is not recognized, *open_unknown()* is called. The *data* argument has the same meaning as the *data* argument of *urlopen()*.

`open_unknown(`*fullurl*, *data=None*`)`
Overridable interface to open unknown URL types.

retrieve(*url*, *filename=None*, *reporthook=None*, *data=None*)
Retrieves the contents of *url* and places it in *filename*. The return value is a tuple consisting of a local filename and either an *email.message.Message* object containing the response headers (for remote URLs) or `None` (for local URLs). The caller must then open and read the contents of *filename*. If *filename* is not given and the URL refers to a local file, the input filename is returned. If the URL is non-local and *filename* is not given, the filename is the output of *tempfile.mktemp()* with a suffix that matches the suffix of the last path component of the input URL. If *reporthook* is given, it must be a function accepting three numeric parameters: A chunk number, the maximum size chunks are read in and the total size of the download (-1 if unknown). It will be called once at the start and after each chunk of data is read from the network. *reporthook* is ignored for local URLs.

If the *url* uses the `http:` scheme identifier, the optional *data* argument may be given to specify a `POST` request (normally the request type is `GET`). The *data* argument must in standard *application/x-www-form-urlencoded* format; see the *urllib.parse.urlencode()* function.

version
Variable that specifies the user agent of the opener object. To get *urllib* to tell servers that it is a particular user agent, set this in a subclass as a class variable or in the constructor before calling the base constructor.

class urllib.request.FancyURLopener(...)
Deprecated since version 3.3.

FancyURLopener subclasses *URLopener* providing default handling for the following HTTP response codes: 301, 302, 303, 307 and 401. For the 30x response codes listed above, the *Location* header is used to fetch the actual URL. For 401 response codes (authentication required), basic HTTP authentication is performed. For the 30x response codes, recursion is bounded by the value of the *maxtries* attribute, which defaults to 10.

For all other response codes, the method `http_error_default()` is called which you can override in subclasses to handle the error appropriately.

Note: According to the letter of **RFC 2616**, 301 and 302 responses to POST requests must not be automatically redirected without confirmation by the user. In reality, browsers do allow automatic redirection of these responses, changing the POST to a GET, and *urllib* reproduces this behaviour.

The parameters to the constructor are the same as those for *URLopener*.

Note: When performing basic authentication, a *FancyURLopener* instance calls its *prompt_user_passwd()* method. The default implementation asks the users for the required information on the controlling terminal. A subclass may override this method to support more appropriate behavior if needed.

The *FancyURLopener* class offers one additional method that should be overloaded to provide the appropriate behavior:

prompt_user_passwd(*host*, *realm*)
Return information needed to authenticate the user at the given host in the specified security realm. The return value should be a tuple, `(user, password)`, which can be used for basic authentication.

The implementation prompts for this information on the terminal; an application should override this method to use an appropriate interaction model in the local environment.

22.6.25 urllib.request Restrictions

- Currently, only the following protocols are supported: HTTP (versions 0.9 and 1.0), FTP, local files, and data URLs.

  Changed in version 3.4: Added support for data URLs.
- The caching feature of *urlretrieve()* has been disabled until someone finds the time to hack proper processing of Expiration time headers.
- There should be a function to query whether a particular URL is in the cache.
- For backward compatibility, if a URL appears to point to a local file but the file can't be opened, the URL is re-interpreted using the FTP protocol. This can sometimes cause confusing error messages.
- The *urlopen()* and *urlretrieve()* functions can cause arbitrarily long delays while waiting for a network connection to be set up. This means that it is difficult to build an interactive Web client using these functions without using threads.
- The data returned by *urlopen()* or *urlretrieve()* is the raw data returned by the server. This may be binary data (such as an image), plain text or (for example) HTML. The HTTP protocol provides type information in the reply header, which can be inspected by looking at the *Content-Type* header. If the returned data is HTML, you can use the module *html.parser* to parse it.
- The code handling the FTP protocol cannot differentiate between a file and a directory. This can lead to unexpected behavior when attempting to read a URL that points to a file that is not accessible. If the URL ends in a `/`, it is assumed to refer to a directory and will be handled accordingly. But if an attempt to read a file leads to a 550 error (meaning the URL cannot be found or is not accessible, often for permission reasons), then the path is treated as a directory in order to handle the case when a directory is specified by a URL but the trailing `/` has been left off. This can cause misleading results when you try to fetch a file whose read permissions make it inaccessible; the FTP code will try to read it, fail with a 550 error, and then perform a directory listing for the unreadable file. If fine-grained control is needed, consider using the *ftplib* module, subclassing *FancyURLopener*, or changing *_urlopener* to meet your needs.

22.7 urllib.response — Response classes used by urllib

The *urllib.response* module defines functions and classes which define a minimal file like interface, including `read()` and `readline()`. The typical response object is an addinfourl instance, which defines an `info()` method and that returns headers and a `geturl()` method that returns the url. Functions defined by this module are used internally by the *urllib.request* module.

22.8 urllib.parse — Parse URLs into components

Source code: Lib/urllib/parse.py

This module defines a standard interface to break Uniform Resource Locator (URL) strings up in components (addressing scheme, network location, path etc.), to combine the components back into a URL string, and to convert a "relative URL" to an absolute URL given a "base URL."

The module has been designed to match the Internet RFC on Relative Uniform Resource Locators. It supports the following URL schemes: `file`, `ftp`, `gopher`, `hdl`, `http`, `https`, `imap`, `mailto`, `mms`, `news`, `nntp`, `prospero`, `rsync`, `rtsp`, `rtspu`, `sftp`, `shttp`, `sip`, `sips`, `snews`, `svn`, `svn+ssh`, `telnet`, `wais`, `ws`, `wss`.

The *urllib.parse* module defines functions that fall into two broad categories: URL parsing and URL quoting. These are covered in detail in the following sections.

22.8.1 URL Parsing

The URL parsing functions focus on splitting a URL string into its components, or on combining URL components into a URL string.

urllib.parse.urlparse(*urlstring*, *scheme=''*, *allow_fragments=True*)

Parse a URL into six components, returning a 6-tuple. This corresponds to the general structure of a URL: `scheme://netloc/path;parameters?query#fragment`. Each tuple item is a string, possibly empty. The components are not broken up in smaller parts (for example, the network location is a single string), and % escapes are not expanded. The delimiters as shown above are not part of the result, except for a leading slash in the *path* component, which is retained if present. For example:

```
>>> from urllib.parse import urlparse
>>> o = urlparse('http://www.cwi.nl:80/%7Eguido/Python.html')
>>> o
ParseResult(scheme='http', netloc='www.cwi.nl:80', path='/%7Eguido/Python.html',
            params='', query='', fragment='')
>>> o.scheme
'http'
>>> o.port
80
>>> o.geturl()
'http://www.cwi.nl:80/%7Eguido/Python.html'
```

Following the syntax specifications in **RFC 1808**, urlparse recognizes a netloc only if it is properly introduced by '//'. Otherwise the input is presumed to be a relative URL and thus to start with a path component.

```
>>> from urllib.parse import urlparse
>>> urlparse('//www.cwi.nl:80/%7Eguido/Python.html')
ParseResult(scheme='', netloc='www.cwi.nl:80', path='/%7Eguido/Python.html',
            params='', query='', fragment='')
>>> urlparse('www.cwi.nl/%7Eguido/Python.html')
ParseResult(scheme='', netloc='', path='www.cwi.nl/%7Eguido/Python.html',
            params='', query='', fragment='')
>>> urlparse('help/Python.html')
ParseResult(scheme='', netloc='', path='help/Python.html', params='',
            query='', fragment='')
```

The *scheme* argument gives the default addressing scheme, to be used only if the URL does not specify one. It should be the same type (text or bytes) as *urlstring*, except that the default value `''` is always allowed, and is automatically converted to `b''` if appropriate.

If the *allow_fragments* argument is false, fragment identifiers are not recognized. Instead, they are parsed as part of the path, parameters or query component, and `fragment` is set to the empty string in the return value.

The return value is actually an instance of a subclass of *tuple*. This class has the following additional read-only convenience attributes:

Attribute	Index	Value	Value if not present
`scheme`	0	URL scheme specifier	*scheme* parameter
`netloc`	1	Network location part	empty string
`path`	2	Hierarchical path	empty string
`params`	3	Parameters for last path element	empty string
`query`	4	Query component	empty string
`fragment`	5	Fragment identifier	empty string
`username`		User name	*None*
`password`		Password	*None*
`hostname`		Host name (lower case)	*None*
`port`		Port number as integer, if present	*None*

Reading the `port` attribute will raise a *ValueError* if an invalid port is specified in the URL. See section *Structured Parse Results* for more information on the result object.

Unmatched square brackets in the `netloc` attribute will raise a *ValueError*.

Changed in version 3.2: Added IPv6 URL parsing capabilities.

Changed in version 3.3: The fragment is now parsed for all URL schemes (unless *allow_fragment* is false), in accordance with **RFC 3986**. Previously, a whitelist of schemes that support fragments existed.

Changed in version 3.6: Out-of-range port numbers now raise *ValueError*, instead of returning *None*.

`urllib.parse.parse_qs`(*qs*, *keep_blank_values=False*, *strict_parsing=False*, *encoding='utf-8'*, *errors='replace'*)

Parse a query string given as a string argument (data of type *application/x-www-form-urlencoded*). Data are returned as a dictionary. The dictionary keys are the unique query variable names and the values are lists of values for each name.

The optional argument *keep_blank_values* is a flag indicating whether blank values in percent-encoded queries should be treated as blank strings. A true value indicates that blanks should be retained as blank strings. The default false value indicates that blank values are to be ignored and treated as if they were not included.

The optional argument *strict_parsing* is a flag indicating what to do with parsing errors. If false (the default), errors are silently ignored. If true, errors raise a *ValueError* exception.

The optional *encoding* and *errors* parameters specify how to decode percent-encoded sequences into Unicode characters, as accepted by the *bytes.decode()* method.

Use the *urllib.parse.urlencode()* function (with the `doseq` parameter set to `True`) to convert such dictionaries into query strings.

Changed in version 3.2: Add *encoding* and *errors* parameters.

`urllib.parse.parse_qsl`(*qs*, *keep_blank_values=False*, *strict_parsing=False*, *encoding='utf-8'*, *errors='replace'*)

Parse a query string given as a string argument (data of type *application/x-www-form-urlencoded*). Data are returned as a list of name, value pairs.

The optional argument *keep_blank_values* is a flag indicating whether blank values in percent-encoded queries should be treated as blank strings. A true value indicates that blanks should be retained as blank strings. The default false value indicates that blank values are to be ignored and treated as if they were not included.

The optional argument *strict_parsing* is a flag indicating what to do with parsing errors. If false (the default), errors are silently ignored. If true, errors raise a *ValueError* exception.

The optional *encoding* and *errors* parameters specify how to decode percent-encoded sequences into Unicode characters, as accepted by the *bytes.decode()* method.

Use the *urllib.parse.urlencode()* function to convert such lists of pairs into query strings.

Changed in version 3.2: Add *encoding* and *errors* parameters.

urllib.parse.urlunparse(*parts*)
Construct a URL from a tuple as returned by `urlparse()`. The *parts* argument can be any six-item iterable. This may result in a slightly different, but equivalent URL, if the URL that was parsed originally had unnecessary delimiters (for example, a `?` with an empty query; the RFC states that these are equivalent).

urllib.parse.urlsplit(*urlstring*, *scheme=''*, *allow_fragments=True*)
This is similar to *urlparse()*, but does not split the params from the URL. This should generally be used instead of *urlparse()* if the more recent URL syntax allowing parameters to be applied to each segment of the *path* portion of the URL (see **RFC 2396**) is wanted. A separate function is needed to separate the path segments and parameters. This function returns a 5-tuple: (addressing scheme, network location, path, query, fragment identifier).

The return value is actually an instance of a subclass of *tuple*. This class has the following additional read-only convenience attributes:

Attribute	Index	Value	Value if not present
`scheme`	0	URL scheme specifier	*scheme* parameter
`netloc`	1	Network location part	empty string
`path`	2	Hierarchical path	empty string
`query`	3	Query component	empty string
`fragment`	4	Fragment identifier	empty string
`username`		User name	*None*
`password`		Password	*None*
`hostname`		Host name (lower case)	*None*
`port`		Port number as integer, if present	*None*

Reading the `port` attribute will raise a *ValueError* if an invalid port is specified in the URL. See section *Structured Parse Results* for more information on the result object.

Unmatched square brackets in the `netloc` attribute will raise a *ValueError*.

Changed in version 3.6: Out-of-range port numbers now raise *ValueError*, instead of returning *None*.

urllib.parse.urlunsplit(*parts*)
Combine the elements of a tuple as returned by *urlsplit()* into a complete URL as a string. The *parts* argument can be any five-item iterable. This may result in a slightly different, but equivalent URL, if the URL that was parsed originally had unnecessary delimiters (for example, a ? with an empty query; the RFC states that these are equivalent).

urllib.parse.urljoin(*base*, *url*, *allow_fragments=True*)
Construct a full ("absolute") URL by combining a "base URL" (*base*) with another URL (*url*). Informally, this uses components of the base URL, in particular the addressing scheme, the network location and (part of) the path, to provide missing components in the relative URL. For example:

```
>>> from urllib.parse import urljoin
>>> urljoin('http://www.cwi.nl/%7Eguido/Python.html', 'FAQ.html')
'http://www.cwi.nl/%7Eguido/FAQ.html'
```

The *allow_fragments* argument has the same meaning and default as for *urlparse()*.

Note: If *url* is an absolute URL (that is, starting with `//` or `scheme://`), the *url*'s host name and/or scheme will be present in the result. For example:

```
>>> urljoin('http://www.cwi.nl/%7Eguido/Python.html',
...         '//www.python.org/%7Eguido')
'http://www.python.org/%7Eguido'
```

If you do not want that behavior, preprocess the *url* with *urlsplit()* and *urlunsplit()*, removing possible *scheme* and *netloc* parts.

Changed in version 3.5: Behaviour updated to match the semantics defined in **RFC 3986**.

`urllib.parse.urldefrag(`*url*`)`

If *url* contains a fragment identifier, return a modified version of *url* with no fragment identifier, and the fragment identifier as a separate string. If there is no fragment identifier in *url*, return *url* unmodified and an empty string.

The return value is actually an instance of a subclass of *tuple*. This class has the following additional read-only convenience attributes:

Attribute	Index	Value	Value if not present
`url`	0	URL with no fragment	empty string
`fragment`	1	Fragment identifier	empty string

See section *Structured Parse Results* for more information on the result object.

Changed in version 3.2: Result is a structured object rather than a simple 2-tuple.

22.8.2 Parsing ASCII Encoded Bytes

The URL parsing functions were originally designed to operate on character strings only. In practice, it is useful to be able to manipulate properly quoted and encoded URLs as sequences of ASCII bytes. Accordingly, the URL parsing functions in this module all operate on *bytes* and *bytearray* objects in addition to *str* objects.

If *str* data is passed in, the result will also contain only *str* data. If *bytes* or *bytearray* data is passed in, the result will contain only *bytes* data.

Attempting to mix *str* data with *bytes* or *bytearray* in a single function call will result in a *TypeError* being raised, while attempting to pass in non-ASCII byte values will trigger *UnicodeDecodeError*.

To support easier conversion of result objects between *str* and *bytes*, all return values from URL parsing functions provide either an `encode()` method (when the result contains *str* data) or a `decode()` method (when the result contains *bytes* data). The signatures of these methods match those of the corresponding *str* and *bytes* methods (except that the default encoding is `'ascii'` rather than `'utf-8'`). Each produces a value of a corresponding type that contains either *bytes* data (for `encode()` methods) or *str* data (for `decode()` methods).

Applications that need to operate on potentially improperly quoted URLs that may contain non-ASCII data will need to do their own decoding from bytes to characters before invoking the URL parsing methods.

The behaviour described in this section applies only to the URL parsing functions. The URL quoting functions use their own rules when producing or consuming byte sequences as detailed in the documentation of the individual URL quoting functions.

Changed in version 3.2: URL parsing functions now accept ASCII encoded byte sequences

22.8.3 Structured Parse Results

The result objects from the *urlparse()*, *urlsplit()* and *urldefrag()* functions are subclasses of the *tuple* type. These subclasses add the attributes listed in the documentation for those functions, the encoding and decoding support described in the previous section, as well as an additional method:

urllib.parse.SplitResult.geturl()

Return the re-combined version of the original URL as a string. This may differ from the original URL in that the scheme may be normalized to lower case and empty components may be dropped. Specifically, empty parameters, queries, and fragment identifiers will be removed.

For *urldefrag()* results, only empty fragment identifiers will be removed. For *urlsplit()* and *urlparse()* results, all noted changes will be made to the URL returned by this method.

The result of this method remains unchanged if passed back through the original parsing function:

```
>>> from urllib.parse import urlsplit
>>> url = 'HTTP://www.Python.org/doc/#'
>>> r1 = urlsplit(url)
>>> r1.geturl()
'http://www.Python.org/doc/'
>>> r2 = urlsplit(r1.geturl())
>>> r2.geturl()
'http://www.Python.org/doc/'
```

The following classes provide the implementations of the structured parse results when operating on *str* objects:

class urllib.parse.DefragResult(*url*, *fragment*)

Concrete class for *urldefrag()* results containing *str* data. The `encode()` method returns a *DefragResultBytes* instance.

New in version 3.2.

class urllib.parse.ParseResult(*scheme*, *netloc*, *path*, *params*, *query*, *fragment*)

Concrete class for *urlparse()* results containing *str* data. The `encode()` method returns a *ParseResultBytes* instance.

class urllib.parse.SplitResult(*scheme*, *netloc*, *path*, *query*, *fragment*)

Concrete class for *urlsplit()* results containing *str* data. The `encode()` method returns a *SplitResultBytes* instance.

The following classes provide the implementations of the parse results when operating on *bytes* or *bytearray* objects:

class urllib.parse.DefragResultBytes(*url*, *fragment*)

Concrete class for *urldefrag()* results containing *bytes* data. The `decode()` method returns a *DefragResult* instance.

New in version 3.2.

class urllib.parse.ParseResultBytes(*scheme*, *netloc*, *path*, *params*, *query*, *fragment*)

Concrete class for *urlparse()* results containing *bytes* data. The `decode()` method returns a *ParseResult* instance.

New in version 3.2.

class urllib.parse.SplitResultBytes(*scheme*, *netloc*, *path*, *query*, *fragment*)

Concrete class for *urlsplit()* results containing *bytes* data. The `decode()` method returns a *SplitResult* instance.

New in version 3.2.

22.8.4 URL Quoting

The URL quoting functions focus on taking program data and making it safe for use as URL components by quoting special characters and appropriately encoding non-ASCII text. They also support reversing these operations to recreate the original data from the contents of a URL component if that task isn't already covered by the URL parsing functions above.

`urllib.parse.quote`(*string*, *safe='/'*, *encoding=None*, *errors=None*)
Replace special characters in *string* using the `%xx` escape. Letters, digits, and the characters `'_.-~'` are never quoted. By default, this function is intended for quoting the path section of URL. The optional *safe* parameter specifies additional ASCII characters that should not be quoted — its default value is `'/'`.

string may be either a *str* or a *bytes*.

Changed in version 3.7: Moved from **RFC 2396** to **RFC 3986** for quoting URL strings. "~" is now included in the set of reserved characters.

The optional *encoding* and *errors* parameters specify how to deal with non-ASCII characters, as accepted by the *str.encode()* method. *encoding* defaults to `'utf-8'`. *errors* defaults to `'strict'`, meaning unsupported characters raise a *UnicodeEncodeError*. *encoding* and *errors* must not be supplied if *string* is a *bytes*, or a *TypeError* is raised.

Note that `quote(string, safe, encoding, errors)` is equivalent to `quote_from_bytes(string.encode(encoding, errors), safe)`.

Example: `quote('/El Niño/')` yields `'/El%20Ni%C3%B1o/'`.

`urllib.parse.quote_plus`(*string*, *safe=''*, *encoding=None*, *errors=None*)
Like *quote()*, but also replace spaces by plus signs, as required for quoting HTML form values when building up a query string to go into a URL. Plus signs in the original string are escaped unless they are included in *safe*. It also does not have *safe* default to `'/'`.

Example: `quote_plus('/El Niño/')` yields `'%2FEl+Ni%C3%B1o%2F'`.

`urllib.parse.quote_from_bytes`(*bytes*, *safe='/'*)
Like *quote()*, but accepts a *bytes* object rather than a *str*, and does not perform string-to-bytes encoding.

Example: `quote_from_bytes(b'a&\xef')` yields `'a%26%EF'`.

`urllib.parse.unquote`(*string*, *encoding='utf-8'*, *errors='replace'*)
Replace `%xx` escapes by their single-character equivalent. The optional *encoding* and *errors* parameters specify how to decode percent-encoded sequences into Unicode characters, as accepted by the *bytes.decode()* method.

string must be a *str*.

encoding defaults to `'utf-8'`. *errors* defaults to `'replace'`, meaning invalid sequences are replaced by a placeholder character.

Example: `unquote('/El%20Ni%C3%B1o/')` yields `'/El Niño/'`.

`urllib.parse.unquote_plus`(*string*, *encoding='utf-8'*, *errors='replace'*)
Like *unquote()*, but also replace plus signs by spaces, as required for unquoting HTML form values.

string must be a *str*.

Example: `unquote_plus('/El+Ni%C3%B1o/')` yields `'/El Niño/'`.

`urllib.parse.unquote_to_bytes`(*string*)
Replace `%xx` escapes by their single-octet equivalent, and return a *bytes* object.

string may be either a *str* or a *bytes*.

If it is a *str*, unescaped non-ASCII characters in *string* are encoded into UTF-8 bytes.

Example: `unquote_to_bytes('a%26%EF')` yields `b'a&\xef'`.

`urllib.parse.urlencode`(*query*, *doseq=False*, *safe=''*, *encoding=None*, *errors=None*, *quote_via=quote_plus*)

Convert a mapping object or a sequence of two-element tuples, which may contain *str* or *bytes* objects, to a percent-encoded ASCII text string. If the resultant string is to be used as a *data* for POST operation with the *urlopen()* function, then it should be encoded to bytes, otherwise it would result in a *TypeError*.

The resulting string is a series of `key=value` pairs separated by `'&'` characters, where both *key* and *value* are quoted using the *quote_via* function. By default, *quote_plus()* is used to quote the values, which means spaces are quoted as a `'+'` character and '/' characters are encoded as `%2F`, which follows the standard for GET requests (`application/x-www-form-urlencoded`). An alternate function that can be passed as *quote_via* is *quote()*, which will encode spaces as `%20` and not encode '/' characters. For maximum control of what is quoted, use `quote` and specify a value for *safe*.

When a sequence of two-element tuples is used as the *query* argument, the first element of each tuple is a key and the second is a value. The value element in itself can be a sequence and in that case, if the optional parameter *doseq* is evaluates to `True`, individual `key=value` pairs separated by `'&'` are generated for each element of the value sequence for the key. The order of parameters in the encoded string will match the order of parameter tuples in the sequence.

The *safe*, *encoding*, and *errors* parameters are passed down to *quote_via* (the *encoding* and *errors* parameters are only passed when a query element is a *str*).

To reverse this encoding process, *parse_qs()* and *parse_qsl()* are provided in this module to parse query strings into Python data structures.

Refer to *urllib examples* to find out how urlencode method can be used for generating query string for a URL or data for POST.

Changed in version 3.2: Query parameter supports bytes and string objects.

New in version 3.5: *quote_via* parameter.

See also:

RFC 3986 - Uniform Resource Identifiers This is the current standard (STD66). Any changes to urllib.parse module should conform to this. Certain deviations could be observed, which are mostly for backward compatibility purposes and for certain de-facto parsing requirements as commonly observed in major browsers.

RFC 2732 - Format for Literal IPv6 Addresses in URL's. This specifies the parsing requirements of IPv6 URLs.

RFC 2396 - Uniform Resource Identifiers (URI): Generic Syntax Document describing the generic syntactic requirements for both Uniform Resource Names (URNs) and Uniform Resource Locators (URLs).

RFC 2368 - The mailto URL scheme. Parsing requirements for mailto URL schemes.

RFC 1808 - Relative Uniform Resource Locators This Request For Comments includes the rules for joining an absolute and a relative URL, including a fair number of "Abnormal Examples" which govern the treatment of border cases.

RFC 1738 - Uniform Resource Locators (URL) This specifies the formal syntax and semantics of absolute URLs.

22.9 `urllib.error` — Exception classes raised by urllib.request

Source code: Lib/urllib/error.py

The *urllib.error* module defines the exception classes for exceptions raised by *urllib.request*. The base exception class is *URLError*.

The following exceptions are raised by *urllib.error* as appropriate:

exception urllib.error.URLError
The handlers raise this exception (or derived exceptions) when they run into a problem. It is a subclass of *OSError*.

reason
The reason for this error. It can be a message string or another exception instance.

Changed in version 3.3: *URLError* has been made a subclass of *OSError* instead of *IOError*.

exception urllib.error.HTTPError
Though being an exception (a subclass of *URLError*), an *HTTPError* can also function as a non-exceptional file-like return value (the same thing that *urlopen()* returns). This is useful when handling exotic HTTP errors, such as requests for authentication.

code
An HTTP status code as defined in **RFC 2616**. This numeric value corresponds to a value found in the dictionary of codes as found in *http.server.BaseHTTPRequestHandler.responses*.

reason
This is usually a string explaining the reason for this error.

headers
The HTTP response headers for the HTTP request that caused the *HTTPError*.

New in version 3.4.

exception urllib.error.ContentTooShortError(*msg*, *content***)**
This exception is raised when the *urlretrieve()* function detects that the amount of the downloaded data is less than the expected amount (given by the *Content-Length* header). The `content` attribute stores the downloaded (and supposedly truncated) data.

22.10 `urllib.robotparser` — Parser for robots.txt

Source code: Lib/urllib/robotparser.py

This module provides a single class, *RobotFileParser*, which answers questions about whether or not a particular user agent can fetch a URL on the Web site that published the `robots.txt` file. For more details on the structure of `robots.txt` files, see http://www.robotstxt.org/orig.html.

class urllib.robotparser.RobotFileParser(*url=''***)**
This class provides methods to read, parse and answer questions about the `robots.txt` file at *url*.

set_url(*url***)**
Sets the URL referring to a `robots.txt` file.

read()
Reads the `robots.txt` URL and feeds it to the parser.

parse(*lines***)**
Parses the lines argument.

can_fetch(*useragent*, *url*)
Returns `True` if the *useragent* is allowed to fetch the *url* according to the rules contained in the parsed `robots.txt` file.

mtime()
Returns the time the `robots.txt` file was last fetched. This is useful for long-running web spiders that need to check for new `robots.txt` files periodically.

modified()
Sets the time the `robots.txt` file was last fetched to the current time.

crawl_delay(*useragent*)
Returns the value of the `Crawl-delay` parameter from `robots.txt` for the *useragent* in question. If there is no such parameter or it doesn't apply to the *useragent* specified or the `robots.txt` entry for this parameter has invalid syntax, return `None`.

New in version 3.6.

request_rate(*useragent*)
Returns the contents of the `Request-rate` parameter from `robots.txt` as a *named tuple* `RequestRate(requests, seconds)`. If there is no such parameter or it doesn't apply to the *useragent* specified or the `robots.txt` entry for this parameter has invalid syntax, return `None`.

New in version 3.6.

The following example demonstrates basic use of the *RobotFileParser* class:

```
>>> import urllib.robotparser
>>> rp = urllib.robotparser.RobotFileParser()
>>> rp.set_url("http://www.musi-cal.com/robots.txt")
>>> rp.read()
>>> rrate = rp.request_rate("*")
>>> rrate.requests
3
>>> rrate.seconds
20
>>> rp.crawl_delay("*")
6
>>> rp.can_fetch("*", "http://www.musi-cal.com/cgi-bin/search?city=San+Francisco")
False
>>> rp.can_fetch("*", "http://www.musi-cal.com/")
True
```

22.11 http — HTTP modules

Source code: Lib/http/__init__.py

---

http is a package that collects several modules for working with the HyperText Transfer Protocol:

- *http.client* is a low-level HTTP protocol client; for high-level URL opening use *urllib.request*
- *http.server* contains basic HTTP server classes based on *socketserver*
- *http.cookies* has utilities for implementing state management with cookies
- *http.cookiejar* provides persistence of cookies

http is also a module that defines a number of HTTP status codes and associated messages through the *http.HTTPStatus* enum:

class http.HTTPStatus

New in version 3.5.

A subclass of *enum.IntEnum* that defines a set of HTTP status codes, reason phrases and long descriptions written in English.

Usage:

```
>>> from http import HTTPStatus
>>> HTTPStatus.OK
<HTTPStatus.OK: 200>
>>> HTTPStatus.OK == 200
True
>>> http.HTTPStatus.OK.value
200
>>> HTTPStatus.OK.phrase
'OK'
>>> HTTPStatus.OK.description
'Request fulfilled, document follows'
>>> list(HTTPStatus)
[<HTTPStatus.CONTINUE: 100>, <HTTPStatus.SWITCHING_PROTOCOLS: 101>, ...]
```

22.11.1 HTTP status codes

Supported, IANA-registered status codes available in *http.HTTPStatus* are:

Code	Enum Name	Details
100	CONTINUE	HTTP/1.1 **RFC 7231**, Section 6.2.1
101	SWITCHING_PROTOCOLS	HTTP/1.1 **RFC 7231**, Section 6.2.2
102	PROCESSING	WebDAV **RFC 2518**, Section 10.1
200	OK	HTTP/1.1 **RFC 7231**, Section 6.3.1
201	CREATED	HTTP/1.1 **RFC 7231**, Section 6.3.2
202	ACCEPTED	HTTP/1.1 **RFC 7231**, Section 6.3.3
203	NON_AUTHORITATIVE_INFORMATION	HTTP/1.1 **RFC 7231**, Section 6.3.4
204	NO_CONTENT	HTTP/1.1 **RFC 7231**, Section 6.3.5
205	RESET_CONTENT	HTTP/1.1 **RFC 7231**, Section 6.3.6
206	PARTIAL_CONTENT	HTTP/1.1 **RFC 7233**, Section 4.1
207	MULTI_STATUS	WebDAV **RFC 4918**, Section 11.1
208	ALREADY_REPORTED	WebDAV Binding Extensions **RFC 5842**, Section 7.1 (Experimental)
226	IM_USED	Delta Encoding in HTTP **RFC 3229**, Section 10.4.1
300	MULTIPLE_CHOICES	HTTP/1.1 **RFC 7231**, Section 6.4.1
301	MOVED_PERMANENTLY	HTTP/1.1 **RFC 7231**, Section 6.4.2
302	FOUND	HTTP/1.1 **RFC 7231**, Section 6.4.3
303	SEE_OTHER	HTTP/1.1 **RFC 7231**, Section 6.4.4
304	NOT_MODIFIED	HTTP/1.1 **RFC 7232**, Section 4.1
305	USE_PROXY	HTTP/1.1 **RFC 7231**, Section 6.4.5
307	TEMPORARY_REDIRECT	HTTP/1.1 **RFC 7231**, Section 6.4.7
308	PERMANENT_REDIRECT	Permanent Redirect **RFC 7238**, Section 3 (Experimental)
400	BAD_REQUEST	HTTP/1.1 **RFC 7231**, Section 6.5.1
401	UNAUTHORIZED	HTTP/1.1 Authentication **RFC 7235**, Section 3.1
402	PAYMENT_REQUIRED	HTTP/1.1 **RFC 7231**, Section 6.5.2
403	FORBIDDEN	HTTP/1.1 **RFC 7231**, Section 6.5.3
404	NOT_FOUND	HTTP/1.1 **RFC 7231**, Section 6.5.4

Continued on

Table 1 – continued from previous page

Code	Enum Name	Details
405	METHOD_NOT_ALLOWED	HTTP/1.1 **RFC 7231**, Section 6.5.5
406	NOT_ACCEPTABLE	HTTP/1.1 **RFC 7231**, Section 6.5.6
407	PROXY_AUTHENTICATION_REQUIRED	HTTP/1.1 Authentication **RFC 7235**, Section 3.2
408	REQUEST_TIMEOUT	HTTP/1.1 **RFC 7231**, Section 6.5.7
409	CONFLICT	HTTP/1.1 **RFC 7231**, Section 6.5.8
410	GONE	HTTP/1.1 **RFC 7231**, Section 6.5.9
411	LENGTH_REQUIRED	HTTP/1.1 **RFC 7231**, Section 6.5.10
412	PRECONDITION_FAILED	HTTP/1.1 **RFC 7232**, Section 4.2
413	REQUEST_ENTITY_TOO_LARGE	HTTP/1.1 **RFC 7231**, Section 6.5.11
414	REQUEST_URI_TOO_LONG	HTTP/1.1 **RFC 7231**, Section 6.5.12
415	UNSUPPORTED_MEDIA_TYPE	HTTP/1.1 **RFC 7231**, Section 6.5.13
416	REQUEST_RANGE_NOT_SATISFIABLE	HTTP/1.1 Range Requests **RFC 7233**, Section 4.4
417	EXPECTATION_FAILED	HTTP/1.1 **RFC 7231**, Section 6.5.14
421	MISDIRECTED_REQUEST	HTTP/2 **RFC 7540**, Section 9.1.2
422	UNPROCESSABLE_ENTITY	WebDAV **RFC 4918**, Section 11.2
423	LOCKED	WebDAV **RFC 4918**, Section 11.3
424	FAILED_DEPENDENCY	WebDAV **RFC 4918**, Section 11.4
426	UPGRADE_REQUIRED	HTTP/1.1 **RFC 7231**, Section 6.5.15
428	PRECONDITION_REQUIRED	Additional HTTP Status Codes **RFC 6585**
429	TOO_MANY_REQUESTS	Additional HTTP Status Codes **RFC 6585**
431	REQUEST_HEADER_FIELDS_TOO_LARGE	Additional HTTP Status Codes **RFC 6585**
500	INTERNAL_SERVER_ERROR	HTTP/1.1 **RFC 7231**, Section 6.6.1
501	NOT_IMPLEMENTED	HTTP/1.1 **RFC 7231**, Section 6.6.2
502	BAD_GATEWAY	HTTP/1.1 **RFC 7231**, Section 6.6.3
503	SERVICE_UNAVAILABLE	HTTP/1.1 **RFC 7231**, Section 6.6.4
504	GATEWAY_TIMEOUT	HTTP/1.1 **RFC 7231**, Section 6.6.5
505	HTTP_VERSION_NOT_SUPPORTED	HTTP/1.1 **RFC 7231**, Section 6.6.6
506	VARIANT_ALSO_NEGOTIATES	Transparent Content Negotiation in HTTP **RFC 2295**, Section 8.1 (Expe
507	INSUFFICIENT_STORAGE	WebDAV **RFC 4918**, Section 11.5
508	LOOP_DETECTED	WebDAV Binding Extensions **RFC 5842**, Section 7.2 (Experimental)
510	NOT_EXTENDED	An HTTP Extension Framework **RFC 2774**, Section 7 (Experimental)
511	NETWORK_AUTHENTICATION_REQUIRED	Additional HTTP Status Codes **RFC 6585**, Section 6

In order to preserve backwards compatibility, enum values are also present in the *http.client* module in the form of constants. The enum name is equal to the constant name (i.e. `http.HTTPStatus.OK` is also available as `http.client.OK`).

Changed in version 3.7: Added `421 MISDIRECTED_REQUEST` status code.

22.12 `http.client` — HTTP protocol client

Source code: Lib/http/client.py

This module defines classes which implement the client side of the HTTP and HTTPS protocols. It is normally not used directly — the module *urllib.request* uses it to handle URLs that use HTTP and HTTPS.

See also:

The Requests package is recommended for a higher-level HTTP client interface.

Note: HTTPS support is only available if Python was compiled with SSL support (through the *ssl* module).

The module provides the following classes:

class http.client.HTTPConnection(*host*, *port=None*[, *timeout*], *source_address=None*, *blocksize=8192*)

An *HTTPConnection* instance represents one transaction with an HTTP server. It should be instantiated passing it a host and optional port number. If no port number is passed, the port is extracted from the host string if it has the form `host:port`, else the default HTTP port (80) is used. If the optional *timeout* parameter is given, blocking operations (like connection attempts) will timeout after that many seconds (if it is not given, the global default timeout setting is used). The optional *source_address* parameter may be a tuple of a (host, port) to use as the source address the HTTP connection is made from. The optional *blocksize* parameter sets the buffer size in bytes for sending a file-like message body.

For example, the following calls all create instances that connect to the server at the same host and port:

```
>>> h1 = http.client.HTTPConnection('www.python.org')
>>> h2 = http.client.HTTPConnection('www.python.org:80')
>>> h3 = http.client.HTTPConnection('www.python.org', 80)
>>> h4 = http.client.HTTPConnection('www.python.org', 80, timeout=10)
```

Changed in version 3.2: *source_address* was added.

Changed in version 3.4: The *strict* parameter was removed. HTTP 0.9-style "Simple Responses" are not longer supported.

Changed in version 3.7: *blocksize* parameter was added.

class http.client.HTTPSConnection(*host*, *port=None*, *key_file=None*, *cert_file=None*[, *timeout*], *source_address=None*, ***, *context=None*, *check_hostname=None*, *blocksize=8192*)

A subclass of *HTTPConnection* that uses SSL for communication with secure servers. Default port is 443. If *context* is specified, it must be a *ssl.SSLContext* instance describing the various SSL options.

Please read *Security considerations* for more information on best practices.

Changed in version 3.2: *source_address*, *context* and *check_hostname* were added.

Changed in version 3.2: This class now supports HTTPS virtual hosts if possible (that is, if *ssl.HAS_SNI* is true).

Changed in version 3.4: The *strict* parameter was removed. HTTP 0.9-style "Simple Responses" are no longer supported.

Changed in version 3.4.3: This class now performs all the necessary certificate and hostname checks by default. To revert to the previous, unverified, behavior `ssl._create_unverified_context()` can be passed to the *context* parameter.

Deprecated since version 3.6: *key_file* and *cert_file* are deprecated in favor of *context*. Please use *ssl.SSLContext.load_cert_chain()* instead, or let *ssl.create_default_context()* select the system's trusted CA certificates for you.

The *check_hostname* parameter is also deprecated; the *ssl.SSLContext.check_hostname* attribute of *context* should be used instead.

class http.client.HTTPResponse(*sock*, *debuglevel=0*, *method=None*, *url=None*)

Class whose instances are returned upon successful connection. Not instantiated directly by user.

Changed in version 3.4: The *strict* parameter was removed. HTTP 0.9 style "Simple Responses" are no longer supported.

The following exceptions are raised as appropriate:

exception http.client.HTTPException
The base class of the other exceptions in this module. It is a subclass of *Exception*.

exception http.client.NotConnected
A subclass of *HTTPException*.

exception http.client.InvalidURL
A subclass of *HTTPException*, raised if a port is given and is either non-numeric or empty.

exception http.client.UnknownProtocol
A subclass of *HTTPException*.

exception http.client.UnknownTransferEncoding
A subclass of *HTTPException*.

exception http.client.UnimplementedFileMode
A subclass of *HTTPException*.

exception http.client.IncompleteRead
A subclass of *HTTPException*.

exception http.client.ImproperConnectionState
A subclass of *HTTPException*.

exception http.client.CannotSendRequest
A subclass of *ImproperConnectionState*.

exception http.client.CannotSendHeader
A subclass of *ImproperConnectionState*.

exception http.client.ResponseNotReady
A subclass of *ImproperConnectionState*.

exception http.client.BadStatusLine
A subclass of *HTTPException*. Raised if a server responds with a HTTP status code that we don't understand.

exception http.client.LineTooLong
A subclass of *HTTPException*. Raised if an excessively long line is received in the HTTP protocol from the server.

exception http.client.RemoteDisconnected
A subclass of *ConnectionResetError* and *BadStatusLine*. Raised by *HTTPConnection.getresponse()* when the attempt to read the response results in no data read from the connection, indicating that the remote end has closed the connection.

New in version 3.5: Previously, *BadStatusLine*`('')` was raised.

The constants defined in this module are:

http.client.HTTP_PORT
The default port for the HTTP protocol (always `80`).

http.client.HTTPS_PORT
The default port for the HTTPS protocol (always `443`).

http.client.responses
This dictionary maps the HTTP 1.1 status codes to the W3C names.

Example: `http.client.responses[http.client.NOT_FOUND]` is `'Not Found'`.

See *HTTP status codes* for a list of HTTP status codes that are available in this module as constants.

22.12.1 HTTPConnection Objects

HTTPConnection instances have the following methods:

HTTPConnection.**request**(*method*, *url*, *body=None*, *headers={}*, ***, *encode_chunked=False*)
This will send a request to the server using the HTTP request method *method* and the selector *url*.

If *body* is specified, the specified data is sent after the headers are finished. It may be a *str*, a *bytes-like object*, an open *file object*, or an iterable of *bytes*. If *body* is a string, it is encoded as ISO-8859-1, the default for HTTP. If it is a bytes-like object, the bytes are sent as is. If it is a *file object*, the contents of the file is sent; this file object should support at least the `read()` method. If the file object is an instance of *io.TextIOBase*, the data returned by the `read()` method will be encoded as ISO-8859-1, otherwise the data returned by `read()` is sent as is. If *body* is an iterable, the elements of the iterable are sent as is until the iterable is exhausted.

The *headers* argument should be a mapping of extra HTTP headers to send with the request.

If *headers* contains neither Content-Length nor Transfer-Encoding, but there is a request body, one of those header fields will be added automatically. If *body* is `None`, the Content-Length header is set to `0` for methods that expect a body (`PUT`, `POST`, and `PATCH`). If *body* is a string or a bytes-like object that is not also a *file*, the Content-Length header is set to its length. Any other type of *body* (files and iterables in general) will be chunk-encoded, and the Transfer-Encoding header will automatically be set instead of Content-Length.

The *encode_chunked* argument is only relevant if Transfer-Encoding is specified in *headers*. If *encode_chunked* is `False`, the HTTPConnection object assumes that all encoding is handled by the calling code. If it is `True`, the body will be chunk-encoded.

Note: Chunked transfer encoding has been added to the HTTP protocol version 1.1. Unless the HTTP server is known to handle HTTP 1.1, the caller must either specify the Content-Length, or must pass a *str* or bytes-like object that is not also a file as the body representation.

New in version 3.2: *body* can now be an iterable.

Changed in version 3.6: If neither Content-Length nor Transfer-Encoding are set in *headers*, file and iterable *body* objects are now chunk-encoded. The *encode_chunked* argument was added. No attempt is made to determine the Content-Length for file objects.

HTTPConnection.**getresponse**()
Should be called after a request is sent to get the response from the server. Returns an *HTTPResponse* instance.

Note: Note that you must have read the whole response before you can send a new request to the server.

Changed in version 3.5: If a *ConnectionError* or subclass is raised, the *HTTPConnection* object will be ready to reconnect when a new request is sent.

HTTPConnection.**set_debuglevel**(*level*)
Set the debugging level. The default debug level is `0`, meaning no debugging output is printed. Any value greater than `0` will cause all currently defined debug output to be printed to stdout. The `debuglevel` is passed to any new *HTTPResponse* objects that are created.

New in version 3.1.

HTTPConnection.**set_tunnel**(*host*, *port=None*, *headers=None*)
Set the host and the port for HTTP Connect Tunnelling. This allows running the connection through a proxy server.

The host and port arguments specify the endpoint of the tunneled connection (i.e. the address included in the CONNECT request, *not* the address of the proxy server).

The headers argument should be a mapping of extra HTTP headers to send with the CONNECT request.

For example, to tunnel through a HTTPS proxy server running locally on port 8080, we would pass the address of the proxy to the *HTTPSConnection* constructor, and the address of the host that we eventually want to reach to the *set_tunnel()* method:

```
>>> import http.client
>>> conn = http.client.HTTPSConnection("localhost", 8080)
>>> conn.set_tunnel("www.python.org")
>>> conn.request("HEAD","/index.html")
```

New in version 3.2.

HTTPConnection.connect()
Connect to the server specified when the object was created. By default, this is called automatically when making a request if the client does not already have a connection.

HTTPConnection.close()
Close the connection to the server.

HTTPConnection.blocksize
Buffer size in bytes for sending a file-like message body.

New in version 3.7.

As an alternative to using the `request()` method described above, you can also send your request step by step, by using the four functions below.

HTTPConnection.putrequest(*method*, *url*, *skip_host=False*, *skip_accept_encoding=False*)
This should be the first call after the connection to the server has been made. It sends a line to the server consisting of the *method* string, the *url* string, and the HTTP version (`HTTP/1.1`). To disable automatic sending of `Host:` or `Accept-Encoding:` headers (for example to accept additional content encodings), specify *skip_host* or *skip_accept_encoding* with non-False values.

HTTPConnection.putheader(*header*, *argument*[, ...])
Send an **RFC 822**-style header to the server. It sends a line to the server consisting of the header, a colon and a space, and the first argument. If more arguments are given, continuation lines are sent, each consisting of a tab and an argument.

HTTPConnection.endheaders(*message_body=None*, ***, *encode_chunked=False*)
Send a blank line to the server, signalling the end of the headers. The optional *message_body* argument can be used to pass a message body associated with the request.

If *encode_chunked* is `True`, the result of each iteration of *message_body* will be chunk-encoded as specified in **RFC 7230**, Section 3.3.1. How the data is encoded is dependent on the type of *message_body*. If *message_body* implements the buffer interface the encoding will result in a single chunk. If *message_body* is a *collections.abc.Iterable*, each iteration of *message_body* will result in a chunk. If *message_body* is a *file object*, each call to `.read()` will result in a chunk. The method automatically signals the end of the chunk-encoded data immediately after *message_body*.

Note: Due to the chunked encoding specification, empty chunks yielded by an iterator body will be ignored by the chunk-encoder. This is to avoid premature termination of the read of the request by the target server due to malformed encoding.

New in version 3.6: Chunked encoding support. The *encode_chunked* parameter was added.

HTTPConnection.**send**(*data*)
Send data to the server. This should be used directly only after the *endheaders()* method has been called and before *getresponse()* is called.

22.12.2 HTTPResponse Objects

An *HTTPResponse* instance wraps the HTTP response from the server. It provides access to the request headers and the entity body. The response is an iterable object and can be used in a with statement.

Changed in version 3.5: The *io.BufferedIOBase* interface is now implemented and all of its reader operations are supported.

HTTPResponse.**read**([*amt*])
Reads and returns the response body, or up to the next *amt* bytes.

HTTPResponse.**readinto**(*b*)
Reads up to the next len(b) bytes of the response body into the buffer *b*. Returns the number of bytes read.

New in version 3.3.

HTTPResponse.**getheader**(*name*, *default=None*)
Return the value of the header *name*, or *default* if there is no header matching *name*. If there is more than one header with the name *name*, return all of the values joined by ', '. If 'default' is any iterable other than a single string, its elements are similarly returned joined by commas.

HTTPResponse.**getheaders**()
Return a list of (header, value) tuples.

HTTPResponse.**fileno**()
Return the `fileno` of the underlying socket.

HTTPResponse.**msg**
A `http.client.HTTPMessage` instance containing the response headers. `http.client.HTTPMessage` is a subclass of *email.message.Message*.

HTTPResponse.**version**
HTTP protocol version used by server. 10 for HTTP/1.0, 11 for HTTP/1.1.

HTTPResponse.**status**
Status code returned by server.

HTTPResponse.**reason**
Reason phrase returned by server.

HTTPResponse.**debuglevel**
A debugging hook. If *debuglevel* is greater than zero, messages will be printed to stdout as the response is read and parsed.

HTTPResponse.**closed**
Is `True` if the stream is closed.

22.12.3 Examples

Here is an example session that uses the `GET` method:

```
>>> import http.client
>>> conn = http.client.HTTPSConnection("www.python.org")
>>> conn.request("GET", "/")
>>> r1 = conn.getresponse()
```

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```
>>> print(r1.status, r1.reason)
200 OK
>>> data1 = r1.read()  # This will return entire content.
>>> # The following example demonstrates reading data in chunks.
>>> conn.request("GET", "/")
>>> r1 = conn.getresponse()
>>> while not r1.closed:
...     print(r1.read(200))  # 200 bytes
b'<!doctype html>\n<!--[if"...
...
>>> # Example of an invalid request
>>> conn.request("GET", "/parrot.spam")
>>> r2 = conn.getresponse()
>>> print(r2.status, r2.reason)
404 Not Found
>>> data2 = r2.read()
>>> conn.close()
```

Here is an example session that uses the `HEAD` method. Note that the `HEAD` method never returns any data.

```
>>> import http.client
>>> conn = http.client.HTTPSConnection("www.python.org")
>>> conn.request("HEAD", "/")
>>> res = conn.getresponse()
>>> print(res.status, res.reason)
200 OK
>>> data = res.read()
>>> print(len(data))
0
>>> data == b''
True
```

Here is an example session that shows how to `POST` requests:

```
>>> import http.client, urllib.parse
>>> params = urllib.parse.urlencode({'@number': 12524, '@type': 'issue', '@action': 'show'})
>>> headers = {"Content-type": "application/x-www-form-urlencoded",
...            "Accept": "text/plain"}
>>> conn = http.client.HTTPConnection("bugs.python.org")
>>> conn.request("POST", "", params, headers)
>>> response = conn.getresponse()
>>> print(response.status, response.reason)
302 Found
>>> data = response.read()
>>> data
b'Redirecting to <a href="http://bugs.python.org/issue12524">http://bugs.python.org/issue12524</a>'
>>> conn.close()
```

Client side `HTTP PUT` requests are very similar to `POST` requests. The difference lies only the server side where HTTP server will allow resources to be created via `PUT` request. It should be noted that custom HTTP methods +are also handled in *`urllib.request.Request`* by sending the appropriate +method attribute.Here is an example session that shows how to do `PUT` request using http.client:

```
>>> # This creates an HTTP message
>>> # with the content of BODY as the enclosed representation
>>> # for the resource http://localhost:8080/file
```

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```
...
>>> import http.client
>>> BODY = "***filecontents***"
>>> conn = http.client.HTTPConnection("localhost", 8080)
>>> conn.request("PUT", "/file", BODY)
>>> response = conn.getresponse()
>>> print(response.status, response.reason)
200, OK
```

22.12.4 HTTPMessage Objects

An `http.client.HTTPMessage` instance holds the headers from an HTTP response. It is implemented using the *email.message.Message* class.

22.13 `ftplib` — FTP protocol client

Source code: Lib/ftplib.py

This module defines the class *FTP* and a few related items. The *FTP* class implements the client side of the FTP protocol. You can use this to write Python programs that perform a variety of automated FTP jobs, such as mirroring other FTP servers. It is also used by the module *urllib.request* to handle URLs that use FTP. For more information on FTP (File Transfer Protocol), see Internet **RFC 959**.

Here's a sample session using the *ftplib* module:

```
>>> from ftplib import FTP
>>> ftp = FTP('ftp.debian.org')     # connect to host, default port
>>> ftp.login()                     # user anonymous, passwd anonymous@
'230 Login successful.'
>>> ftp.cwd('debian')               # change into "debian" directory
>>> ftp.retrlines('LIST')           # list directory contents
-rw-rw-r--    1 1176     1176         1063 Jun 15 10:18 README
...
drwxr-sr-x    5 1176     1176         4096 Dec 19  2000 pool
drwxr-sr-x    4 1176     1176         4096 Nov 17  2008 project
drwxr-xr-x    3 1176     1176         4096 Oct 10  2012 tools
'226 Directory send OK.'
>>> ftp.retrbinary('RETR README', open('README', 'wb').write)
'226 Transfer complete.'
>>> ftp.quit()
```

The module defines the following items:

class ftplib.FTP(*host=''*, *user=''*, *passwd=''*, *acct=''*, *timeout=None*, *source_address=None*)

Return a new instance of the *FTP* class. When *host* is given, the method call `connect(host)` is made. When *user* is given, additionally the method call `login(user, passwd, acct)` is made (where *passwd* and *acct* default to the empty string when not given). The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if is not specified, the global default timeout setting will be used). *source_address* is a 2-tuple `(host, port)` for the socket to bind to as its source address before connecting.

The *FTP* class supports the `with` statement, e.g.:

```
>>> from ftplib import FTP
>>> with FTP("ftp1.at.proftpd.org") as ftp:
...     ftp.login()
...     ftp.dir()
...
'230 Anonymous login ok, restrictions apply.'
dr-xr-xr-x   9 ftp      ftp           154 May  6 10:43 .
dr-xr-xr-x   9 ftp      ftp           154 May  6 10:43 ..
dr-xr-xr-x   5 ftp      ftp          4096 May  6 10:43 CentOS
dr-xr-xr-x   3 ftp      ftp            18 Jul 10  2008 Fedora
>>>
```

Changed in version 3.2: Support for the `with` statement was added.

Changed in version 3.3: *source_address* parameter was added.

class ftplib.FTP_TLS(*host=''*, *user=''*, *passwd=''*, *acct=''*, *keyfile=None*, *certfile=None*, *context=None*, *timeout=None*, *source_address=None*)

A *FTP* subclass which adds TLS support to FTP as described in **RFC 4217**. Connect as usual to port 21 implicitly securing the FTP control connection before authenticating. Securing the data connection requires the user to explicitly ask for it by calling the *prot_p()* method. *context* is a *ssl.SSLContext* object which allows bundling SSL configuration options, certificates and private keys into a single (potentially long-lived) structure. Please read *Security considerations* for best practices.

keyfile and *certfile* are a legacy alternative to *context* – they can point to PEM-formatted private key and certificate chain files (respectively) for the SSL connection.

New in version 3.2.

Changed in version 3.3: *source_address* parameter was added.

Changed in version 3.4: The class now supports hostname check with *ssl.SSLContext.check_hostname* and *Server Name Indication* (see *ssl.HAS_SNI*).

Deprecated since version 3.6: *keyfile* and *certfile* are deprecated in favor of *context*. Please use *ssl.SSLContext.load_cert_chain()* instead, or let *ssl.create_default_context()* select the system's trusted CA certificates for you.

Here's a sample session using the *FTP_TLS* class:

```
>>> ftps = FTP_TLS('ftp.pureftpd.org')
>>> ftps.login()
'230 Anonymous user logged in'
>>> ftps.prot_p()
'200 Data protection level set to "private"'
>>> ftps.nlst()
['6jack', 'OpenBSD', 'antilink', 'blogbench', 'bsdcam', 'clockspeed', 'djbdns-jedi', 'docs',
↪'eaccelerator-jedi', 'favicon.ico', 'francotone', 'fugu', 'ignore', 'libpuzzle', 'metalog',
↪'minidentd', 'misc', 'mysql-udf-global-user-variables', 'php-jenkins-hash', 'php-skein-hash
↪', 'php-webdav', 'phpaudit', 'phpbench', 'pincaster', 'ping', 'posto', 'pub', 'public',
↪'public_keys', 'pure-ftpd', 'qscan', 'qtc', 'sharedance', 'skycache', 'sound', 'tmp', 'ucarp
↪']
```

exception ftplib.error_reply

Exception raised when an unexpected reply is received from the server.

exception ftplib.error_temp

Exception raised when an error code signifying a temporary error (response codes in the range 400–499) is received.

exception ftplib.error_perm

Exception raised when an error code signifying a permanent error (response codes in the range 500–599)

is received.

exception ftplib.error_proto
Exception raised when a reply is received from the server that does not fit the response specifications of the File Transfer Protocol, i.e. begin with a digit in the range 1–5.

ftplib.all_errors
The set of all exceptions (as a tuple) that methods of *FTP* instances may raise as a result of problems with the FTP connection (as opposed to programming errors made by the caller). This set includes the four exceptions listed above as well as *OSError*.

See also:

Module *netrc* Parser for the `.netrc` file format. The file `.netrc` is typically used by FTP clients to load user authentication information before prompting the user.

22.13.1 FTP Objects

Several methods are available in two flavors: one for handling text files and another for binary files. These are named for the command which is used followed by `lines` for the text version or `binary` for the binary version.

FTP instances have the following methods:

FTP.set_debuglevel(*level*)
Set the instance's debugging level. This controls the amount of debugging output printed. The default, `0`, produces no debugging output. A value of `1` produces a moderate amount of debugging output, generally a single line per request. A value of `2` or higher produces the maximum amount of debugging output, logging each line sent and received on the control connection.

FTP.connect(*host=''*, *port=0*, *timeout=None*, *source_address=None*)
Connect to the given host and port. The default port number is `21`, as specified by the FTP protocol specification. It is rarely needed to specify a different port number. This function should be called only once for each instance; it should not be called at all if a host was given when the instance was created. All other methods can only be used after a connection has been made. The optional *timeout* parameter specifies a timeout in seconds for the connection attempt. If no *timeout* is passed, the global default timeout setting will be used. *source_address* is a 2-tuple `(host, port)` for the socket to bind to as its source address before connecting.

Changed in version 3.3: *source_address* parameter was added.

FTP.getwelcome()
Return the welcome message sent by the server in reply to the initial connection. (This message sometimes contains disclaimers or help information that may be relevant to the user.)

FTP.login(*user='anonymous'*, *passwd=''*, *acct=''*)
Log in as the given *user*. The *passwd* and *acct* parameters are optional and default to the empty string. If no *user* is specified, it defaults to `'anonymous'`. If *user* is `'anonymous'`, the default *passwd* is `'anonymous@'`. This function should be called only once for each instance, after a connection has been established; it should not be called at all if a host and user were given when the instance was created. Most FTP commands are only allowed after the client has logged in. The *acct* parameter supplies "accounting information"; few systems implement this.

FTP.abort()
Abort a file transfer that is in progress. Using this does not always work, but it's worth a try.

FTP.sendcmd(*cmd*)
Send a simple command string to the server and return the response string.

FTP.**voidcmd**(*cmd*)
Send a simple command string to the server and handle the response. Return nothing if a response code corresponding to success (codes in the range 200–299) is received. Raise *error_reply* otherwise.

FTP.**retrbinary**(*cmd*, *callback*, *blocksize=8192*, *rest=None*)
Retrieve a file in binary transfer mode. *cmd* should be an appropriate `RETR` command: `'RETR filename'`. The *callback* function is called for each block of data received, with a single bytes argument giving the data block. The optional *blocksize* argument specifies the maximum chunk size to read on the low-level socket object created to do the actual transfer (which will also be the largest size of the data blocks passed to *callback*). A reasonable default is chosen. *rest* means the same thing as in the *transfercmd()* method.

FTP.**retrlines**(*cmd*, *callback=None*)
Retrieve a file or directory listing in ASCII transfer mode. *cmd* should be an appropriate `RETR` command (see *retrbinary()*) or a command such as `LIST` or `NLST` (usually just the string `'LIST'`). `LIST` retrieves a list of files and information about those files. `NLST` retrieves a list of file names. The *callback* function is called for each line with a string argument containing the line with the trailing CRLF stripped. The default *callback* prints the line to `sys.stdout`.

FTP.**set_pasv**(*val*)
Enable "passive" mode if *val* is true, otherwise disable passive mode. Passive mode is on by default.

FTP.**storbinary**(*cmd*, *fp*, *blocksize=8192*, *callback=None*, *rest=None*)
Store a file in binary transfer mode. *cmd* should be an appropriate `STOR` command: `"STOR filename"`. *fp* is a *file object* (opened in binary mode) which is read until EOF using its `read()` method in blocks of size *blocksize* to provide the data to be stored. The *blocksize* argument defaults to 8192. *callback* is an optional single parameter callable that is called on each block of data after it is sent. *rest* means the same thing as in the *transfercmd()* method.

Changed in version 3.2: *rest* parameter added.

FTP.**storlines**(*cmd*, *fp*, *callback=None*)
Store a file in ASCII transfer mode. *cmd* should be an appropriate `STOR` command (see *storbinary()*). Lines are read until EOF from the *file object* *fp* (opened in binary mode) using its *readline()* method to provide the data to be stored. *callback* is an optional single parameter callable that is called on each line after it is sent.

FTP.**transfercmd**(*cmd*, *rest=None*)
Initiate a transfer over the data connection. If the transfer is active, send an `EPRT` or `PORT` command and the transfer command specified by *cmd*, and accept the connection. If the server is passive, send an `EPSV` or `PASV` command, connect to it, and start the transfer command. Either way, return the socket for the connection.

If optional *rest* is given, a `REST` command is sent to the server, passing *rest* as an argument. *rest* is usually a byte offset into the requested file, telling the server to restart sending the file's bytes at the requested offset, skipping over the initial bytes. Note however that **RFC 959** requires only that *rest* be a string containing characters in the printable range from ASCII code 33 to ASCII code 126. The *transfercmd()* method, therefore, converts *rest* to a string, but no check is performed on the string's contents. If the server does not recognize the `REST` command, an *error_reply* exception will be raised. If this happens, simply call *transfercmd()* without a *rest* argument.

FTP.**ntransfercmd**(*cmd*, *rest=None*)
Like *transfercmd()*, but returns a tuple of the data connection and the expected size of the data. If the expected size could not be computed, `None` will be returned as the expected size. *cmd* and *rest* means the same thing as in *transfercmd()*.

FTP.**mlsd**(*path=""*, *facts=[]*)
List a directory in a standardized format by using `MLSD` command (**RFC 3659**). If *path* is omitted the current directory is assumed. *facts* is a list of strings representing the type of information desired (e.g. `["type", "size", "perm"]`). Return a generator object yielding a tuple of two elements for

every file found in path. First element is the file name, the second one is a dictionary containing facts about the file name. Content of this dictionary might be limited by the *facts* argument but server is not guaranteed to return all requested facts.

New in version 3.3.

FTP.**nlst**(*argument*[, *...*])
Return a list of file names as returned by the NLST command. The optional *argument* is a directory to list (default is the current server directory). Multiple arguments can be used to pass non-standard options to the NLST command.

Note: If your server supports the command, *mlsd()* offers a better API.

FTP.**dir**(*argument*[, *...*])
Produce a directory listing as returned by the LIST command, printing it to standard output. The optional *argument* is a directory to list (default is the current server directory). Multiple arguments can be used to pass non-standard options to the LIST command. If the last argument is a function, it is used as a *callback* function as for *retrlines()*; the default prints to sys.stdout. This method returns None.

Note: If your server supports the command, *mlsd()* offers a better API.

FTP.**rename**(*fromname*, *toname*)
Rename file *fromname* on the server to *toname*.

FTP.**delete**(*filename*)
Remove the file named *filename* from the server. If successful, returns the text of the response, otherwise raises *error_perm* on permission errors or *error_reply* on other errors.

FTP.**cwd**(*pathname*)
Set the current directory on the server.

FTP.**mkd**(*pathname*)
Create a new directory on the server.

FTP.**pwd**()
Return the pathname of the current directory on the server.

FTP.**rmd**(*dirname*)
Remove the directory named *dirname* on the server.

FTP.**size**(*filename*)
Request the size of the file named *filename* on the server. On success, the size of the file is returned as an integer, otherwise None is returned. Note that the SIZE command is not standardized, but is supported by many common server implementations.

FTP.**quit**()
Send a QUIT command to the server and close the connection. This is the "polite" way to close a connection, but it may raise an exception if the server responds with an error to the QUIT command. This implies a call to the *close()* method which renders the *FTP* instance useless for subsequent calls (see below).

FTP.**close**()
Close the connection unilaterally. This should not be applied to an already closed connection such as after a successful call to *quit()*. After this call the *FTP* instance should not be used any more (after a call to *close()* or *quit()* you cannot reopen the connection by issuing another *login()* method).

22.13.2 FTP_TLS Objects

FTP_TLS class inherits from *FTP*, defining these additional objects:

FTP_TLS.ssl_version
The SSL version to use (defaults to *ssl.PROTOCOL_SSLv23*).

FTP_TLS.auth()
Set up a secure control connection by using TLS or SSL, depending on what is specified in the *ssl_version* attribute.

Changed in version 3.4: The method now supports hostname check with *ssl.SSLContext.check_hostname* and *Server Name Indication* (see *ssl.HAS_SNI*).

FTP_TLS.ccc()
Revert control channel back to plaintext. This can be useful to take advantage of firewalls that know how to handle NAT with non-secure FTP without opening fixed ports.

New in version 3.3.

FTP_TLS.prot_p()
Set up secure data connection.

FTP_TLS.prot_c()
Set up clear text data connection.

22.14 poplib — POP3 protocol client

Source code: Lib/poplib.py

This module defines a class, *POP3*, which encapsulates a connection to a POP3 server and implements the protocol as defined in **RFC 1939**. The *POP3* class supports both the minimal and optional command sets from **RFC 1939**. The *POP3* class also supports the `STLS` command introduced in **RFC 2595** to enable encrypted communication on an already established connection.

Additionally, this module provides a class *POP3_SSL*, which provides support for connecting to POP3 servers that use SSL as an underlying protocol layer.

Note that POP3, though widely supported, is obsolescent. The implementation quality of POP3 servers varies widely, and too many are quite poor. If your mailserver supports IMAP, you would be better off using the *imaplib.IMAP4* class, as IMAP servers tend to be better implemented.

The *poplib* module provides two classes:

class poplib.POP3(*host*, *port=POP3_PORT*[, *timeout*])
This class implements the actual POP3 protocol. The connection is created when the instance is initialized. If *port* is omitted, the standard POP3 port (110) is used. The optional *timeout* parameter specifies a timeout in seconds for the connection attempt (if not specified, the global default timeout setting will be used).

class poplib.POP3_SSL(*host*, *port=POP3_SSL_PORT*, *keyfile=None*, *certfile=None*, *timeout=None*, *context=None*)
This is a subclass of *POP3* that connects to the server over an SSL encrypted socket. If *port* is not specified, 995, the standard POP3-over-SSL port is used. *timeout* works as in the *POP3* constructor. *context* is an optional *ssl.SSLContext* object which allows bundling SSL configuration options, certificates and private keys into a single (potentially long-lived) structure. Please read *Security considerations* for best practices.

keyfile and *certfile* are a legacy alternative to *context* - they can point to PEM-formatted private key and certificate chain files, respectively, for the SSL connection.

Changed in version 3.2: *context* parameter added.

Changed in version 3.4: The class now supports hostname check with *ssl.SSLContext.check_hostname* and *Server Name Indication* (see *ssl.HAS_SNI*).

Deprecated since version 3.6: *keyfile* and *certfile* are deprecated in favor of *context*. Please use *ssl.SSLContext.load_cert_chain()* instead, or let *ssl.create_default_context()* select the system's trusted CA certificates for you.

One exception is defined as an attribute of the *poplib* module:

exception poplib.**error_proto**
Exception raised on any errors from this module (errors from *socket* module are not caught). The reason for the exception is passed to the constructor as a string.

See also:

Module *imaplib* The standard Python IMAP module.

Frequently Asked Questions About Fetchmail The FAQ for the **fetchmail** POP/IMAP client collects information on POP3 server variations and RFC noncompliance that may be useful if you need to write an application based on the POP protocol.

22.14.1 POP3 Objects

All POP3 commands are represented by methods of the same name, in lower-case; most return the response text sent by the server.

An *POP3* instance has the following methods:

POP3.**set_debuglevel**(*level*)
Set the instance's debugging level. This controls the amount of debugging output printed. The default, `0`, produces no debugging output. A value of `1` produces a moderate amount of debugging output, generally a single line per request. A value of `2` or higher produces the maximum amount of debugging output, logging each line sent and received on the control connection.

POP3.**getwelcome**()
Returns the greeting string sent by the POP3 server.

POP3.**capa**()
Query the server's capabilities as specified in **RFC 2449**. Returns a dictionary in the form `{'name': ['param'...]}`.

New in version 3.4.

POP3.**user**(*username*)
Send user command, response should indicate that a password is required.

POP3.**pass_**(*password*)
Send password, response includes message count and mailbox size. Note: the mailbox on the server is locked until `quit()` is called.

POP3.**apop**(*user*, *secret*)
Use the more secure APOP authentication to log into the POP3 server.

POP3.**rpop**(*user*)
Use RPOP authentication (similar to UNIX r-commands) to log into POP3 server.

POP3.**stat**()
Get mailbox status. The result is a tuple of 2 integers: `(message count, mailbox size)`.

POP3.**list**([*which*])
Request message list, result is in the form `(response, ['mesg_num octets', ...], octets)`. If *which* is set, it is the message to list.

POP3.**retr**(*which*)
Retrieve whole message number *which*, and set its seen flag. Result is in form `(response, ['line', ...], octets)`.

POP3.**dele**(*which*)
Flag message number *which* for deletion. On most servers deletions are not actually performed until QUIT (the major exception is Eudora QPOP, which deliberately violates the RFCs by doing pending deletes on any disconnect).

POP3.**rset**()
Remove any deletion marks for the mailbox.

POP3.**noop**()
Do nothing. Might be used as a keep-alive.

POP3.**quit**()
Signoff: commit changes, unlock mailbox, drop connection.

POP3.**top**(*which*, *howmuch*)
Retrieves the message header plus *howmuch* lines of the message after the header of message number *which*. Result is in form `(response, ['line', ...], octets)`.

The POP3 TOP command this method uses, unlike the RETR command, doesn't set the message's seen flag; unfortunately, TOP is poorly specified in the RFCs and is frequently broken in off-brand servers. Test this method by hand against the POP3 servers you will use before trusting it.

POP3.**uidl**(*which=None*)
Return message digest (unique id) list. If *which* is specified, result contains the unique id for that message in the form `'response mesgnum uid`, otherwise result is list `(response, ['mesgnum uid', ...], octets)`.

POP3.**utf8**()
Try to switch to UTF-8 mode. Returns the server response if successful, raises *error_proto* if not. Specified in **RFC 6856**.

New in version 3.5.

POP3.**stls**(*context=None*)
Start a TLS session on the active connection as specified in **RFC 2595**. This is only allowed before user authentication

context parameter is a *ssl.SSLContext* object which allows bundling SSL configuration options, certificates and private keys into a single (potentially long-lived) structure. Please read *Security considerations* for best practices.

This method supports hostname checking via *ssl.SSLContext.check_hostname* and *Server Name Indication* (see *ssl.HAS_SNI*).

New in version 3.4.

Instances of *POP3_SSL* have no additional methods. The interface of this subclass is identical to its parent.

22.14.2 POP3 Example

Here is a minimal example (without error checking) that opens a mailbox and retrieves and prints all messages:

```
import getpass, poplib

M = poplib.POP3('localhost')
M.user(getpass.getuser())
M.pass_(getpass.getpass())
numMessages = len(M.list()[1])
for i in range(numMessages):
    for j in M.retr(i+1)[1]:
        print(j)
```

At the end of the module, there is a test section that contains a more extensive example of usage.

22.15 imaplib — IMAP4 protocol client

Source code: Lib/imaplib.py

This module defines three classes, *IMAP4*, *IMAP4_SSL* and *IMAP4_stream*, which encapsulate a connection to an IMAP4 server and implement a large subset of the IMAP4rev1 client protocol as defined in **RFC 2060**. It is backward compatible with IMAP4 (**RFC 1730**) servers, but note that the `STATUS` command is not supported in IMAP4.

Three classes are provided by the *imaplib* module, *IMAP4* is the base class:

class imaplib.**IMAP4**(*host=''*, *port=IMAP4_PORT*)

This class implements the actual IMAP4 protocol. The connection is created and protocol version (IMAP4 or IMAP4rev1) is determined when the instance is initialized. If *host* is not specified, `''` (the local host) is used. If *port* is omitted, the standard IMAP4 port (143) is used.

The *IMAP4* class supports the `with` statement. When used like this, the IMAP4 `LOGOUT` command is issued automatically when the `with` statement exits. E.g.:

```
>>> from imaplib import IMAP4
>>> with IMAP4("domain.org") as M:
...     M.noop()
...
('OK', [b'Nothing Accomplished. d25if65hy903weo.87'])
```

Changed in version 3.5: Support for the `with` statement was added.

Three exceptions are defined as attributes of the *IMAP4* class:

exception IMAP4.**error**

Exception raised on any errors. The reason for the exception is passed to the constructor as a string.

exception IMAP4.**abort**

IMAP4 server errors cause this exception to be raised. This is a sub-class of *IMAP4.error*. Note that closing the instance and instantiating a new one will usually allow recovery from this exception.

exception IMAP4.**readonly**

This exception is raised when a writable mailbox has its status changed by the server. This is a sub-class of *IMAP4.error*. Some other client now has write permission, and the mailbox will need to be re-opened to re-obtain write permission.

There's also a subclass for secure connections:

class imaplib.**IMAP4_SSL**(*host=''*, *port=IMAP4_SSL_PORT*, *keyfile=None*, *certfile=None*, *ssl_context=None*)

This is a subclass derived from *IMAP4* that connects over an SSL encrypted socket (to use this class

you need a socket module that was compiled with SSL support). If *host* is not specified, `''` (the local host) is used. If *port* is omitted, the standard IMAP4-over-SSL port (993) is used. *ssl_context* is a *ssl.SSLContext* object which allows bundling SSL configuration options, certificates and private keys into a single (potentially long-lived) structure. Please read *Security considerations* for best practices.

keyfile and *certfile* are a legacy alternative to *ssl_context* - they can point to PEM-formatted private key and certificate chain files for the SSL connection. Note that the *keyfile*/*certfile* parameters are mutually exclusive with *ssl_context*, a *ValueError* is raised if *keyfile*/*certfile* is provided along with *ssl_context*.

Changed in version 3.3: *ssl_context* parameter added.

Changed in version 3.4: The class now supports hostname check with *ssl.SSLContext.check_hostname* and *Server Name Indication* (see *ssl.HAS_SNI*).

Deprecated since version 3.6: *keyfile* and *certfile* are deprecated in favor of *ssl_context*. Please use *ssl.SSLContext.load_cert_chain()* instead, or let *ssl.create_default_context()* select the system's trusted CA certificates for you.

The second subclass allows for connections created by a child process:

class imaplib.**IMAP4_stream**(*command*)
This is a subclass derived from *IMAP4* that connects to the `stdin/stdout` file descriptors created by passing *command* to `subprocess.Popen()`.

The following utility functions are defined:

imaplib.**Internaldate2tuple**(*datestr*)
Parse an IMAP4 `INTERNALDATE` string and return corresponding local time. The return value is a *time.struct_time* tuple or `None` if the string has wrong format.

imaplib.**Int2AP**(*num*)
Converts an integer into a string representation using characters from the set [`A` .. `P`].

imaplib.**ParseFlags**(*flagstr*)
Converts an IMAP4 `FLAGS` response to a tuple of individual flags.

imaplib.**Time2Internaldate**(*date_time*)
Convert *date_time* to an IMAP4 `INTERNALDATE` representation. The return value is a string in the form: `"DD-Mmm-YYYY HH:MM:SS +HHMM"` (including double-quotes). The *date_time* argument can be a number (int or float) representing seconds since epoch (as returned by *time.time()*), a 9-tuple representing local time an instance of *time.struct_time* (as returned by *time.localtime()*), an aware instance of *datetime.datetime*, or a double-quoted string. In the last case, it is assumed to already be in the correct format.

Note that IMAP4 message numbers change as the mailbox changes; in particular, after an `EXPUNGE` command performs deletions the remaining messages are renumbered. So it is highly advisable to use UIDs instead, with the UID command.

At the end of the module, there is a test section that contains a more extensive example of usage.

See also:

Documents describing the protocol, and sources and binaries for servers implementing it, can all be found at the University of Washington's *IMAP Information Center* (https://www.washington.edu/imap/).

22.15.1 IMAP4 Objects

All IMAP4rev1 commands are represented by methods of the same name, either upper-case or lower-case.

All arguments to commands are converted to strings, except for `AUTHENTICATE`, and the last argument to `APPEND` which is passed as an IMAP4 literal. If necessary (the string contains IMAP4 protocol-sensitive characters and isn't enclosed with either parentheses or double quotes) each string is quoted. However, the

password argument to the LOGIN command is always quoted. If you want to avoid having an argument string quoted (eg: the *flags* argument to STORE) then enclose the string in parentheses (eg: r'(\Deleted)').

Each command returns a tuple: (type, [data, ...]) where *type* is usually 'OK' or 'NO', and *data* is either the text from the command response, or mandated results from the command. Each *data* is either a string, or a tuple. If a tuple, then the first part is the header of the response, and the second part contains the data (ie: 'literal' value).

The *message_set* options to commands below is a string specifying one or more messages to be acted upon. It may be a simple message number ('1'), a range of message numbers ('2:4'), or a group of non-contiguous ranges separated by commas ('1:3,6:9'). A range can contain an asterisk to indicate an infinite upper bound ('3:*').

An *IMAP4* instance has the following methods:

IMAP4.**append**(*mailbox*, *flags*, *date_time*, *message*)
Append *message* to named mailbox.

IMAP4.**authenticate**(*mechanism*, *authobject*)
Authenticate command — requires response processing.

mechanism specifies which authentication mechanism is to be used - it should appear in the instance variable capabilities in the form AUTH=mechanism.

authobject must be a callable object:

```
data = authobject(response)
```

It will be called to process server continuation responses; the *response* argument it is passed will be bytes. It should return bytes *data* that will be base64 encoded and sent to the server. It should return None if the client abort response * should be sent instead.

Changed in version 3.5: string usernames and passwords are now encoded to utf-8 instead of being limited to ASCII.

IMAP4.**check**()
Checkpoint mailbox on server.

IMAP4.**close**()
Close currently selected mailbox. Deleted messages are removed from writable mailbox. This is the recommended command before LOGOUT.

IMAP4.**copy**(*message_set*, *new_mailbox*)
Copy *message_set* messages onto end of *new_mailbox*.

IMAP4.**create**(*mailbox*)
Create new mailbox named *mailbox*.

IMAP4.**delete**(*mailbox*)
Delete old mailbox named *mailbox*.

IMAP4.**deleteacl**(*mailbox*, *who*)
Delete the ACLs (remove any rights) set for who on mailbox.

IMAP4.**enable**(*capability*)
Enable *capability* (see **RFC 5161**). Most capabilities do not need to be enabled. Currently only the UTF8=ACCEPT capability is supported (see **RFC 6855**).

New in version 3.5: The *enable()* method itself, and **RFC 6855** support.

IMAP4.**expunge**()
Permanently remove deleted items from selected mailbox. Generates an EXPUNGE response for each deleted message. Returned data contains a list of EXPUNGE message numbers in order received.

IMAP4.**fetch**(*message_set*, *message_parts*)
Fetch (parts of) messages. *message_parts* should be a string of message part names enclosed within parentheses, eg: `"(UID BODY[TEXT])"`. Returned data are tuples of message part envelope and data.

IMAP4.**getacl**(*mailbox*)
Get the ACLs for *mailbox*. The method is non-standard, but is supported by the `Cyrus` server.

IMAP4.**getannotation**(*mailbox*, *entry*, *attribute*)
Retrieve the specified `ANNOTATION`s for *mailbox*. The method is non-standard, but is supported by the `Cyrus` server.

IMAP4.**getquota**(*root*)
Get the `quota` *root*'s resource usage and limits. This method is part of the IMAP4 QUOTA extension defined in rfc2087.

IMAP4.**getquotaroot**(*mailbox*)
Get the list of `quota roots` for the named *mailbox*. This method is part of the IMAP4 QUOTA extension defined in rfc2087.

IMAP4.**list**(*[directory[, pattern]]*)
List mailbox names in *directory* matching *pattern*. *directory* defaults to the top-level mail folder, and *pattern* defaults to match anything. Returned data contains a list of `LIST` responses.

IMAP4.**login**(*user*, *password*)
Identify the client using a plaintext password. The *password* will be quoted.

IMAP4.**login_cram_md5**(*user*, *password*)
Force use of `CRAM-MD5` authentication when identifying the client to protect the password. Will only work if the server `CAPABILITY` response includes the phrase `AUTH=CRAM-MD5`.

IMAP4.**logout**()
Shutdown connection to server. Returns server `BYE` response.

IMAP4.**lsub**(*directory='""'*, *pattern='*'*)
List subscribed mailbox names in directory matching pattern. *directory* defaults to the top level directory and *pattern* defaults to match any mailbox. Returned data are tuples of message part envelope and data.

IMAP4.**myrights**(*mailbox*)
Show my ACLs for a mailbox (i.e. the rights that I have on mailbox).

IMAP4.**namespace**()
Returns IMAP namespaces as defined in **RFC 2342**.

IMAP4.**noop**()
Send `NOOP` to server.

IMAP4.**open**(*host*, *port*)
Opens socket to *port* at *host*. This method is implicitly called by the *IMAP4* constructor. The connection objects established by this method will be used in the *IMAP4.read()*, *IMAP4.readline()*, *IMAP4.send()*, and *IMAP4.shutdown()* methods. You may override this method.

IMAP4.**partial**(*message_num*, *message_part*, *start*, *length*)
Fetch truncated part of a message. Returned data is a tuple of message part envelope and data.

IMAP4.**proxyauth**(*user*)
Assume authentication as *user*. Allows an authorised administrator to proxy into any user's mailbox.

IMAP4.**read**(*size*)
Reads *size* bytes from the remote server. You may override this method.

IMAP4.**readline**()
Reads one line from the remote server. You may override this method.

IMAP4.**recent**()
Prompt server for an update. Returned data is `None` if no new messages, else value of `RECENT` response.

IMAP4.**rename**(*oldmailbox*, *newmailbox*)
Rename mailbox named *oldmailbox* to *newmailbox*.

IMAP4.**response**(*code*)
Return data for response *code* if received, or `None`. Returns the given code, instead of the usual type.

IMAP4.**search**(*charset*, *criterion*[, ...])
Search mailbox for matching messages. *charset* may be `None`, in which case no `CHARSET` will be specified in the request to the server. The IMAP protocol requires that at least one criterion be specified; an exception will be raised when the server returns an error. *charset* must be `None` if the `UTF8=ACCEPT` capability was enabled using the *enable()* command.

Example:

```
# M is a connected IMAP4 instance...
typ, msgnums = M.search(None, 'FROM', '"LDJ"')

# or:
typ, msgnums = M.search(None, '(FROM "LDJ")')
```

IMAP4.**select**(*mailbox='INBOX'*, *readonly=False*)
Select a mailbox. Returned data is the count of messages in *mailbox* (`EXISTS` response). The default *mailbox* is `'INBOX'`. If the *readonly* flag is set, modifications to the mailbox are not allowed.

IMAP4.**send**(*data*)
Sends `data` to the remote server. You may override this method.

IMAP4.**setacl**(*mailbox*, *who*, *what*)
Set an `ACL` for *mailbox*. The method is non-standard, but is supported by the `Cyrus` server.

IMAP4.**setannotation**(*mailbox*, *entry*, *attribute*[, ...])
Set `ANNOTATION`s for *mailbox*. The method is non-standard, but is supported by the `Cyrus` server.

IMAP4.**setquota**(*root*, *limits*)
Set the `quota` *root*'s resource *limits*. This method is part of the IMAP4 QUOTA extension defined in rfc2087.

IMAP4.**shutdown**()
Close connection established in `open`. This method is implicitly called by *IMAP4.logout()*. You may override this method.

IMAP4.**socket**()
Returns socket instance used to connect to server.

IMAP4.**sort**(*sort_criteria*, *charset*, *search_criterion*[, ...])
The `sort` command is a variant of `search` with sorting semantics for the results. Returned data contains a space separated list of matching message numbers.

Sort has two arguments before the *search_criterion* argument(s); a parenthesized list of *sort_criteria*, and the searching *charset*. Note that unlike `search`, the searching *charset* argument is mandatory. There is also a `uid sort` command which corresponds to `sort` the way that `uid search` corresponds to `search`. The `sort` command first searches the mailbox for messages that match the given searching criteria using the charset argument for the interpretation of strings in the searching criteria. It then returns the numbers of matching messages.

This is an `IMAP4rev1` extension command.

IMAP4.**starttls**(*ssl_context=None*)
Send a `STARTTLS` command. The *ssl_context* argument is optional and should be a *ssl.SSLContext*

object. This will enable encryption on the IMAP connection. Please read *Security considerations* for best practices.

New in version 3.2.

Changed in version 3.4: The method now supports hostname check with *ssl.SSLContext.check_hostname* and *Server Name Indication* (see *ssl.HAS_SNI*).

IMAP4.**status**(*mailbox*, *names*)
Request named status conditions for *mailbox*.

IMAP4.**store**(*message_set*, *command*, *flag_list*)
Alters flag dispositions for messages in mailbox. *command* is specified by section 6.4.6 of **RFC 2060** as being one of "FLAGS", "+FLAGS", or "-FLAGS", optionally with a suffix of ".SILENT".

For example, to set the delete flag on all messages:

```
typ, data = M.search(None, 'ALL')
for num in data[0].split():
   M.store(num, '+FLAGS', '\\Deleted')
M.expunge()
```

Note: Creating flags containing '\]' (for example: "[test]") violates **RFC 3501** (the IMAP protocol). However, imaplib has historically allowed creation of such tags, and popular IMAP servers, such as Gmail, accept and produce such flags. There are non-Python programs which also create such tags. Although it is an RFC violation and IMAP clients and servers are supposed to be strict, imaplib nonetheless continues to allow such tags to be created for backward compatibility reasons, and as of python 3.6, handles them if they are sent from the server, since this improves real-world compatibility.

IMAP4.**subscribe**(*mailbox*)
Subscribe to new mailbox.

IMAP4.**thread**(*threading_algorithm*, *charset*, *search_criterion*[, *...*])
The **thread** command is a variant of **search** with threading semantics for the results. Returned data contains a space separated list of thread members.

Thread members consist of zero or more messages numbers, delimited by spaces, indicating successive parent and child.

Thread has two arguments before the *search_criterion* argument(s); a *threading_algorithm*, and the searching *charset*. Note that unlike **search**, the searching *charset* argument is mandatory. There is also a **uid thread** command which corresponds to **thread** the way that **uid search** corresponds to **search**. The **thread** command first searches the mailbox for messages that match the given searching criteria using the charset argument for the interpretation of strings in the searching criteria. It then returns the matching messages threaded according to the specified threading algorithm.

This is an **IMAP4rev1** extension command.

IMAP4.**uid**(*command*, *arg*[, *...*])
Execute command args with messages identified by UID, rather than message number. Returns response appropriate to command. At least one argument must be supplied; if none are provided, the server will return an error and an exception will be raised.

IMAP4.**unsubscribe**(*mailbox*)
Unsubscribe from old mailbox.

IMAP4.**xatom**(*name*[, *...*])
Allow simple extension commands notified by server in **CAPABILITY** response.

The following attributes are defined on instances of *IMAP4*:

`IMAP4.PROTOCOL_VERSION`
: The most recent supported protocol in the `CAPABILITY` response from the server.

`IMAP4.debug`
: Integer value to control debugging output. The initialize value is taken from the module variable `Debug`. Values greater than three trace each command.

`IMAP4.utf8_enabled`
: Boolean value that is normally `False`, but is set to `True` if an *enable()* command is successfully issued for the `UTF8=ACCEPT` capability.

  New in version 3.5.

22.15.2 IMAP4 Example

Here is a minimal example (without error checking) that opens a mailbox and retrieves and prints all messages:

```
import getpass, imaplib

M = imaplib.IMAP4()
M.login(getpass.getuser(), getpass.getpass())
M.select()
typ, data = M.search(None, 'ALL')
for num in data[0].split():
    typ, data = M.fetch(num, '(RFC822)')
    print('Message %s\n%s\n' % (num, data[0][1]))
M.close()
M.logout()
```

22.16 `nntplib` — NNTP protocol client

Source code: Lib/nntplib.py

This module defines the class *NNTP* which implements the client side of the Network News Transfer Protocol. It can be used to implement a news reader or poster, or automated news processors. It is compatible with **RFC 3977** as well as the older **RFC 977** and **RFC 2980**.

Here are two small examples of how it can be used. To list some statistics about a newsgroup and print the subjects of the last 10 articles:

```
>>> s = nntplib.NNTP('news.gmane.org')
>>> resp, count, first, last, name = s.group('gmane.comp.python.committers')
>>> print('Group', name, 'has', count, 'articles, range', first, 'to', last)
Group gmane.comp.python.committers has 1096 articles, range 1 to 1096
>>> resp, overviews = s.over((last - 9, last))
>>> for id, over in overviews:
...     print(id, nntplib.decode_header(over['subject']))
...
1087 Re: Commit privileges for Łukasz Langa
1088 Re: 3.2 alpha 2 freeze
1089 Re: 3.2 alpha 2 freeze
1090 Re: Commit privileges for Łukasz Langa
1091 Re: Commit privileges for Łukasz Langa
```

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```
1092 Updated ssh key
1093 Re: Updated ssh key
1094 Re: Updated ssh key
1095 Hello fellow committers!
1096 Re: Hello fellow committers!
>>> s.quit()
'205 Bye!'
```

To post an article from a binary file (this assumes that the article has valid headers, and that you have right to post on the particular newsgroup):

```
>>> s = nntplib.NNTP('news.gmane.org')
>>> f = open('article.txt', 'rb')
>>> s.post(f)
'240 Article posted successfully.'
>>> s.quit()
'205 Bye!'
```

The module itself defines the following classes:

class nntplib.NNTP(*host*, *port=119*, *user=None*, *password=None*, *readermode=None*, *usenetrc=False*[, *timeout*])

Return a new *NNTP* object, representing a connection to the NNTP server running on host *host*, listening at port *port*. An optional *timeout* can be specified for the socket connection. If the optional *user* and *password* are provided, or if suitable credentials are present in `/.netrc` and the optional flag *usenetrc* is true, the `AUTHINFO USER` and `AUTHINFO PASS` commands are used to identify and authenticate the user to the server. If the optional flag *readermode* is true, then a `mode reader` command is sent before authentication is performed. Reader mode is sometimes necessary if you are connecting to an NNTP server on the local machine and intend to call reader-specific commands, such as `group`. If you get unexpected *NNTPPermanentError*s, you might need to set *readermode*. The *NNTP* class supports the `with` statement to unconditionally consume *OSError* exceptions and to close the NNTP connection when done, e.g.:

```
>>> from nntplib import NNTP
>>> with NNTP('news.gmane.org') as n:
...     n.group('gmane.comp.python.committers')
...
('211 1755 1 1755 gmane.comp.python.committers', 1755, 1, 1755, 'gmane.comp.python.committers
↪')
>>>
```

Changed in version 3.2: *usenetrc* is now `False` by default.

Changed in version 3.3: Support for the `with` statement was added.

class nntplib.NNTP_SSL(*host*, *port=563*, *user=None*, *password=None*, *ssl_context=None*, *readermode=None*, *usenetrc=False*[, *timeout*])

Return a new *NNTP_SSL* object, representing an encrypted connection to the NNTP server running on host *host*, listening at port *port*. *NNTP_SSL* objects have the same methods as *NNTP* objects. If *port* is omitted, port 563 (NNTPS) is used. *ssl_context* is also optional, and is a *SSLContext* object. Please read *Security considerations* for best practices. All other parameters behave the same as for *NNTP*.

Note that SSL-on-563 is discouraged per **RFC 4642**, in favor of STARTTLS as described below. However, some servers only support the former.

New in version 3.2.

Changed in version 3.4: The class now supports hostname check with *ssl.SSLContext.check_hostname* and *Server Name Indication* (see *ssl.HAS_SNI*).

exception nntplib.NNTPError
Derived from the standard exception *Exception*, this is the base class for all exceptions raised by the *nntplib* module. Instances of this class have the following attribute:

response
The response of the server if available, as a *str* object.

exception nntplib.NNTPReplyError
Exception raised when an unexpected reply is received from the server.

exception nntplib.NNTPTemporaryError
Exception raised when a response code in the range 400–499 is received.

exception nntplib.NNTPPermanentError
Exception raised when a response code in the range 500–599 is received.

exception nntplib.NNTPProtocolError
Exception raised when a reply is received from the server that does not begin with a digit in the range 1–5.

exception nntplib.NNTPDataError
Exception raised when there is some error in the response data.

22.16.1 NNTP Objects

When connected, *NNTP* and *NNTP_SSL* objects support the following methods and attributes.

Attributes

NNTP.nntp_version
An integer representing the version of the NNTP protocol supported by the server. In practice, this should be `2` for servers advertising **RFC 3977** compliance and `1` for others.

New in version 3.2.

NNTP.nntp_implementation
A string describing the software name and version of the NNTP server, or *None* if not advertised by the server.

New in version 3.2.

Methods

The *response* that is returned as the first item in the return tuple of almost all methods is the server's response: a string beginning with a three-digit code. If the server's response indicates an error, the method raises one of the above exceptions.

Many of the following methods take an optional keyword-only argument *file*. When the *file* argument is supplied, it must be either a *file object* opened for binary writing, or the name of an on-disk file to be written to. The method will then write any data returned by the server (except for the response line and the terminating dot) to the file; any list of lines, tuples or objects that the method normally returns will be empty.

Changed in version 3.2: Many of the following methods have been reworked and fixed, which makes them incompatible with their 3.1 counterparts.

NNTP.quit()
Send a QUIT command and close the connection. Once this method has been called, no other methods of the NNTP object should be called.

NNTP.getwelcome()
Return the welcome message sent by the server in reply to the initial connection. (This message sometimes contains disclaimers or help information that may be relevant to the user.)

NNTP.getcapabilities()
Return the **RFC 3977** capabilities advertised by the server, as a *dict* instance mapping capability names to (possibly empty) lists of values. On legacy servers which don't understand the CAPABILITIES command, an empty dictionary is returned instead.

```
>>> s = NNTP('news.gmane.org')
>>> 'POST' in s.getcapabilities()
True
```

New in version 3.2.

NNTP.login(*user=None*, *password=None*, *usenetrc=True*)
Send AUTHINFO commands with the user name and password. If *user* and *password* are None and *usenetrc* is true, credentials from ~/.netrc will be used if possible.

Unless intentionally delayed, login is normally performed during the *NNTP* object initialization and separately calling this function is unnecessary. To force authentication to be delayed, you must not set *user* or *password* when creating the object, and must set *usenetrc* to False.

New in version 3.2.

NNTP.starttls(*ssl_context=None*)
Send a STARTTLS command. This will enable encryption on the NNTP connection. The *ssl_context* argument is optional and should be a *ssl.SSLContext* object. Please read *Security considerations* for best practices.

Note that this may not be done after authentication information has been transmitted, and authentication occurs by default if possible during a *NNTP* object initialization. See *NNTP.login()* for information on suppressing this behavior.

New in version 3.2.

Changed in version 3.4: The method now supports hostname check with *ssl.SSLContext.check_hostname* and *Server Name Indication* (see *ssl.HAS_SNI*).

NNTP.newgroups(*date*, ***, *file=None*)
Send a NEWGROUPS command. The *date* argument should be a *datetime.date* or *datetime.datetime* object. Return a pair (response, groups) where *groups* is a list representing the groups that are new since the given *date*. If *file* is supplied, though, then *groups* will be empty.

```
>>> from datetime import date, timedelta
>>> resp, groups = s.newgroups(date.today() - timedelta(days=3))
>>> len(groups)
85
>>> groups[0]
GroupInfo(group='gmane.network.tor.devel', last='4', first='1', flag='m')
```

NNTP.newnews(*group*, *date*, ***, *file=None*)
Send a NEWNEWS command. Here, *group* is a group name or '*', and *date* has the same meaning as for *newgroups()*. Return a pair (response, articles) where *articles* is a list of message ids.

This command is frequently disabled by NNTP server administrators.

NNTP.**list**(*group_pattern=None*, *, *file=None*)
Send a `LIST` or `LIST ACTIVE` command. Return a pair `(response, list)` where *list* is a list of tuples representing all the groups available from this NNTP server, optionally matching the pattern string *group_pattern*. Each tuple has the form `(group, last, first, flag)`, where *group* is a group name, *last* and *first* are the last and first article numbers, and *flag* usually takes one of these values:

- `y`: Local postings and articles from peers are allowed.
- `m`: The group is moderated and all postings must be approved.
- `n`: No local postings are allowed, only articles from peers.
- `j`: Articles from peers are filed in the junk group instead.
- `x`: No local postings, and articles from peers are ignored.
- `=foo.bar`: Articles are filed in the `foo.bar` group instead.

If *flag* has another value, then the status of the newsgroup should be considered unknown.

This command can return very large results, especially if *group_pattern* is not specified. It is best to cache the results offline unless you really need to refresh them.

Changed in version 3.2: *group_pattern* was added.

NNTP.**descriptions**(*grouppattern*)
Send a `LIST NEWSGROUPS` command, where *grouppattern* is a wildmat string as specified in **RFC 3977** (it's essentially the same as DOS or UNIX shell wildcard strings). Return a pair `(response, descriptions)`, where *descriptions* is a dictionary mapping group names to textual descriptions.

```
>>> resp, descs = s.descriptions('gmane.comp.python.*')
>>> len(descs)
295
>>> descs.popitem()
('gmane.comp.python.bio.general', 'BioPython discussion list (Moderated)')
```

NNTP.**description**(*group*)
Get a description for a single group *group*. If more than one group matches (if 'group' is a real wildmat string), return the first match. If no group matches, return an empty string.

This elides the response code from the server. If the response code is needed, use *descriptions()*.

NNTP.**group**(*name*)
Send a `GROUP` command, where *name* is the group name. The group is selected as the current group, if it exists. Return a tuple `(response, count, first, last, name)` where *count* is the (estimated) number of articles in the group, *first* is the first article number in the group, *last* is the last article number in the group, and *name* is the group name.

NNTP.**over**(*message_spec*, *, *file=None*)
Send an `OVER` command, or an `XOVER` command on legacy servers. *message_spec* can be either a string representing a message id, or a `(first, last)` tuple of numbers indicating a range of articles in the current group, or a `(first, None)` tuple indicating a range of articles starting from *first* to the last article in the current group, or *None* to select the current article in the current group.

Return a pair `(response, overviews)`. *overviews* is a list of `(article_number, overview)` tuples, one for each article selected by *message_spec*. Each *overview* is a dictionary with the same number of items, but this number depends on the server. These items are either message headers (the key is then the lower-cased header name) or metadata items (the key is then the metadata name prepended with `":"`). The following items are guaranteed to be present by the NNTP specification:

- the `subject`, `from`, `date`, `message-id` and `references` headers
- the `:bytes` metadata: the number of bytes in the entire raw article (including headers and body)
- the `:lines` metadata: the number of lines in the article body

The value of each item is either a string, or *None* if not present.

It is advisable to use the *decode_header()* function on header values when they may contain non-ASCII characters:

```
>>> _, _, first, last, _ = s.group('gmane.comp.python.devel')
>>> resp, overviews = s.over((last, last))
>>> art_num, over = overviews[0]
>>> art_num
117216
>>> list(over.keys())
['xref', 'from', ':lines', ':bytes', 'references', 'date', 'message-id', 'subject']
>>> over['from']
'=?UTF-8?B?Ik1hcnRpbiB2LiBMw7Z3aXMi?= <martin@v.loewis.de>'
>>> nntplib.decode_header(over['from'])
'"Martin v. Löwis" <martin@v.loewis.de>'
```

New in version 3.2.

NNTP.**help**(**, file=None*)
Send a HELP command. Return a pair `(response, list)` where *list* is a list of help strings.

NNTP.**stat**(*message_spec=None*)
Send a STAT command, where *message_spec* is either a message id (enclosed in '<' and '>') or an article number in the current group. If *message_spec* is omitted or *None*, the current article in the current group is considered. Return a triple `(response, number, id)` where *number* is the article number and *id* is the message id.

```
>>> _, _, first, last, _ = s.group('gmane.comp.python.devel')
>>> resp, number, message_id = s.stat(first)
>>> number, message_id
(9099, '<20030112190404.GE29873@epoch.metaslash.com>')
```

NNTP.**next**()
Send a NEXT command. Return as for *stat()*.

NNTP.**last**()
Send a LAST command. Return as for *stat()*.

NNTP.**article**(*message_spec=None, *, file=None*)
Send an ARTICLE command, where *message_spec* has the same meaning as for *stat()*. Return a tuple `(response, info)` where *info* is a *namedtuple* with three attributes *number*, *message_id* and *lines* (in that order). *number* is the article number in the group (or 0 if the information is not available), *message_id* the message id as a string, and *lines* a list of lines (without terminating newlines) comprising the raw message including headers and body.

```
>>> resp, info = s.article('<20030112190404.GE29873@epoch.metaslash.com>')
>>> info.number
0
>>> info.message_id
'<20030112190404.GE29873@epoch.metaslash.com>'
>>> len(info.lines)
65
>>> info.lines[0]
b'Path: main.gmane.org!not-for-mail'
>>> info.lines[1]
b'From: Neal Norwitz <neal@metaslash.com>'
>>> info.lines[-3:]
[b'There is a patch for 2.3 as well as 2.2.', b'', b'Neal']
```

NNTP.**head**(*message_spec=None*, *, *file=None*)
Same as *article()*, but sends a HEAD command. The *lines* returned (or written to *file*) will only contain the message headers, not the body.

NNTP.**body**(*message_spec=None*, *, *file=None*)
Same as *article()*, but sends a BODY command. The *lines* returned (or written to *file*) will only contain the message body, not the headers.

NNTP.**post**(*data*)
Post an article using the POST command. The *data* argument is either a *file object* opened for binary reading, or any iterable of bytes objects (representing raw lines of the article to be posted). It should represent a well-formed news article, including the required headers. The *post()* method automatically escapes lines beginning with . and appends the termination line.

If the method succeeds, the server's response is returned. If the server refuses posting, a *NNTPReplyError* is raised.

NNTP.**ihave**(*message_id*, *data*)
Send an IHAVE command. *message_id* is the id of the message to send to the server (enclosed in '<' and '>'). The *data* parameter and the return value are the same as for *post()*.

NNTP.**date**()
Return a pair (response, date). *date* is a *datetime* object containing the current date and time of the server.

NNTP.**slave**()
Send a SLAVE command. Return the server's *response*.

NNTP.**set_debuglevel**(*level*)
Set the instance's debugging level. This controls the amount of debugging output printed. The default, 0, produces no debugging output. A value of 1 produces a moderate amount of debugging output, generally a single line per request or response. A value of 2 or higher produces the maximum amount of debugging output, logging each line sent and received on the connection (including message text).

The following are optional NNTP extensions defined in **RFC 2980**. Some of them have been superseded by newer commands in **RFC 3977**.

NNTP.**xhdr**(*hdr*, *str*, *, *file=None*)
Send an XHDR command. The *hdr* argument is a header keyword, e.g. 'subject'. The *str* argument should have the form 'first-last' where *first* and *last* are the first and last article numbers to search. Return a pair (response, list), where *list* is a list of pairs (id, text), where *id* is an article number (as a string) and *text* is the text of the requested header for that article. If the *file* parameter is supplied, then the output of the XHDR command is stored in a file. If *file* is a string, then the method will open a file with that name, write to it then close it. If *file* is a *file object*, then it will start calling write() on it to store the lines of the command output. If *file* is supplied, then the returned *list* is an empty list.

NNTP.**xover**(*start*, *end*, *, *file=None*)
Send an XOVER command. *start* and *end* are article numbers delimiting the range of articles to select. The return value is the same of for *over()*. It is recommended to use *over()* instead, since it will automatically use the newer OVER command if available.

NNTP.**xpath**(*id*)
Return a pair (resp, path), where *path* is the directory path to the article with message ID *id*. Most of the time, this extension is not enabled by NNTP server administrators.

Deprecated since version 3.3: The XPATH extension is not actively used.

22.16.2 Utility functions

The module also defines the following utility function:

nntplib.**decode_header**(*header_str*)

Decode a header value, un-escaping any escaped non-ASCII characters. *header_str* must be a *str* object. The unescaped value is returned. Using this function is recommended to display some headers in a human readable form:

```
>>> decode_header("Some subject")
'Some subject'
>>> decode_header("=?ISO-8859-15?Q?D=E9buter_en_Python?=")
'Débuter en Python'
>>> decode_header("Re: =?UTF-8?B?cHJvYmzDqG1lIGRlIG1hdHJpY2U=?=")
'Re: problème de matrice'
```

22.17 smtplib — SMTP protocol client

Source code: Lib/smtplib.py

The *smtplib* module defines an SMTP client session object that can be used to send mail to any Internet machine with an SMTP or ESMTP listener daemon. For details of SMTP and ESMTP operation, consult **RFC 821** (Simple Mail Transfer Protocol) and **RFC 1869** (SMTP Service Extensions).

class smtplib.**SMTP**(*host=''*, *port=0*, *local_hostname=None*[, *timeout*], *source_address=None*)

An *SMTP* instance encapsulates an SMTP connection. It has methods that support a full repertoire of SMTP and ESMTP operations. If the optional host and port parameters are given, the SMTP *connect()* method is called with those parameters during initialization. If specified, *local_hostname* is used as the FQDN of the local host in the HELO/EHLO command. Otherwise, the local hostname is found using *socket.getfqdn()*. If the *connect()* call returns anything other than a success code, an *SMTPConnectError* is raised. The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used). If the timeout expires, *socket.timeout* is raised. The optional source_address parameter allows binding to some specific source address in a machine with multiple network interfaces, and/or to some specific source TCP port. It takes a 2-tuple (host, port), for the socket to bind to as its source address before connecting. If omitted (or if host or port are `''` and/or 0 respectively) the OS default behavior will be used.

For normal use, you should only require the initialization/connect, *sendmail()*, and `quit()` methods. An example is included below.

The *SMTP* class supports the `with` statement. When used like this, the SMTP `QUIT` command is issued automatically when the `with` statement exits. E.g.:

```
>>> from smtplib import SMTP
>>> with SMTP("domain.org") as smtp:
...     smtp.noop()
...
(250, b'Ok')
>>>
```

Changed in version 3.3: Support for the `with` statement was added.

Changed in version 3.3: source_address argument was added.

New in version 3.5: The SMTPUTF8 extension (**RFC 6531**) is now supported.

class smtplib.**SMTP_SSL**(*host=''*, *port=0*, *local_hostname=None*, *keyfile=None*, *certfile=None*[, *timeout*], *context=None*, *source_address=None*)

An *SMTP_SSL* instance behaves exactly the same as instances of *SMTP*. *SMTP_SSL* should be used for

situations where SSL is required from the beginning of the connection and using `starttls()` is not appropriate. If *host* is not specified, the local host is used. If *port* is zero, the standard SMTP-over-SSL port (465) is used. The optional arguments *local_hostname*, *timeout* and *source_address* have the same meaning as they do in the *SMTP* class. *context*, also optional, can contain a *SSLContext* and allows configuring various aspects of the secure connection. Please read *Security considerations* for best practices.

keyfile and *certfile* are a legacy alternative to *context*, and can point to a PEM formatted private key and certificate chain file for the SSL connection.

Changed in version 3.3: *context* was added.

Changed in version 3.3: source_address argument was added.

Changed in version 3.4: The class now supports hostname check with *ssl.SSLContext.check_hostname* and *Server Name Indication* (see *ssl.HAS_SNI*).

Deprecated since version 3.6: *keyfile* and *certfile* are deprecated in favor of *context*. Please use *ssl.SSLContext.load_cert_chain()* instead, or let *ssl.create_default_context()* select the system's trusted CA certificates for you.

class smtplib.**LMTP**(*host=''*, *port=LMTP_PORT*, *local_hostname=None*, *source_address=None*)

The LMTP protocol, which is very similar to ESMTP, is heavily based on the standard SMTP client. It's common to use Unix sockets for LMTP, so our `connect()` method must support that as well as a regular host:port server. The optional arguments local_hostname and source_address have the same meaning as they do in the *SMTP* class. To specify a Unix socket, you must use an absolute path for *host*, starting with a '/'.

Authentication is supported, using the regular SMTP mechanism. When using a Unix socket, LMTP generally don't support or require any authentication, but your mileage might vary.

A nice selection of exceptions is defined as well:

exception smtplib.**SMTPException**

Subclass of *OSError* that is the base exception class for all the other exceptions provided by this module.

Changed in version 3.4: SMTPException became subclass of *OSError*

exception smtplib.**SMTPServerDisconnected**

This exception is raised when the server unexpectedly disconnects, or when an attempt is made to use the *SMTP* instance before connecting it to a server.

exception smtplib.**SMTPResponseException**

Base class for all exceptions that include an SMTP error code. These exceptions are generated in some instances when the SMTP server returns an error code. The error code is stored in the `smtp_code` attribute of the error, and the `smtp_error` attribute is set to the error message.

exception smtplib.**SMTPSenderRefused**

Sender address refused. In addition to the attributes set by on all *SMTPResponseException* exceptions, this sets 'sender' to the string that the SMTP server refused.

exception smtplib.**SMTPRecipientsRefused**

All recipient addresses refused. The errors for each recipient are accessible through the attribute `recipients`, which is a dictionary of exactly the same sort as *SMTP.sendmail()* returns.

exception smtplib.**SMTPDataError**

The SMTP server refused to accept the message data.

exception smtplib.**SMTPConnectError**

Error occurred during establishment of a connection with the server.

exception smtplib.**SMTPHeloError**

The server refused our `HELO` message.

exception smtplib.SMTPNotSupportedError
The command or option attempted is not supported by the server.

New in version 3.5.

exception smtplib.SMTPAuthenticationError
SMTP authentication went wrong. Most probably the server didn't accept the username/password combination provided.

See also:

RFC 821 - Simple Mail Transfer Protocol Protocol definition for SMTP. This document covers the model, operating procedure, and protocol details for SMTP.

RFC 1869 - SMTP Service Extensions Definition of the ESMTP extensions for SMTP. This describes a framework for extending SMTP with new commands, supporting dynamic discovery of the commands provided by the server, and defines a few additional commands.

22.17.1 SMTP Objects

An *SMTP* instance has the following methods:

SMTP.set_debuglevel(*level*)
Set the debug output level. A value of 1 or `True` for *level* results in debug messages for connection and for all messages sent to and received from the server. A value of 2 for *level* results in these messages being timestamped.

Changed in version 3.5: Added debuglevel 2.

SMTP.docmd(*cmd*, *args=''*)
Send a command *cmd* to the server. The optional argument *args* is simply concatenated to the command, separated by a space.

This returns a 2-tuple composed of a numeric response code and the actual response line (multiline responses are joined into one long line.)

In normal operation it should not be necessary to call this method explicitly. It is used to implement other methods and may be useful for testing private extensions.

If the connection to the server is lost while waiting for the reply, *SMTPServerDisconnected* will be raised.

SMTP.connect(*host='localhost'*, *port=0*)
Connect to a host on a given port. The defaults are to connect to the local host at the standard SMTP port (25). If the hostname ends with a colon (`':'`) followed by a number, that suffix will be stripped off and the number interpreted as the port number to use. This method is automatically invoked by the constructor if a host is specified during instantiation. Returns a 2-tuple of the response code and message sent by the server in its connection response.

SMTP.helo(*name=''*)
Identify yourself to the SMTP server using `HELO`. The hostname argument defaults to the fully qualified domain name of the local host. The message returned by the server is stored as the `helo_resp` attribute of the object.

In normal operation it should not be necessary to call this method explicitly. It will be implicitly called by the *sendmail()* when necessary.

SMTP.ehlo(*name=''*)
Identify yourself to an ESMTP server using `EHLO`. The hostname argument defaults to the fully qualified domain name of the local host. Examine the response for ESMTP option and store them for use by *has_extn()*. Also sets several informational attributes: the message returned by the server is stored as the `ehlo_resp` attribute, `does_esmtp` is set to true or false depending on whether the server supports

ESMTP, and `esmtp_features` will be a dictionary containing the names of the SMTP service extensions this server supports, and their parameters (if any).

Unless you wish to use *has_extn()* before sending mail, it should not be necessary to call this method explicitly. It will be implicitly called by *sendmail()* when necessary.

SMTP.**ehlo_or_helo_if_needed**()
This method call *ehlo()* and or *helo()* if there has been no previous `EHLO` or `HELO` command this session. It tries ESMTP `EHLO` first.

SMTPHeloError The server didn't reply properly to the `HELO` greeting.

SMTP.**has_extn**(*name*)
Return *True* if *name* is in the set of SMTP service extensions returned by the server, *False* otherwise. Case is ignored.

SMTP.**verify**(*address*)
Check the validity of an address on this server using SMTP `VRFY`. Returns a tuple consisting of code 250 and a full **RFC 822** address (including human name) if the user address is valid. Otherwise returns an SMTP error code of 400 or greater and an error string.

Note: Many sites disable SMTP `VRFY` in order to foil spammers.

SMTP.**login**(*user*, *password*, ***, *initial_response_ok=True*)
Log in on an SMTP server that requires authentication. The arguments are the username and the password to authenticate with. If there has been no previous `EHLO` or `HELO` command this session, this method tries ESMTP `EHLO` first. This method will return normally if the authentication was successful, or may raise the following exceptions:

SMTPHeloError The server didn't reply properly to the `HELO` greeting.

SMTPAuthenticationError The server didn't accept the username/password combination.

SMTPNotSupportedError The `AUTH` command is not supported by the server.

SMTPException No suitable authentication method was found.

Each of the authentication methods supported by *smtplib* are tried in turn if they are advertised as supported by the server. See *auth()* for a list of supported authentication methods. *initial_response_ok* is passed through to *auth()*.

Optional keyword argument *initial_response_ok* specifies whether, for authentication methods that support it, an "initial response" as specified in **RFC 4954** can be sent along with the `AUTH` command, rather than requiring a challenge/response.

Changed in version 3.5: *SMTPNotSupportedError* may be raised, and the *initial_response_ok* parameter was added.

SMTP.**auth**(*mechanism*, *authobject*, ***, *initial_response_ok=True*)
Issue an `SMTP AUTH` command for the specified authentication *mechanism*, and handle the challenge response via *authobject*.

mechanism specifies which authentication mechanism is to be used as argument to the `AUTH` command; the valid values are those listed in the `auth` element of `esmtp_features`.

authobject must be a callable object taking an optional single argument:

data = authobject(challenge=None)

If optional keyword argument *initial_response_ok* is true, `authobject()` will be called first with no argument. It can return the **RFC 4954** "initial response" bytes which will be encoded and sent with the `AUTH` command as below. If the `authobject()` does not support an initial response (e.g. because it

requires a challenge), it should return `None` when called with `challenge=None`. If *initial_response_ok* is false, then `authobject()` will not be called first with `None`.

If the initial response check returns `None`, or if *initial_response_ok* is false, `authobject()` will be called to process the server's challenge response; the *challenge* argument it is passed will be a `bytes`. It should return `bytes` *data* that will be base64 encoded and sent to the server.

The `SMTP` class provides `authobjects` for the `CRAM-MD5`, `PLAIN`, and `LOGIN` mechanisms; they are named `SMTP.auth_cram_md5`, `SMTP.auth_plain`, and `SMTP.auth_login` respectively. They all require that the `user` and `password` properties of the `SMTP` instance are set to appropriate values.

User code does not normally need to call `auth` directly, but can instead call the *login()* method, which will try each of the above mechanisms in turn, in the order listed. `auth` is exposed to facilitate the implementation of authentication methods not (or not yet) supported directly by *smtplib*.

New in version 3.5.

`SMTP.starttls`(*keyfile=None*, *certfile=None*, *context=None*)
Put the SMTP connection in TLS (Transport Layer Security) mode. All SMTP commands that follow will be encrypted. You should then call *ehlo()* again.

If *keyfile* and *certfile* are provided, these are passed to the *socket* module's *ssl()* function.

Optional *context* parameter is a *ssl.SSLContext* object; This is an alternative to using a keyfile and a certfile and if specified both *keyfile* and *certfile* should be `None`.

If there has been no previous `EHLO` or `HELO` command this session, this method tries ESMTP `EHLO` first.

SMTPHeloError The server didn't reply properly to the `HELO` greeting.

SMTPNotSupportedError The server does not support the STARTTLS extension.

RuntimeError SSL/TLS support is not available to your Python interpreter.

Changed in version 3.3: *context* was added.

Changed in version 3.4: The method now supports hostname check with `SSLContext.check_hostname` and *Server Name Indicator* (see *HAS_SNI*).

Changed in version 3.5: The error raised for lack of STARTTLS support is now the *SMTPNotSupportedError* subclass instead of the base *SMTPException*.

`SMTP.sendmail`(*from_addr*, *to_addrs*, *msg*, *mail_options=[]*, *rcpt_options=[]*)
Send mail. The required arguments are an **RFC 822** from-address string, a list of **RFC 822** to-address strings (a bare string will be treated as a list with 1 address), and a message string. The caller may pass a list of ESMTP options (such as `8bitmime`) to be used in `MAIL FROM` commands as *mail_options*. ESMTP options (such as `DSN` commands) that should be used with all `RCPT` commands can be passed as *rcpt_options*. (If you need to use different ESMTP options to different recipients you have to use the low-level methods such as `mail()`, `rcpt()` and `data()` to send the message.)

Note: The *from_addr* and *to_addrs* parameters are used to construct the message envelope used by the transport agents. `sendmail` does not modify the message headers in any way.

---

msg may be a string containing characters in the ASCII range, or a byte string. A string is encoded to bytes using the ascii codec, and lone `\r` and `\n` characters are converted to `\r\n` characters. A byte string is not modified.

If there has been no previous `EHLO` or `HELO` command this session, this method tries ESMTP `EHLO` first. If the server does ESMTP, message size and each of the specified options will be passed to it (if the option is in the feature set the server advertises). If `EHLO` fails, `HELO` will be tried and ESMTP options suppressed.

This method will return normally if the mail is accepted for at least one recipient. Otherwise it will raise an exception. That is, if this method does not raise an exception, then someone should get your mail. If this method does not raise an exception, it returns a dictionary, with one entry for each recipient that was refused. Each entry contains a tuple of the SMTP error code and the accompanying error message sent by the server.

If `SMTPUTF8` is included in *mail_options*, and the server supports it, *from_addr* and *to_addrs* may contain non-ASCII characters.

This method may raise the following exceptions:

SMTPRecipientsRefused All recipients were refused. Nobody got the mail. The `recipients` attribute of the exception object is a dictionary with information about the refused recipients (like the one returned when at least one recipient was accepted).

SMTPHeloError The server didn't reply properly to the `HELO` greeting.

SMTPSenderRefused The server didn't accept the *from_addr*.

SMTPDataError The server replied with an unexpected error code (other than a refusal of a recipient).

SMTPNotSupportedError `SMTPUTF8` was given in the *mail_options* but is not supported by the server.

Unless otherwise noted, the connection will be open even after an exception is raised.

Changed in version 3.2: *msg* may be a byte string.

Changed in version 3.5: `SMTPUTF8` support added, and *SMTPNotSupportedError* may be raised if `SMTPUTF8` is specified but the server does not support it.

`SMTP.send_message`(*msg*, *from_addr=None*, *to_addrs=None*, *mail_options=[]*, *rcpt_options=[]*)
This is a convenience method for calling *sendmail()* with the message represented by an *email.message.Message* object. The arguments have the same meaning as for *sendmail()*, except that *msg* is a `Message` object.

If *from_addr* is `None` or *to_addrs* is `None`, `send_message` fills those arguments with addresses extracted from the headers of *msg* as specified in **RFC 5322**: *from_addr* is set to the *Sender* field if it is present, and otherwise to the *From* field. *to_addrs* combines the values (if any) of the *To*, *Cc*, and *Bcc* fields from *msg*. If exactly one set of *Resent-** headers appear in the message, the regular headers are ignored and the *Resent-** headers are used instead. If the message contains more than one set of *Resent-** headers, a *ValueError* is raised, since there is no way to unambiguously detect the most recent set of *Resent-* headers.

`send_message` serializes *msg* using *BytesGenerator* with `\r\n` as the *linesep*, and calls *sendmail()* to transmit the resulting message. Regardless of the values of *from_addr* and *to_addrs*, `send_message` does not transmit any *Bcc* or *Resent-Bcc* headers that may appear in *msg*. If any of the addresses in *from_addr* and *to_addrs* contain non-ASCII characters and the server does not advertise `SMTPUTF8` support, an `SMTPNotSupported` error is raised. Otherwise the `Message` is serialized with a clone of its *policy* with the *utf8* attribute set to `True`, and `SMTPUTF8` and `BODY=8BITMIME` are added to *mail_options*.

New in version 3.2.

New in version 3.5: Support for internationalized addresses (`SMTPUTF8`).

`SMTP.quit`()
Terminate the SMTP session and close the connection. Return the result of the SMTP `QUIT` command.

Low-level methods corresponding to the standard SMTP/ESMTP commands `HELP`, `RSET`, `NOOP`, `MAIL`, `RCPT`, and `DATA` are also supported. Normally these do not need to be called directly, so they are not documented here. For details, consult the module code.

22.17.2 SMTP Example

This example prompts the user for addresses needed in the message envelope ('To' and 'From' addresses), and the message to be delivered. Note that the headers to be included with the message must be included in the message as entered; this example doesn't do any processing of the **RFC 822** headers. In particular, the 'To' and 'From' addresses must be included in the message headers explicitly.

```
import smtplib

def prompt(prompt):
    return input(prompt).strip()

fromaddr = prompt("From: ")
toaddrs  = prompt("To: ").split()
print("Enter message, end with ^D (Unix) or ^Z (Windows):")

# Add the From: and To: headers at the start!
msg = ("From: %s\r\nTo: %s\r\n\r\n"
       % (fromaddr, ", ".join(toaddrs)))
while True:
    try:
        line = input()
    except EOFError:
        break
    if not line:
        break
    msg = msg + line

print("Message length is", len(msg))

server = smtplib.SMTP('localhost')
server.set_debuglevel(1)
server.sendmail(fromaddr, toaddrs, msg)
server.quit()
```

Note: In general, you will want to use the *email* package's features to construct an email message, which you can then send via *send_message()*; see *email: Examples*.

22.18 smtpd — SMTP Server

Source code: Lib/smtpd.py

This module offers several classes to implement SMTP (email) servers.

See also:

The aiosmtpd package is a recommended replacement for this module. It is based on *asyncio* and provides a more straightforward API. *smtpd* should be considered deprecated.

Several server implementations are present; one is a generic do-nothing implementation, which can be overridden, while the other two offer specific mail-sending strategies.

Additionally the SMTPChannel may be extended to implement very specific interaction behaviour with SMTP clients.

The code supports **RFC 5321**, plus the **RFC 1870** SIZE and **RFC 6531** SMTPUTF8 extensions.

22.18.1 SMTPServer Objects

`class smtpd.SMTPServer(`*localaddr*, *remoteaddr*, *data_size_limit=33554432*, *map=None*, *enable_SMTPUTF8=False*, *decode_data=False*`)`

Create a new *SMTPServer* object, which binds to local address *localaddr*. It will treat *remoteaddr* as an upstream SMTP relayer. Both *localaddr* and *remoteaddr* should be a *(host, port)* tuple. The object inherits from *asyncore.dispatcher*, and so will insert itself into *asyncore*'s event loop on instantiation.

data_size_limit specifies the maximum number of bytes that will be accepted in a `DATA` command. A value of `None` or `0` means no limit.

map is the socket map to use for connections (an initially empty dictionary is a suitable value). If not specified the *asyncore* global socket map is used.

enable_SMTPUTF8 determines whether the `SMTPUTF8` extension (as defined in **RFC 6531**) should be enabled. The default is `False`. When `True`, `SMTPUTF8` is accepted as a parameter to the `MAIL` command and when present is passed to *process_message()* in the `kwargs['mail_options']` list. *decode_data* and *enable_SMTPUTF8* cannot be set to `True` at the same time.

decode_data specifies whether the data portion of the SMTP transaction should be decoded using UTF-8. When *decode_data* is `False` (the default), the server advertises the `8BITMIME` extension (**RFC 6152**), accepts the `BODY=8BITMIME` parameter to the `MAIL` command, and when present passes it to *process_message()* in the `kwargs['mail_options']` list. *decode_data* and *enable_SMTPUTF8* cannot be set to `True` at the same time.

`process_message(`*peer*, *mailfrom*, *rcpttos*, *data*, ***kwargs*`)`

Raise a *NotImplementedError* exception. Override this in subclasses to do something useful with this message. Whatever was passed in the constructor as *remoteaddr* will be available as the `_remoteaddr` attribute. *peer* is the remote host's address, *mailfrom* is the envelope originator, *rcpttos* are the envelope recipients and *data* is a string containing the contents of the e-mail (which should be in **RFC 5321** format).

If the *decode_data* constructor keyword is set to `True`, the *data* argument will be a unicode string. If it is set to `False`, it will be a bytes object.

kwargs is a dictionary containing additional information. It is empty if `decode_data=True` was given as an init argument, otherwise it contains the following keys:

***mail_options*:** a list of all received parameters to the `MAIL` command (the elements are uppercase strings; example: `['BODY=8BITMIME', 'SMTPUTF8']`).

***rcpt_options*:** same as *mail_options* but for the `RCPT` command. Currently no `RCPT TO` options are supported, so for now this will always be an empty list.

Implementations of `process_message` should use the `**kwargs` signature to accept arbitrary keyword arguments, since future feature enhancements may add keys to the kwargs dictionary.

Return `None` to request a normal `250 Ok` response; otherwise return the desired response string in **RFC 5321** format.

`channel_class`

Override this in subclasses to use a custom *SMTPChannel* for managing SMTP clients.

New in version 3.4: The *map* constructor argument.

Changed in version 3.5: *localaddr* and *remoteaddr* may now contain IPv6 addresses.

New in version 3.5: The *decode_data* and *enable_SMTPUTF8* constructor parameters, and the *kwargs* parameter to *process_message()* when *decode_data* is `False`.

Changed in version 3.6: *decode_data* is now `False` by default.

22.18.2 DebuggingServer Objects

class smtpd.DebuggingServer(*localaddr*, *remoteaddr*)
Create a new debugging server. Arguments are as per *SMTPServer*. Messages will be discarded, and printed on stdout.

22.18.3 PureProxy Objects

class smtpd.PureProxy(*localaddr*, *remoteaddr*)
Create a new pure proxy server. Arguments are as per *SMTPServer*. Everything will be relayed to *remoteaddr*. Note that running this has a good chance to make you into an open relay, so please be careful.

22.18.4 MailmanProxy Objects

class smtpd.MailmanProxy(*localaddr*, *remoteaddr*)
Create a new pure proxy server. Arguments are as per *SMTPServer*. Everything will be relayed to *remoteaddr*, unless local mailman configurations knows about an address, in which case it will be handled via mailman. Note that running this has a good chance to make you into an open relay, so please be careful.

22.18.5 SMTPChannel Objects

class smtpd.SMTPChannel(*server*, *conn*, *addr*, *data_size_limit=33554432*, *map=None*, *enable_SMTPUTF8=False*, *decode_data=False*)
Create a new *SMTPChannel* object which manages the communication between the server and a single SMTP client.

conn and *addr* are as per the instance variables described below.

data_size_limit specifies the maximum number of bytes that will be accepted in a `DATA` command. A value of `None` or `0` means no limit.

enable_SMTPUTF8 determines whether the `SMTPUTF8` extension (as defined in **RFC 6531**) should be enabled. The default is `False`. *decode_data* and *enable_SMTPUTF8* cannot be set to `True` at the same time.

A dictionary can be specified in *map* to avoid using a global socket map.

decode_data specifies whether the data portion of the SMTP transaction should be decoded using UTF-8. The default is `False`. *decode_data* and *enable_SMTPUTF8* cannot be set to `True` at the same time.

To use a custom SMTPChannel implementation you need to override the *SMTPServer.channel_class* of your *SMTPServer*.

Changed in version 3.5: The *decode_data* and *enable_SMTPUTF8* parameters were added.

Changed in version 3.6: *decode_data* is now `False` by default.

The *SMTPChannel* has the following instance variables:

smtp_server
Holds the *SMTPServer* that spawned this channel.

conn
Holds the socket object connecting to the client.

addr
Holds the address of the client, the second value returned by *socket.accept*

received_lines
Holds a list of the line strings (decoded using UTF-8) received from the client. The lines have their `"\r\n"` line ending translated to `"\n"`.

smtp_state
Holds the current state of the channel. This will be either `COMMAND` initially and then `DATA` after the client sends a "DATA" line.

seen_greeting
Holds a string containing the greeting sent by the client in its "HELO".

mailfrom
Holds a string containing the address identified in the "MAIL FROM:" line from the client.

rcpttos
Holds a list of strings containing the addresses identified in the "RCPT TO:" lines from the client.

received_data
Holds a string containing all of the data sent by the client during the DATA state, up to but not including the terminating `"\r\n.\r\n"`.

fqdn
Holds the fully-qualified domain name of the server as returned by *socket.getfqdn()*.

peer
Holds the name of the client peer as returned by `conn.getpeername()` where `conn` is *conn*.

The *SMTPChannel* operates by invoking methods named `smtp_<command>` upon reception of a command line from the client. Built into the base *SMTPChannel* class are methods for handling the following commands (and responding to them appropriately):

Command	Action taken
HELO	Accepts the greeting from the client and stores it in *seen_greeting*. Sets server to base command mode.
EHLO	Accepts the greeting from the client and stores it in *seen_greeting*. Sets server to extended command mode.
NOOP	Takes no action.
QUIT	Closes the connection cleanly.
MAIL	Accepts the "MAIL FROM:" syntax and stores the supplied address as *mailfrom*. In extended command mode, accepts the **RFC 1870** SIZE attribute and responds appropriately based on the value of *data_size_limit*.
RCPT	Accepts the "RCPT TO:" syntax and stores the supplied addresses in the *rcpttos* list.
RSET	Resets the *mailfrom*, *rcpttos*, and *received_data*, but not the greeting.
DATA	Sets the internal state to `DATA` and stores remaining lines from the client in *received_data* until the terminator `"\r\n.\r\n"` is received.
HELP	Returns minimal information on command syntax
VRFY	Returns code 252 (the server doesn't know if the address is valid)
EXPN	Reports that the command is not implemented.

22.19 telnetlib — Telnet client

Source code: Lib/telnetlib.py

The *telnetlib* module provides a *Telnet* class that implements the Telnet protocol. See **RFC 854** for details about the protocol. In addition, it provides symbolic constants for the protocol characters (see below), and for the telnet options. The symbolic names of the telnet options follow the definitions in `arpa/telnet.h`, with the leading `TELOPT_` removed. For symbolic names of options which are traditionally not included in `arpa/telnet.h`, see the module source itself.

The symbolic constants for the telnet commands are: IAC, DONT, DO, WONT, WILL, SE (Subnegotiation End), NOP (No Operation), DM (Data Mark), BRK (Break), IP (Interrupt process), AO (Abort output), AYT (Are You There), EC (Erase Character), EL (Erase Line), GA (Go Ahead), SB (Subnegotiation Begin).

class telnetlib.Telnet(*host=None*, *port=0*[, *timeout*])

Telnet represents a connection to a Telnet server. The instance is initially not connected by default; the *open()* method must be used to establish a connection. Alternatively, the host name and optional port number can be passed to the constructor too, in which case the connection to the server will be established before the constructor returns. The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used).

Do not reopen an already connected instance.

This class has many `read_*()` methods. Note that some of them raise *EOFError* when the end of the connection is read, because they can return an empty string for other reasons. See the individual descriptions below.

A *Telnet* object is a context manager and can be used in a `with` statement. When the `with` block ends, the *close()* method is called:

```
>>> from telnetlib import Telnet
>>> with Telnet('localhost', 23) as tn:
...     tn.interact()
...
```

Changed in version 3.6: Context manager support added

See also:

RFC 854 - Telnet Protocol Specification Definition of the Telnet protocol.

22.19.1 Telnet Objects

Telnet instances have the following methods:

Telnet.read_until(*expected*, *timeout=None*)

Read until a given byte string, *expected*, is encountered or until *timeout* seconds have passed.

When no match is found, return whatever is available instead, possibly empty bytes. Raise *EOFError* if the connection is closed and no cooked data is available.

Telnet.read_all()

Read all data until EOF as bytes; block until connection closed.

Telnet.read_some()

Read at least one byte of cooked data unless EOF is hit. Return `b''` if EOF is hit. Block if no data is immediately available.

Telnet.**read_very_eager**()
Read everything that can be without blocking in I/O (eager).

Raise *EOFError* if connection closed and no cooked data available. Return `b''` if no cooked data available otherwise. Do not block unless in the midst of an IAC sequence.

Telnet.**read_eager**()
Read readily available data.

Raise *EOFError* if connection closed and no cooked data available. Return `b''` if no cooked data available otherwise. Do not block unless in the midst of an IAC sequence.

Telnet.**read_lazy**()
Process and return data already in the queues (lazy).

Raise *EOFError* if connection closed and no data available. Return `b''` if no cooked data available otherwise. Do not block unless in the midst of an IAC sequence.

Telnet.**read_very_lazy**()
Return any data available in the cooked queue (very lazy).

Raise *EOFError* if connection closed and no data available. Return `b''` if no cooked data available otherwise. This method never blocks.

Telnet.**read_sb_data**()
Return the data collected between a SB/SE pair (suboption begin/end). The callback should access these data when it was invoked with a `SE` command. This method never blocks.

Telnet.**open**(*host*, *port=0*[, *timeout*])
Connect to a host. The optional second argument is the port number, which defaults to the standard Telnet port (23). The optional *timeout* parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used).

Do not try to reopen an already connected instance.

Telnet.**msg**(*msg*, **args*)
Print a debug message when the debug level is > 0. If extra arguments are present, they are substituted in the message using the standard string formatting operator.

Telnet.**set_debuglevel**(*debuglevel*)
Set the debug level. The higher the value of *debuglevel*, the more debug output you get (on `sys.stdout`).

Telnet.**close**()
Close the connection.

Telnet.**get_socket**()
Return the socket object used internally.

Telnet.**fileno**()
Return the file descriptor of the socket object used internally.

Telnet.**write**(*buffer*)
Write a byte string to the socket, doubling any IAC characters. This can block if the connection is blocked. May raise *OSError* if the connection is closed.

Changed in version 3.3: This method used to raise *socket.error*, which is now an alias of *OSError*.

Telnet.**interact**()
Interaction function, emulates a very dumb Telnet client.

Telnet.**mt_interact**()
Multithreaded version of *interact()*.

Telnet.expect(*list*, *timeout=None*)
Read until one from a list of a regular expressions matches.

The first argument is a list of regular expressions, either compiled (*regex objects*) or uncompiled (byte strings). The optional second argument is a timeout, in seconds; the default is to block indefinitely.

Return a tuple of three items: the index in the list of the first regular expression that matches; the match object returned; and the bytes read up till and including the match.

If end of file is found and no bytes were read, raise *EOFError*. Otherwise, when nothing matches, return `(-1, None, data)` where *data* is the bytes received so far (may be empty bytes if a timeout happened).

If a regular expression ends with a greedy match (such as `.*`) or if more than one expression can match the same input, the results are non-deterministic, and may depend on the I/O timing.

Telnet.set_option_negotiation_callback(*callback*)
Each time a telnet option is read on the input flow, this *callback* (if set) is called with the following parameters: callback(telnet socket, command (DO/DONT/WILL/WONT), option). No other action is done afterwards by telnetlib.

22.19.2 Telnet Example

A simple example illustrating typical use:

```
import getpass
import telnetlib

HOST = "localhost"
user = input("Enter your remote account: ")
password = getpass.getpass()

tn = telnetlib.Telnet(HOST)

tn.read_until(b"login: ")
tn.write(user.encode('ascii') + b"\n")
if password:
    tn.read_until(b"Password: ")
    tn.write(password.encode('ascii') + b"\n")

tn.write(b"ls\n")
tn.write(b"exit\n")

print(tn.read_all().decode('ascii'))
```

22.20 uuid — UUID objects according to RFC 4122

Source code: Lib/uuid.py

This module provides immutable *UUID* objects (the *UUID* class) and the functions *uuid1()*, *uuid3()*, *uuid4()*, *uuid5()* for generating version 1, 3, 4, and 5 UUIDs as specified in **RFC 4122**.

If all you want is a unique ID, you should probably call *uuid1()* or *uuid4()*. Note that *uuid1()* may compromise privacy since it creates a UUID containing the computer's network address. *uuid4()* creates a random UUID.

Depending on support from the underlying platform, *uuid1()* may or may not return a "safe" UUID. A safe UUID is one which is generated using synchronization methods that ensure no two processes can obtain the same UUID. All instances of *UUID* have an `is_safe` attribute which relays any information about the UUID's safety, using this enumeration:

class uuid.SafeUUID

New in version 3.7.

safe
The UUID was generated by the platform in a multiprocessing-safe way.

unsafe
The UUID was not generated in a multiprocessing-safe way.

unknown
The platform does not provide information on whether the UUID was generated safely or not.

class uuid.UUID(*hex=None*, *bytes=None*, *bytes_le=None*, *fields=None*, *int=None*, *version=None*, ***, *is_safe=SafeUUID.unknown*)

Create a UUID from either a string of 32 hexadecimal digits, a string of 16 bytes in big-endian order as the *bytes* argument, a string of 16 bytes in little-endian order as the *bytes_le* argument, a tuple of six integers (32-bit *time_low*, 16-bit *time_mid*, 16-bit *time_hi_version*, 8-bit *clock_seq_hi_variant*, 8-bit *clock_seq_low*, 48-bit *node*) as the *fields* argument, or a single 128-bit integer as the *int* argument. When a string of hex digits is given, curly braces, hyphens, and a URN prefix are all optional. For example, these expressions all yield the same UUID:

```
UUID('{12345678-1234-5678-1234-567812345678}')
UUID('12345678123456781234567812345678')
UUID('urn:uuid:12345678-1234-5678-1234-567812345678')
UUID(bytes=b'\x12\x34\x56\x78'*4)
UUID(bytes_le=b'\x78\x56\x34\x12\x34\x12\x78\x56' +
              b'\x12\x34\x56\x78\x12\x34\x56\x78')
UUID(fields=(0x12345678, 0x1234, 0x5678, 0x12, 0x34, 0x567812345678))
UUID(int=0x12345678123456781234567812345678)
```

Exactly one of *hex*, *bytes*, *bytes_le*, *fields*, or *int* must be given. The *version* argument is optional; if given, the resulting UUID will have its variant and version number set according to **RFC 4122**, overriding bits in the given *hex*, *bytes*, *bytes_le*, *fields*, or *int*.

Comparison of UUID objects are made by way of comparing their *UUID.int* attributes. Comparison with a non-UUID object raises a *TypeError*.

`str(uuid)` returns a string in the form `12345678-1234-5678-1234-567812345678` where the 32 hexadecimal digits represent the UUID.

UUID instances have these read-only attributes:

UUID.bytes
The UUID as a 16-byte string (containing the six integer fields in big-endian byte order).

UUID.bytes_le
The UUID as a 16-byte string (with *time_low*, *time_mid*, and *time_hi_version* in little-endian byte order).

UUID.fields
A tuple of the six integer fields of the UUID, which are also available as six individual attributes and two derived attributes:

Field	Meaning
`time_low`	the first 32 bits of the UUID
`time_mid`	the next 16 bits of the UUID
`time_hi_version`	the next 16 bits of the UUID
`clock_seq_hi_variant`	the next 8 bits of the UUID
`clock_seq_low`	the next 8 bits of the UUID
`node`	the last 48 bits of the UUID
time	the 60-bit timestamp
`clock_seq`	the 14-bit sequence number

UUID.hex
The UUID as a 32-character hexadecimal string.

UUID.int
The UUID as a 128-bit integer.

UUID.urn
The UUID as a URN as specified in **RFC 4122**.

UUID.variant
The UUID variant, which determines the internal layout of the UUID. This will be one of the constants *RESERVED_NCS*, *RFC_4122*, *RESERVED_MICROSOFT*, or *RESERVED_FUTURE*.

UUID.version
The UUID version number (1 through 5, meaningful only when the variant is *RFC_4122*).

UUID.is_safe
An enumeration of *SafeUUID* which indicates whether the platform generated the UUID in a multiprocessing-safe way.

New in version 3.7.

The *uuid* module defines the following functions:

uuid.getnode()
Get the hardware address as a 48-bit positive integer. The first time this runs, it may launch a separate program, which could be quite slow. If all attempts to obtain the hardware address fail, we choose a random 48-bit number with the multicast bit (least significant bit of the first octet) set to 1 as recommended in **RFC 4122**. "Hardware address" means the MAC address of a network interface. On a machine with multiple network interfaces, universally administered MAC addresses (i.e. where the second least significant bit of the first octet is *unset*) will be preferred over locally administered MAC addresses, but with no other ordering guarantees.

Changed in version 3.7: Universally administered MAC addresses are preferred over locally administered MAC addresses, since the former are guaranteed to be globally unique, while the latter are not.

uuid.uuid1(*node=None*, *clock_seq=None*)
Generate a UUID from a host ID, sequence number, and the current time. If *node* is not given, *getnode()* is used to obtain the hardware address. If *clock_seq* is given, it is used as the sequence number; otherwise a random 14-bit sequence number is chosen.

uuid.uuid3(*namespace*, *name*)
Generate a UUID based on the MD5 hash of a namespace identifier (which is a UUID) and a name (which is a string).

uuid.uuid4()
Generate a random UUID.

uuid.uuid5(*namespace*, *name*)
Generate a UUID based on the SHA-1 hash of a namespace identifier (which is a UUID) and a name (which is a string).

The *uuid* module defines the following namespace identifiers for use with *uuid3()* or *uuid5()*.

uuid.NAMESPACE_DNS
When this namespace is specified, the *name* string is a fully-qualified domain name.

uuid.NAMESPACE_URL
When this namespace is specified, the *name* string is a URL.

uuid.NAMESPACE_OID
When this namespace is specified, the *name* string is an ISO OID.

uuid.NAMESPACE_X500
When this namespace is specified, the *name* string is an X.500 DN in DER or a text output format.

The *uuid* module defines the following constants for the possible values of the `variant` attribute:

uuid.RESERVED_NCS
Reserved for NCS compatibility.

uuid.RFC_4122
Specifies the UUID layout given in **RFC 4122**.

uuid.RESERVED_MICROSOFT
Reserved for Microsoft compatibility.

uuid.RESERVED_FUTURE
Reserved for future definition.

See also:

RFC 4122 - A Universally Unique IDentifier (UUID) URN Namespace This specification defines a Uniform Resource Name namespace for UUIDs, the internal format of UUIDs, and methods of generating UUIDs.

22.20.1 Example

Here are some examples of typical usage of the *uuid* module:

```
>>> import uuid

>>> # make a UUID based on the host ID and current time
>>> uuid.uuid1()
UUID('a8098c1a-f86e-11da-bd1a-00112444be1e')

>>> # make a UUID using an MD5 hash of a namespace UUID and a name
>>> uuid.uuid3(uuid.NAMESPACE_DNS, 'python.org')
UUID('6fa459ea-ee8a-3ca4-894e-db77e160355e')

>>> # make a random UUID
>>> uuid.uuid4()
UUID('16fd2706-8baf-433b-82eb-8c7fada847da')

>>> # make a UUID using a SHA-1 hash of a namespace UUID and a name
>>> uuid.uuid5(uuid.NAMESPACE_DNS, 'python.org')
UUID('886313e1-3b8a-5372-9b90-0c9aee199e5d')

>>> # make a UUID from a string of hex digits (braces and hyphens ignored)
```

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```
>>> x = uuid.UUID('{00010203-0405-0607-0809-0a0b0c0d0e0f}')

>>> # convert a UUID to a string of hex digits in standard form
>>> str(x)
'00010203-0405-0607-0809-0a0b0c0d0e0f'

>>> # get the raw 16 bytes of the UUID
>>> x.bytes
b'\x00\x01\x02\x03\x04\x05\x06\x07\x08\t\n\x0b\x0c\r\x0e\x0f'

>>> # make a UUID from a 16-byte string
>>> uuid.UUID(bytes=x.bytes)
UUID('00010203-0405-0607-0809-0a0b0c0d0e0f')
```

22.21 socketserver — A framework for network servers

Source code: Lib/socketserver.py

The *socketserver* module simplifies the task of writing network servers.

There are four basic concrete server classes:

class socketserver.TCPServer(*server_address*, *RequestHandlerClass*, *bind_and_activate=True*)
This uses the Internet TCP protocol, which provides for continuous streams of data between the client and server. If *bind_and_activate* is true, the constructor automatically attempts to invoke *server_bind()* and *server_activate()*. The other parameters are passed to the *BaseServer* base class.

class socketserver.UDPServer(*server_address*, *RequestHandlerClass*, *bind_and_activate=True*)
This uses datagrams, which are discrete packets of information that may arrive out of order or be lost while in transit. The parameters are the same as for *TCPServer*.

class socketserver.UnixStreamServer(*server_address*, *RequestHandlerClass*, *bind_and_activate=True*)
class socketserver.UnixDatagramServer(*server_address*, *RequestHandlerClass*, *bind_and_activate=True*)
These more infrequently used classes are similar to the TCP and UDP classes, but use Unix domain sockets; they're not available on non-Unix platforms. The parameters are the same as for *TCPServer*.

These four classes process requests *synchronously*; each request must be completed before the next request can be started. This isn't suitable if each request takes a long time to complete, because it requires a lot of computation, or because it returns a lot of data which the client is slow to process. The solution is to create a separate process or thread to handle each request; the *ForkingMixIn* and *ThreadingMixIn* mix-in classes can be used to support asynchronous behaviour.

Creating a server requires several steps. First, you must create a request handler class by subclassing the *BaseRequestHandler* class and overriding its *handle()* method; this method will process incoming requests. Second, you must instantiate one of the server classes, passing it the server's address and the request handler class. It is recommended to use the server in a `with` statement. Then call the *handle_request()* or *serve_forever()* method of the server object to process one or many requests. Finally, call *server_close()* to close the socket (unless you used a `with` statement).

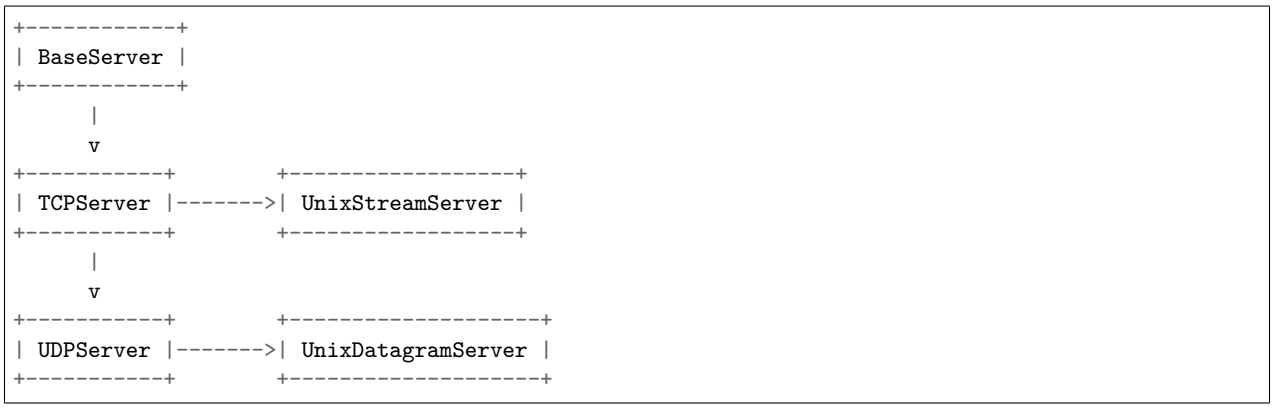
When inheriting from *ThreadingMixIn* for threaded connection behavior, you should explicitly declare how you want your threads to behave on an abrupt shutdown. The *ThreadingMixIn* class defines an attribute *daemon_threads*, which indicates whether or not the server should wait for thread termination. You should

set the flag explicitly if you would like threads to behave autonomously; the default is *False*, meaning that Python will not exit until all threads created by *ThreadingMixIn* have exited.

Server classes have the same external methods and attributes, no matter what network protocol they use.

22.21.1 Server Creation Notes

There are five classes in an inheritance diagram, four of which represent synchronous servers of four types:



Note that *UnixDatagramServer* derives from *UDPServer*, not from *UnixStreamServer* — the only difference between an IP and a Unix stream server is the address family, which is simply repeated in both Unix server classes.

class socketserver.ForkingMixIn
class socketserver.ThreadingMixIn

Forking and threading versions of each type of server can be created using these mix-in classes. For instance, *ThreadingUDPServer* is created as follows:

```
class ThreadingUDPServer(ThreadingMixIn, UDPServer):
    pass
```

The mix-in class comes first, since it overrides a method defined in *UDPServer*. Setting the various attributes also changes the behavior of the underlying server mechanism.

ForkingMixIn and the Forking classes mentioned below are only available on POSIX platforms that support *fork()*.

`socketserver.ForkingMixIn.server_close()` waits until all child processes complete, except if `socketserver.ForkingMixIn.block_on_close` attribute is false.

`socketserver.ThreadingMixIn.server_close()` waits until all non-daemon threads complete, except if `socketserver.ThreadingMixIn.block_on_close` attribute is false. Use daemonic threads by setting `ThreadingMixIn.daemon_threads` to `True` to not wait until threads complete.

Changed in version 3.7: `socketserver.ForkingMixIn.server_close()` and `socketserver.ThreadingMixIn.server_close()` now waits until all child processes and non-daemonic threads complete. Add a new `socketserver.ForkingMixIn.block_on_close` class attribute to opt-in for the pre-3.7 behaviour.

class socketserver.ForkingTCPServer
class socketserver.ForkingUDPServer
class socketserver.ThreadingTCPServer
class socketserver.ThreadingUDPServer

These classes are pre-defined using the mix-in classes.

To implement a service, you must derive a class from *BaseRequestHandler* and redefine its *handle()* method. You can then run various versions of the service by combining one of the server classes with your request handler class. The request handler class must be different for datagram or stream services. This can be hidden by using the handler subclasses *StreamRequestHandler* or *DatagramRequestHandler*.

Of course, you still have to use your head! For instance, it makes no sense to use a forking server if the service contains state in memory that can be modified by different requests, since the modifications in the child process would never reach the initial state kept in the parent process and passed to each child. In this case, you can use a threading server, but you will probably have to use locks to protect the integrity of the shared data.

On the other hand, if you are building an HTTP server where all data is stored externally (for instance, in the file system), a synchronous class will essentially render the service "deaf" while one request is being handled – which may be for a very long time if a client is slow to receive all the data it has requested. Here a threading or forking server is appropriate.

In some cases, it may be appropriate to process part of a request synchronously, but to finish processing in a forked child depending on the request data. This can be implemented by using a synchronous server and doing an explicit fork in the request handler class *handle()* method.

Another approach to handling multiple simultaneous requests in an environment that supports neither threads nor *fork()* (or where these are too expensive or inappropriate for the service) is to maintain an explicit table of partially finished requests and to use *selectors* to decide which request to work on next (or whether to handle a new incoming request). This is particularly important for stream services where each client can potentially be connected for a long time (if threads or subprocesses cannot be used). See *asyncore* for another way to manage this.

22.21.2 Server Objects

class socketserver.BaseServer(*server_address*, *RequestHandlerClass*)

This is the superclass of all Server objects in the module. It defines the interface, given below, but does not implement most of the methods, which is done in subclasses. The two parameters are stored in the respective *server_address* and *RequestHandlerClass* attributes.

fileno()

Return an integer file descriptor for the socket on which the server is listening. This function is most commonly passed to *selectors*, to allow monitoring multiple servers in the same process.

handle_request()

Process a single request. This function calls the following methods in order: *get_request()*, *verify_request()*, and *process_request()*. If the user-provided *handle()* method of the handler class raises an exception, the server's *handle_error()* method will be called. If no request is received within *timeout* seconds, *handle_timeout()* will be called and *handle_request()* will return.

serve_forever(*poll_interval=0.5*)

Handle requests until an explicit *shutdown()* request. Poll for shutdown every *poll_interval* seconds. Ignores the *timeout* attribute. It also calls *service_actions()*, which may be used by a subclass or mixin to provide actions specific to a given service. For example, the *ForkingMixIn* class uses *service_actions()* to clean up zombie child processes.

Changed in version 3.3: Added `service_actions` call to the `serve_forever` method.

service_actions()

This is called in the *serve_forever()* loop. This method can be overridden by subclasses or mixin classes to perform actions specific to a given service, such as cleanup actions.

New in version 3.3.

shutdown()
Tell the *serve_forever()* loop to stop and wait until it does.

server_close()
Clean up the server. May be overridden.

address_family
The family of protocols to which the server's socket belongs. Common examples are *socket.AF_INET* and *socket.AF_UNIX*.

RequestHandlerClass
The user-provided request handler class; an instance of this class is created for each request.

server_address
The address on which the server is listening. The format of addresses varies depending on the protocol family; see the documentation for the *socket* module for details. For Internet protocols, this is a tuple containing a string giving the address, and an integer port number: `('127.0.0.1', 80)`, for example.

socket
The socket object on which the server will listen for incoming requests.

The server classes support the following class variables:

allow_reuse_address
Whether the server will allow the reuse of an address. This defaults to *False*, and can be set in subclasses to change the policy.

request_queue_size
The size of the request queue. If it takes a long time to process a single request, any requests that arrive while the server is busy are placed into a queue, up to *request_queue_size* requests. Once the queue is full, further requests from clients will get a "Connection denied" error. The default value is usually 5, but this can be overridden by subclasses.

socket_type
The type of socket used by the server; *socket.SOCK_STREAM* and *socket.SOCK_DGRAM* are two common values.

timeout
Timeout duration, measured in seconds, or *None* if no timeout is desired. If *handle_request()* receives no incoming requests within the timeout period, the *handle_timeout()* method is called.

There are various server methods that can be overridden by subclasses of base server classes like *TCPServer*; these methods aren't useful to external users of the server object.

finish_request(*request*, *client_address*)
Actually processes the request by instantiating *RequestHandlerClass* and calling its *handle()* method.

get_request()
Must accept a request from the socket, and return a 2-tuple containing the *new* socket object to be used to communicate with the client, and the client's address.

handle_error(*request*, *client_address*)
This function is called if the *handle()* method of a *RequestHandlerClass* instance raises an exception. The default action is to print the traceback to standard error and continue handling further requests.

Changed in version 3.6: Now only called for exceptions derived from the *Exception* class.

handle_timeout()
This function is called when the *timeout* attribute has been set to a value other than *None* and the timeout period has passed with no requests being received. The default action for forking

servers is to collect the status of any child processes that have exited, while in threading servers this method does nothing.

process_request(*request*, *client_address*)
Calls *finish_request()* to create an instance of the *RequestHandlerClass*. If desired, this function can create a new process or thread to handle the request; the *ForkingMixIn* and *ThreadingMixIn* classes do this.

server_activate()
Called by the server's constructor to activate the server. The default behavior for a TCP server just invokes *listen()* on the server's socket. May be overridden.

server_bind()
Called by the server's constructor to bind the socket to the desired address. May be overridden.

verify_request(*request*, *client_address*)
Must return a Boolean value; if the value is *True*, the request will be processed, and if it's *False*, the request will be denied. This function can be overridden to implement access controls for a server. The default implementation always returns *True*.

Changed in version 3.6: Support for the *context manager* protocol was added. Exiting the context manager is equivalent to calling *server_close()*.

22.21.3 Request Handler Objects

class socketserver.**BaseRequestHandler**
This is the superclass of all request handler objects. It defines the interface, given below. A concrete request handler subclass must define a new *handle()* method, and can override any of the other methods. A new instance of the subclass is created for each request.

setup()
Called before the *handle()* method to perform any initialization actions required. The default implementation does nothing.

handle()
This function must do all the work required to service a request. The default implementation does nothing. Several instance attributes are available to it; the request is available as `self.request`; the client address as `self.client_address`; and the server instance as `self.server`, in case it needs access to per-server information.

The type of `self.request` is different for datagram or stream services. For stream services, `self.request` is a socket object; for datagram services, `self.request` is a pair of string and socket.

finish()
Called after the *handle()* method to perform any clean-up actions required. The default implementation does nothing. If *setup()* raises an exception, this function will not be called.

class socketserver.**StreamRequestHandler**
class socketserver.**DatagramRequestHandler**
These *BaseRequestHandler* subclasses override the *setup()* and *finish()* methods, and provide `self.rfile` and `self.wfile` attributes. The `self.rfile` and `self.wfile` attributes can be read or written, respectively, to get the request data or return data to the client.

The `rfile` attributes of both classes support the *io.BufferedIOBase* readable interface, and `DatagramRequestHandler.wfile` supports the *io.BufferedIOBase* writable interface.

Changed in version 3.6: `StreamRequestHandler.wfile` also supports the *io.BufferedIOBase* writable interface.

22.21.4 Examples

socketserver.TCPServer Example

This is the server side:

```
import socketserver

class MyTCPHandler(socketserver.BaseRequestHandler):
    """
    The request handler class for our server.

    It is instantiated once per connection to the server, and must
    override the handle() method to implement communication to the
    client.
    """

    def handle(self):
        # self.request is the TCP socket connected to the client
        self.data = self.request.recv(1024).strip()
        print("{} wrote:".format(self.client_address[0]))
        print(self.data)
        # just send back the same data, but upper-cased
        self.request.sendall(self.data.upper())

if __name__ == "__main__":
    HOST, PORT = "localhost", 9999

    # Create the server, binding to localhost on port 9999
    with socketserver.TCPServer((HOST, PORT), MyTCPHandler) as server:
        # Activate the server; this will keep running until you
        # interrupt the program with Ctrl-C
        server.serve_forever()
```

An alternative request handler class that makes use of streams (file-like objects that simplify communication by providing the standard file interface):

```
class MyTCPHandler(socketserver.StreamRequestHandler):

    def handle(self):
        # self.rfile is a file-like object created by the handler;
        # we can now use e.g. readline() instead of raw recv() calls
        self.data = self.rfile.readline().strip()
        print("{} wrote:".format(self.client_address[0]))
        print(self.data)
        # Likewise, self.wfile is a file-like object used to write back
        # to the client
        self.wfile.write(self.data.upper())
```

The difference is that the `readline()` call in the second handler will call `recv()` multiple times until it encounters a newline character, while the single `recv()` call in the first handler will just return what has been sent from the client in one `sendall()` call.

This is the client side:

```
import socket
import sys
```

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```
HOST, PORT = "localhost", 9999
data = " ".join(sys.argv[1:])

# Create a socket (SOCK_STREAM means a TCP socket)
with socket.socket(socket.AF_INET, socket.SOCK_STREAM) as sock:
    # Connect to server and send data
    sock.connect((HOST, PORT))
    sock.sendall(bytes(data + "\n", "utf-8"))

    # Receive data from the server and shut down
    received = str(sock.recv(1024), "utf-8")

print("Sent:     {}".format(data))
print("Received: {}".format(received))
```

The output of the example should look something like this:

Server:

```
$ python TCPServer.py
127.0.0.1 wrote:
b'hello world with TCP'
127.0.0.1 wrote:
b'python is nice'
```

Client:

```
$ python TCPClient.py hello world with TCP
Sent:     hello world with TCP
Received: HELLO WORLD WITH TCP
$ python TCPClient.py python is nice
Sent:     python is nice
Received: PYTHON IS NICE
```

socketserver.UDPServer Example

This is the server side:

```
import socketserver

class MyUDPHandler(socketserver.BaseRequestHandler):
    """
    This class works similar to the TCP handler class, except that
    self.request consists of a pair of data and client socket, and since
    there is no connection the client address must be given explicitly
    when sending data back via sendto().
    """

    def handle(self):
        data = self.request[0].strip()
        socket = self.request[1]
        print("{} wrote:".format(self.client_address[0]))
        print(data)
        socket.sendto(data.upper(), self.client_address)

if __name__ == "__main__":
```

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```
    HOST, PORT = "localhost", 9999
    with socketserver.UDPServer((HOST, PORT), MyUDPHandler) as server:
        server.serve_forever()
```

This is the client side:

```
import socket
import sys

HOST, PORT = "localhost", 9999
data = " ".join(sys.argv[1:])

# SOCK_DGRAM is the socket type to use for UDP sockets
sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)

# As you can see, there is no connect() call; UDP has no connections.
# Instead, data is directly sent to the recipient via sendto().
sock.sendto(bytes(data + "\n", "utf-8"), (HOST, PORT))
received = str(sock.recv(1024), "utf-8")

print("Sent:     {}".format(data))
print("Received: {}".format(received))
```

The output of the example should look exactly like for the TCP server example.

Asynchronous Mixins

To build asynchronous handlers, use the *ThreadingMixIn* and *ForkingMixIn* classes.

An example for the *ThreadingMixIn* class:

```
import socket
import threading
import socketserver

class ThreadedTCPRequestHandler(socketserver.BaseRequestHandler):

    def handle(self):
        data = str(self.request.recv(1024), 'ascii')
        cur_thread = threading.current_thread()
        response = bytes("{}: {}".format(cur_thread.name, data), 'ascii')
        self.request.sendall(response)

class ThreadedTCPServer(socketserver.ThreadingMixIn, socketserver.TCPServer):
    pass

def client(ip, port, message):
    with socket.socket(socket.AF_INET, socket.SOCK_STREAM) as sock:
        sock.connect((ip, port))
        sock.sendall(bytes(message, 'ascii'))
        response = str(sock.recv(1024), 'ascii')
        print("Received: {}".format(response))

if __name__ == "__main__":
    # Port 0 means to select an arbitrary unused port
    HOST, PORT = "localhost", 0
```

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```
    server = ThreadedTCPServer((HOST, PORT), ThreadedTCPRequestHandler)
    with server:
        ip, port = server.server_address

        # Start a thread with the server -- that thread will then start one
        # more thread for each request
        server_thread = threading.Thread(target=server.serve_forever)
        # Exit the server thread when the main thread terminates
        server_thread.daemon = True
        server_thread.start()
        print("Server loop running in thread:", server_thread.name)

        client(ip, port, "Hello World 1")
        client(ip, port, "Hello World 2")
        client(ip, port, "Hello World 3")

        server.shutdown()
```

The output of the example should look something like this:

```
$ python ThreadedTCPServer.py
Server loop running in thread: Thread-1
Received: Thread-2: Hello World 1
Received: Thread-3: Hello World 2
Received: Thread-4: Hello World 3
```

The *ForkingMixIn* class is used in the same way, except that the server will spawn a new process for each request. Available only on POSIX platforms that support *fork()*.

22.22 http.server — HTTP servers

Source code: Lib/http/server.py

This module defines classes for implementing HTTP servers (Web servers).

One class, *HTTPServer*, is a *socketserver.TCPServer* subclass. It creates and listens at the HTTP socket, dispatching the requests to a handler. Code to create and run the server looks like this:

```
def run(server_class=HTTPServer, handler_class=BaseHTTPRequestHandler):
    server_address = ('', 8000)
    httpd = server_class(server_address, handler_class)
    httpd.serve_forever()
```

class http.server.**HTTPServer**(*server_address*, *RequestHandlerClass*)

This class builds on the *TCPServer* class by storing the server address as instance variables named `server_name` and `server_port`. The server is accessible by the handler, typically through the handler's `server` instance variable.

class http.server.**ThreadingHTTPServer**(*server_address*, *RequestHandlerClass*)

This class is identical to HTTPServer but uses threads to handle requests by using the *ThreadingMixIn*. This is useful to handle web browsers pre-opening sockets, on which *HTTPServer* would wait indefinitely.

New in version 3.7.

The *HTTPServer* and *ThreadingHTTPServer* must be given a *RequestHandlerClass* on instantiation, of which this module provides three different variants:

class http.server.**BaseHTTPRequestHandler**(*request*, *client_address*, *server*)

This class is used to handle the HTTP requests that arrive at the server. By itself, it cannot respond to any actual HTTP requests; it must be subclassed to handle each request method (e.g. GET or POST). *BaseHTTPRequestHandler* provides a number of class and instance variables, and methods for use by subclasses.

The handler will parse the request and the headers, then call a method specific to the request type. The method name is constructed from the request. For example, for the request method `SPAM`, the `do_SPAM()` method will be called with no arguments. All of the relevant information is stored in instance variables of the handler. Subclasses should not need to override or extend the `__init__()` method.

BaseHTTPRequestHandler has the following instance variables:

client_address
Contains a tuple of the form `(host, port)` referring to the client's address.

server
Contains the server instance.

close_connection
Boolean that should be set before *handle_one_request()* returns, indicating if another request may be expected, or if the connection should be shut down.

requestline
Contains the string representation of the HTTP request line. The terminating CRLF is stripped. This attribute should be set by *handle_one_request()*. If no valid request line was processed, it should be set to the empty string.

command
Contains the command (request type). For example, `'GET'`.

path
Contains the request path.

request_version
Contains the version string from the request. For example, `'HTTP/1.0'`.

headers
Holds an instance of the class specified by the *MessageClass* class variable. This instance parses and manages the headers in the HTTP request. The `parse_headers()` function from *http.client* is used to parse the headers and it requires that the HTTP request provide a valid **RFC 2822** style header.

rfile
An *io.BufferedIOBase* input stream, ready to read from the start of the optional input data.

wfile
Contains the output stream for writing a response back to the client. Proper adherence to the HTTP protocol must be used when writing to this stream in order to achieve successful interoperation with HTTP clients.

Changed in version 3.6: This is an *io.BufferedIOBase* stream.

BaseHTTPRequestHandler has the following attributes:

server_version
Specifies the server software version. You may want to override this. The format is multiple whitespace-separated strings, where each string is of the form name[/version]. For example, `'BaseHTTP/0.2'`.

sys_version
Contains the Python system version, in a form usable by the *version_string* method and the *server_version* class variable. For example, `'Python/1.4'`.

error_message_format
Specifies a format string that should be used by *send_error()* method for building an error response to the client. The string is filled by default with variables from *responses* based on the status code that passed to *send_error()*.

error_content_type
Specifies the Content-Type HTTP header of error responses sent to the client. The default value is `'text/html'`.

protocol_version
This specifies the HTTP protocol version used in responses. If set to `'HTTP/1.1'`, the server will permit HTTP persistent connections; however, your server *must* then include an accurate `Content-Length` header (using *send_header()*) in all of its responses to clients. For backwards compatibility, the setting defaults to `'HTTP/1.0'`.

MessageClass
Specifies an *email.message.Message*-like class to parse HTTP headers. Typically, this is not overridden, and it defaults to `http.client.HTTPMessage`.

responses
This attribute contains a mapping of error code integers to two-element tuples containing a short and long message. For example, `{code: (shortmessage, longmessage)}`. The *shortmessage* is usually used as the *message* key in an error response, and *longmessage* as the *explain* key. It is used by *send_response_only()* and *send_error()* methods.

A *BaseHTTPRequestHandler* instance has the following methods:

handle()
Calls *handle_one_request()* once (or, if persistent connections are enabled, multiple times) to handle incoming HTTP requests. You should never need to override it; instead, implement appropriate `do_*()` methods.

handle_one_request()
This method will parse and dispatch the request to the appropriate `do_*()` method. You should never need to override it.

handle_expect_100()
When a HTTP/1.1 compliant server receives an `Expect: 100-continue` request header it responds back with a `100 Continue` followed by `200 OK` headers. This method can be overridden to raise an error if the server does not want the client to continue. For e.g. server can chose to send `417 Expectation Failed` as a response header and `return False`.

New in version 3.2.

send_error(*code*, *message=None*, *explain=None*)
Sends and logs a complete error reply to the client. The numeric *code* specifies the HTTP error code, with *message* as an optional, short, human readable description of the error. The *explain* argument can be used to provide more detailed information about the error; it will be formatted using the *error_message_format* attribute and emitted, after a complete set of headers, as the response body. The *responses* attribute holds the default values for *message* and *explain* that will be used if no value is provided; for unknown codes the default value for both is the string `???`. The body will be empty if the method is HEAD or the response code is one of the following: `1xx`, `204 No Content`, `205 Reset Content`, `304 Not Modified`.

Changed in version 3.4: The error response includes a Content-Length header. Added the *explain* argument.

send_response(*code*, *message=None*)
Adds a response header to the headers buffer and logs the accepted request. The HTTP response line is written to the internal buffer, followed by *Server* and *Date* headers. The values for these two headers are picked up from the *version_string()* and *date_time_string()* methods, respectively. If the server does not intend to send any other headers using the *send_header()* method, then *send_response()* should be followed by an *end_headers()* call.

Changed in version 3.3: Headers are stored to an internal buffer and *end_headers()* needs to be called explicitly.

send_header(*keyword*, *value*)
Adds the HTTP header to an internal buffer which will be written to the output stream when either *end_headers()* or *flush_headers()* is invoked. *keyword* should specify the header keyword, with *value* specifying its value. Note that, after the send_header calls are done, *end_headers()* MUST BE called in order to complete the operation.

Changed in version 3.2: Headers are stored in an internal buffer.

send_response_only(*code*, *message=None*)
Sends the response header only, used for the purposes when `100 Continue` response is sent by the server to the client. The headers not buffered and sent directly the output stream.If the *message* is not specified, the HTTP message corresponding the response *code* is sent.

New in version 3.2.

end_headers()
Adds a blank line (indicating the end of the HTTP headers in the response) to the headers buffer and calls *flush_headers()*.

Changed in version 3.2: The buffered headers are written to the output stream.

flush_headers()
Finally send the headers to the output stream and flush the internal headers buffer.

New in version 3.3.

log_request(*code='-'*, *size='-'*)
Logs an accepted (successful) request. *code* should specify the numeric HTTP code associated with the response. If a size of the response is available, then it should be passed as the *size* parameter.

log_error(*...*)
Logs an error when a request cannot be fulfilled. By default, it passes the message to *log_message()*, so it takes the same arguments (*format* and additional values).

log_message(*format*, *...*)
Logs an arbitrary message to `sys.stderr`. This is typically overridden to create custom error logging mechanisms. The *format* argument is a standard printf-style format string, where the additional arguments to *log_message()* are applied as inputs to the formatting. The client ip address and current date and time are prefixed to every message logged.

version_string()
Returns the server software's version string. This is a combination of the *server_version* and *sys_version* attributes.

date_time_string(*timestamp=None*)
Returns the date and time given by *timestamp* (which must be `None` or in the format returned by *time.time()*), formatted for a message header. If *timestamp* is omitted, it uses the current date and time.

The result looks like `'Sun, 06 Nov 1994 08:49:37 GMT'`.

`log_date_time_string()`
Returns the current date and time, formatted for logging.

`address_string()`
Returns the client address.

Changed in version 3.3: Previously, a name lookup was performed. To avoid name resolution delays, it now always returns the IP address.

`class http.server.SimpleHTTPRequestHandler(`*request*, *client_address*, *server*, *directory=None*`)`
This class serves files from the current directory and below, directly mapping the directory structure to HTTP requests.

A lot of the work, such as parsing the request, is done by the base class *BaseHTTPRequestHandler*. This class implements the *do_GET()* and *do_HEAD()* functions.

The following are defined as class-level attributes of *SimpleHTTPRequestHandler*:

`server_version`
This will be `"SimpleHTTP/" + __version__`, where `__version__` is defined at the module level.

`extensions_map`
A dictionary mapping suffixes into MIME types. The default is signified by an empty string, and is considered to be `application/octet-stream`. The mapping is used case-insensitively, and so should contain only lower-cased keys.

`directory`
If not specified, the directory to serve is the current working directory.

The *SimpleHTTPRequestHandler* class defines the following methods:

`do_HEAD()`
This method serves the `'HEAD'` request type: it sends the headers it would send for the equivalent `GET` request. See the *do_GET()* method for a more complete explanation of the possible headers.

`do_GET()`
The request is mapped to a local file by interpreting the request as a path relative to the current working directory.

If the request was mapped to a directory, the directory is checked for a file named `index.html` or `index.htm` (in that order). If found, the file's contents are returned; otherwise a directory listing is generated by calling the `list_directory()` method. This method uses *os.listdir()* to scan the directory, and returns a `404` error response if the *listdir()* fails.

If the request was mapped to a file, it is opened. Any *OSError* exception in opening the requested file is mapped to a `404`, `'File not found'` error. If there was a `'If-Modified-Since'` header in the request, and the file was not modified after this time, a `304`, `'Not Modified'` response is sent. Otherwise, the content type is guessed by calling the `guess_type()` method, which in turn uses the *extensions_map* variable, and the file contents are returned.

A `'Content-type:'` header with the guessed content type is output, followed by a `'Content-Length:'` header with the file's size and a `'Last-Modified:'` header with the file's modification time.

Then follows a blank line signifying the end of the headers, and then the contents of the file are output. If the file's MIME type starts with `text/` the file is opened in text mode; otherwise binary mode is used.

For example usage, see the implementation of the *test()* function invocation in the *http.server* module.

Changed in version 3.7: Support of the `'If-Modified-Since'` header.

The *SimpleHTTPRequestHandler* class can be used in the following manner in order to create a very basic webserver serving files relative to the current directory:

```
import http.server
import socketserver

PORT = 8000

Handler = http.server.SimpleHTTPRequestHandler

with socketserver.TCPServer(("", PORT), Handler) as httpd:
    print("serving at port", PORT)
    httpd.serve_forever()
```

http.server can also be invoked directly using the `-m` switch of the interpreter with a `port number` argument. Similar to the previous example, this serves files relative to the current directory:

```
python -m http.server 8000
```

By default, server binds itself to all interfaces. The option `-b/--bind` specifies a specific address to which it should bind. For example, the following command causes the server to bind to localhost only:

```
python -m http.server 8000 --bind 127.0.0.1
```

New in version 3.4: `--bind` argument was introduced.

By default, server uses the current directory. The option `-d/--directory` specifies a directory to which it should serve the files. For example, the following command uses a specific directory:

```
python -m http.server --directory /tmp/
```

New in version 3.7: `--directory` specify alternate directory

class http.server.**CGIHTTPRequestHandler**(*request*, *client_address*, *server*)

This class is used to serve either files or output of CGI scripts from the current directory and below. Note that mapping HTTP hierarchic structure to local directory structure is exactly as in *SimpleHTTPRequestHandler*.

Note: CGI scripts run by the *CGIHTTPRequestHandler* class cannot execute redirects (HTTP code 302), because code 200 (script output follows) is sent prior to execution of the CGI script. This pre-empts the status code.

The class will however, run the CGI script, instead of serving it as a file, if it guesses it to be a CGI script. Only directory-based CGI are used — the other common server configuration is to treat special extensions as denoting CGI scripts.

The `do_GET()` and `do_HEAD()` functions are modified to run CGI scripts and serve the output, instead of serving files, if the request leads to somewhere below the `cgi_directories` path.

The *CGIHTTPRequestHandler* defines the following data member:

`cgi_directories`

This defaults to `['/cgi-bin', '/htbin']` and describes directories to treat as containing CGI scripts.

The *CGIHTTPRequestHandler* defines the following method:

`do_POST()`

This method serves the `'POST'` request type, only allowed for CGI scripts. Error 501, "Can only POST to CGI scripts", is output when trying to POST to a non-CGI url.

Note that CGI scripts will be run with UID of user nobody, for security reasons. Problems with the CGI script will be translated to error 403.

CGIHTTPRequestHandler can be enabled in the command line by passing the `--cgi` option:

```
python -m http.server --cgi 8000
```

22.23 http.cookies — HTTP state management

Source code: Lib/http/cookies.py

The *http.cookies* module defines classes for abstracting the concept of cookies, an HTTP state management mechanism. It supports both simple string-only cookies, and provides an abstraction for having any serializable data-type as cookie value.

The module formerly strictly applied the parsing rules described in the **RFC 2109** and **RFC 2068** specifications. It has since been discovered that MSIE 3.0x doesn't follow the character rules outlined in those specs and also many current day browsers and servers have relaxed parsing rules when comes to Cookie handling. As a result, the parsing rules used are a bit less strict.

The character set, *string.ascii_letters*, *string.digits* and `!#$%&'*+-.^_`|~:` denote the set of valid characters allowed by this module in Cookie name (as *key*).

Changed in version 3.3: Allowed ':' as a valid Cookie name character.

Note: On encountering an invalid cookie, *CookieError* is raised, so if your cookie data comes from a browser you should always prepare for invalid data and catch *CookieError* on parsing.

---

exception http.cookies.**CookieError**
Exception failing because of **RFC 2109** invalidity: incorrect attributes, incorrect *Set-Cookie* header, etc.

class http.cookies.**BaseCookie**([*input*])
This class is a dictionary-like object whose keys are strings and whose values are *Morsel* instances. Note that upon setting a key to a value, the value is first converted to a *Morsel* containing the key and the value.

If *input* is given, it is passed to the *load()* method.

class http.cookies.**SimpleCookie**([*input*])
This class derives from *BaseCookie* and overrides `value_decode()` and `value_encode()` to be the identity and *str()* respectively.

See also:

Module *http.cookiejar* HTTP cookie handling for web *clients*. The *http.cookiejar* and *http.cookies* modules do not depend on each other.

RFC 2109 - HTTP State Management Mechanism This is the state management specification implemented by this module.

22.23.1 Cookie Objects

BaseCookie.**value_decode**(*val*)
Return a decoded value from a string representation. Return value can be any type. This method does nothing in *BaseCookie* — it exists so it can be overridden.

BaseCookie.value_encode(*val*)
Return an encoded value. *val* can be any type, but return value must be a string. This method does nothing in *BaseCookie* — it exists so it can be overridden.

In general, it should be the case that *value_encode()* and *value_decode()* are inverses on the range of *value_decode*.

BaseCookie.output(*attrs=None*, *header='Set-Cookie:'*, *sep='\r\n'*)
Return a string representation suitable to be sent as HTTP headers. *attrs* and *header* are sent to each *Morsel*'s *output()* method. *sep* is used to join the headers together, and is by default the combination `'\r\n'` (CRLF).

BaseCookie.js_output(*attrs=None*)
Return an embeddable JavaScript snippet, which, if run on a browser which supports JavaScript, will act the same as if the HTTP headers was sent.

The meaning for *attrs* is the same as in *output()*.

BaseCookie.load(*rawdata*)
If *rawdata* is a string, parse it as an `HTTP_COOKIE` and add the values found there as *Morsel*s. If it is a dictionary, it is equivalent to:

```
for k, v in rawdata.items():
    cookie[k] = v
```

22.23.2 Morsel Objects

class http.cookies.Morsel
Abstract a key/value pair, which has some **RFC 2109** attributes.

Morsels are dictionary-like objects, whose set of keys is constant — the valid **RFC 2109** attributes, which are

- `expires`
- `path`
- `comment`
- `domain`
- `max-age`
- `secure`
- `version`
- `httponly`

The attribute `httponly` specifies that the cookie is only transferred in HTTP requests, and is not accessible through JavaScript. This is intended to mitigate some forms of cross-site scripting.

The keys are case-insensitive and their default value is `''`.

Changed in version 3.5: `__eq__()` now takes *key* and *value* into account.

Changed in version 3.7: Attributes *key*, *value* and *coded_value* are read-only. Use *set()* for setting them.

Morsel.value
The value of the cookie.

Morsel.coded_value
The encoded value of the cookie — this is what should be sent.

`Morsel.key`
The name of the cookie.

`Morsel.set`(*key*, *value*, *coded_value*)
Set the *key*, *value* and *coded_value* attributes.

`Morsel.isReservedKey`(*K*)
Whether *K* is a member of the set of keys of a *Morsel*.

`Morsel.output`(*attrs=None*, *header='Set-Cookie:'*)
Return a string representation of the Morsel, suitable to be sent as an HTTP header. By default, all the attributes are included, unless *attrs* is given, in which case it should be a list of attributes to use. *header* is by default `"Set-Cookie:"`.

`Morsel.js_output`(*attrs=None*)
Return an embeddable JavaScript snippet, which, if run on a browser which supports JavaScript, will act the same as if the HTTP header was sent.

The meaning for *attrs* is the same as in *output()*.

`Morsel.OutputString`(*attrs=None*)
Return a string representing the Morsel, without any surrounding HTTP or JavaScript.

The meaning for *attrs* is the same as in *output()*.

`Morsel.update`(*values*)
Update the values in the Morsel dictionary with the values in the dictionary *values*. Raise an error if any of the keys in the *values* dict is not a valid **RFC 2109** attribute.

Changed in version 3.5: an error is raised for invalid keys.

`Morsel.copy`(*value*)
Return a shallow copy of the Morsel object.

Changed in version 3.5: return a Morsel object instead of a dict.

`Morsel.setdefault`(*key*, *value=None*)
Raise an error if key is not a valid **RFC 2109** attribute, otherwise behave the same as *dict.setdefault()*.

22.23.3 Example

The following example demonstrates how to use the *http.cookies* module.

```
>>> from http import cookies
>>> C = cookies.SimpleCookie()
>>> C["fig"] = "newton"
>>> C["sugar"] = "wafer"
>>> print(C) # generate HTTP headers
Set-Cookie: fig=newton
Set-Cookie: sugar=wafer
>>> print(C.output()) # same thing
Set-Cookie: fig=newton
Set-Cookie: sugar=wafer
>>> C = cookies.SimpleCookie()
>>> C["rocky"] = "road"
>>> C["rocky"]["path"] = "/cookie"
>>> print(C.output(header="Cookie:"))
Cookie: rocky=road; Path=/cookie
>>> print(C.output(attrs=[], header="Cookie:"))
Cookie: rocky=road
```

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```
>>> C = cookies.SimpleCookie()
>>> C.load("chips=ahoy; vienna=finger") # load from a string (HTTP header)
>>> print(C)
Set-Cookie: chips=ahoy
Set-Cookie: vienna=finger
>>> C = cookies.SimpleCookie()
>>> C.load('keebler="E=everybody; L=\\"Loves\\"; fudge=\\012;";')
>>> print(C)
Set-Cookie: keebler="E=everybody; L=\"Loves\"; fudge=\012;"
>>> C = cookies.SimpleCookie()
>>> C["oreo"] = "doublestuff"
>>> C["oreo"]["path"] = "/"
>>> print(C)
Set-Cookie: oreo=doublestuff; Path=/
>>> C = cookies.SimpleCookie()
>>> C["twix"] = "none for you"
>>> C["twix"].value
'none for you'
>>> C = cookies.SimpleCookie()
>>> C["number"] = 7 # equivalent to C["number"] = str(7)
>>> C["string"] = "seven"
>>> C["number"].value
'7'
>>> C["string"].value
'seven'
>>> print(C)
Set-Cookie: number=7
Set-Cookie: string=seven
```

22.24 `http.cookiejar` — Cookie handling for HTTP clients

Source code: Lib/http/cookiejar.py

The *`http.cookiejar`* module defines classes for automatic handling of HTTP cookies. It is useful for accessing web sites that require small pieces of data – *cookies* – to be set on the client machine by an HTTP response from a web server, and then returned to the server in later HTTP requests.

Both the regular Netscape cookie protocol and the protocol defined by **RFC 2965** are handled. RFC 2965 handling is switched off by default. **RFC 2109** cookies are parsed as Netscape cookies and subsequently treated either as Netscape or RFC 2965 cookies according to the 'policy' in effect. Note that the great majority of cookies on the Internet are Netscape cookies. *`http.cookiejar`* attempts to follow the de-facto Netscape cookie protocol (which differs substantially from that set out in the original Netscape specification), including taking note of the `max-age` and `port` cookie-attributes introduced with RFC 2965.

Note: The various named parameters found in *`Set-Cookie`* and *`Set-Cookie2`* headers (eg. `domain` and `expires`) are conventionally referred to as *attributes*. To distinguish them from Python attributes, the documentation for this module uses the term *cookie-attribute* instead.

The module defines the following exception:

exception `http.cookiejar.LoadError`

Instances of *`FileCookieJar`* raise this exception on failure to load cookies from a file. *`LoadError`* is a subclass of *`OSError`*.

Changed in version 3.3: LoadError was made a subclass of *OSError* instead of *IOError*.

The following classes are provided:

class http.cookiejar.CookieJar(*policy=None*)
policy is an object implementing the *CookiePolicy* interface.

The *CookieJar* class stores HTTP cookies. It extracts cookies from HTTP requests, and returns them in HTTP responses. *CookieJar* instances automatically expire contained cookies when necessary. Subclasses are also responsible for storing and retrieving cookies from a file or database.

class http.cookiejar.FileCookieJar(*filename*, *delayload=None*, *policy=None*)
policy is an object implementing the *CookiePolicy* interface. For the other arguments, see the documentation for the corresponding attributes.

A *CookieJar* which can load cookies from, and perhaps save cookies to, a file on disk. Cookies are **NOT** loaded from the named file until either the *load()* or *revert()* method is called. Subclasses of this class are documented in section *FileCookieJar subclasses and co-operation with web browsers*.

class http.cookiejar.CookiePolicy
This class is responsible for deciding whether each cookie should be accepted from / returned to the server.

class http.cookiejar.DefaultCookiePolicy(*blocked_domains=None*, *allowed_domains=None*, *netscape=True*, *rfc2965=False*, *rfc2109_as_netscape=None*, *hide_cookie2=False*, *strict_domain=False*, *strict_rfc2965_unverifiable=True*, *strict_ns_unverifiable=False*, *strict_ns_domain=DefaultCookiePolicy.DomainLiberal*, *strict_ns_set_initial_dollar=False*, *strict_ns_set_path=False*)
Constructor arguments should be passed as keyword arguments only. *blocked_domains* is a sequence of domain names that we never accept cookies from, nor return cookies to. *allowed_domains* if not *None*, this is a sequence of the only domains for which we accept and return cookies. For all other arguments, see the documentation for *CookiePolicy* and *DefaultCookiePolicy* objects.

DefaultCookiePolicy implements the standard accept / reject rules for Netscape and **RFC 2965** cookies. By default, **RFC 2109** cookies (ie. cookies received in a *Set-Cookie* header with a version cookie-attribute of 1) are treated according to the RFC 2965 rules. However, if RFC 2965 handling is turned off or *rfc2109_as_netscape* is `True`, RFC 2109 cookies are 'downgraded' by the *CookieJar* instance to Netscape cookies, by setting the `version` attribute of the *Cookie* instance to 0. *DefaultCookiePolicy* also provides some parameters to allow some fine-tuning of policy.

class http.cookiejar.Cookie
This class represents Netscape, **RFC 2109** and **RFC 2965** cookies. It is not expected that users of *http.cookiejar* construct their own *Cookie* instances. Instead, if necessary, call `make_cookies()` on a *CookieJar* instance.

See also:

Module *urllib.request* URL opening with automatic cookie handling.

Module *http.cookies* HTTP cookie classes, principally useful for server-side code. The *http.cookiejar* and *http.cookies* modules do not depend on each other.

https://curl.haxx.se/rfc/cookie_spec.html The specification of the original Netscape cookie protocol. Though this is still the dominant protocol, the 'Netscape cookie protocol' implemented by all the major browsers (and *http.cookiejar*) only bears a passing resemblance to the one sketched out in `cookie_spec.html`.

RFC 2109 - HTTP State Management Mechanism Obsoleted by **RFC 2965**. Uses *Set-Cookie* with version=1.

RFC 2965 - HTTP State Management Mechanism The Netscape protocol with the bugs fixed. Uses *Set-Cookie2* in place of *Set-Cookie*. Not widely used.

http://kristol.org/cookie/errata.html Unfinished errata to **RFC 2965**.

RFC 2964 - Use of HTTP State Management

22.24.1 CookieJar and FileCookieJar Objects

CookieJar objects support the *iterator* protocol for iterating over contained *Cookie* objects.

CookieJar has the following methods:

`CookieJar.add_cookie_header(`*request*`)`
Add correct *Cookie* header to *request*.

If policy allows (ie. the `rfc2965` and `hide_cookie2` attributes of the *CookieJar*'s *CookiePolicy* instance are true and false respectively), the *Cookie2* header is also added when appropriate.

The *request* object (usually a `urllib.request..Request` instance) must support the methods `get_full_url()`, `get_host()`, `get_type()`, `unverifiable()`, `has_header()`, `get_header()`, `header_items()`, `add_unredirected_header()` and `origin_req_host` attribute as documented by *urllib.request*.

Changed in version 3.3: *request* object needs `origin_req_host` attribute. Dependency on a deprecated method `get_origin_req_host()` has been removed.

`CookieJar.extract_cookies(`*response*, *request*`)`
Extract cookies from HTTP *response* and store them in the *CookieJar*, where allowed by policy.

The *CookieJar* will look for allowable *Set-Cookie* and *Set-Cookie2* headers in the *response* argument, and store cookies as appropriate (subject to the *CookiePolicy.set_ok()* method's approval).

The *response* object (usually the result of a call to *urllib.request.urlopen()*, or similar) should support an `info()` method, which returns an *email.message.Message* instance.

The *request* object (usually a *urllib.request.Request* instance) must support the methods `get_full_url()`, `get_host()`, `unverifiable()`, and `origin_req_host` attribute, as documented by *urllib.request*. The request is used to set default values for cookie-attributes as well as for checking that the cookie is allowed to be set.

Changed in version 3.3: *request* object needs `origin_req_host` attribute. Dependency on a deprecated method `get_origin_req_host()` has been removed.

`CookieJar.set_policy(`*policy*`)`
Set the *CookiePolicy* instance to be used.

`CookieJar.make_cookies(`*response*, *request*`)`
Return sequence of *Cookie* objects extracted from *response* object.

See the documentation for *extract_cookies()* for the interfaces required of the *response* and *request* arguments.

`CookieJar.set_cookie_if_ok(`*cookie*, *request*`)`
Set a *Cookie* if policy says it's OK to do so.

`CookieJar.set_cookie(`*cookie*`)`
Set a *Cookie*, without checking with policy to see whether or not it should be set.

CookieJar.clear([*domain*[, *path*[, *name*]]])
Clear some cookies.

If invoked without arguments, clear all cookies. If given a single argument, only cookies belonging to that *domain* will be removed. If given two arguments, cookies belonging to the specified *domain* and URL *path* are removed. If given three arguments, then the cookie with the specified *domain*, *path* and *name* is removed.

Raises *KeyError* if no matching cookie exists.

CookieJar.clear_session_cookies()
Discard all session cookies.

Discards all contained cookies that have a true `discard` attribute (usually because they had either no `max-age` or `expires` cookie-attribute, or an explicit `discard` cookie-attribute). For interactive browsers, the end of a session usually corresponds to closing the browser window.

Note that the `save()` method won't save session cookies anyway, unless you ask otherwise by passing a true *ignore_discard* argument.

FileCookieJar implements the following additional methods:

FileCookieJar.save(*filename=None*, *ignore_discard=False*, *ignore_expires=False*)
Save cookies to a file.

This base class raises *NotImplementedError*. Subclasses may leave this method unimplemented.

filename is the name of file in which to save cookies. If *filename* is not specified, `self.filename` is used (whose default is the value passed to the constructor, if any); if `self.filename` is *None*, *ValueError* is raised.

ignore_discard: save even cookies set to be discarded. *ignore_expires*: save even cookies that have expired

The file is overwritten if it already exists, thus wiping all the cookies it contains. Saved cookies can be restored later using the *load()* or *revert()* methods.

FileCookieJar.load(*filename=None*, *ignore_discard=False*, *ignore_expires=False*)
Load cookies from a file.

Old cookies are kept unless overwritten by newly loaded ones.

Arguments are as for *save()*.

The named file must be in the format understood by the class, or *LoadError* will be raised. Also, *OSError* may be raised, for example if the file does not exist.

Changed in version 3.3: *IOError* used to be raised, it is now an alias of *OSError*.

FileCookieJar.revert(*filename=None*, *ignore_discard=False*, *ignore_expires=False*)
Clear all cookies and reload cookies from a saved file.

revert() can raise the same exceptions as *load()*. If there is a failure, the object's state will not be altered.

FileCookieJar instances have the following public attributes:

FileCookieJar.filename
Filename of default file in which to keep cookies. This attribute may be assigned to.

FileCookieJar.delayload
If true, load cookies lazily from disk. This attribute should not be assigned to. This is only a hint, since this only affects performance, not behaviour (unless the cookies on disk are changing). A *CookieJar* object may ignore it. None of the *FileCookieJar* classes included in the standard library lazily loads cookies.

22.24.2 FileCookieJar subclasses and co-operation with web browsers

The following *CookieJar* subclasses are provided for reading and writing.

class http.cookiejar.**MozillaCookieJar**(*filename*, *delayload=None*, *policy=None*)
A *FileCookieJar* that can load from and save cookies to disk in the Mozilla `cookies.txt` file format (which is also used by the Lynx and Netscape browsers).

Note: This loses information about **RFC 2965** cookies, and also about newer or non-standard cookie-attributes such as `port`.

Warning: Back up your cookies before saving if you have cookies whose loss / corruption would be inconvenient (there are some subtleties which may lead to slight changes in the file over a load / save round-trip).

Also note that cookies saved while Mozilla is running will get clobbered by Mozilla.

class http.cookiejar.**LWPCookieJar**(*filename*, *delayload=None*, *policy=None*)
A *FileCookieJar* that can load from and save cookies to disk in format compatible with the libwww-perl library's `Set-Cookie3` file format. This is convenient if you want to store cookies in a human-readable file.

22.24.3 CookiePolicy Objects

Objects implementing the *CookiePolicy* interface have the following methods:

CookiePolicy.**set_ok**(*cookie*, *request*)
Return boolean value indicating whether cookie should be accepted from server.

cookie is a *Cookie* instance. *request* is an object implementing the interface defined by the documentation for *CookieJar.extract_cookies()*.

CookiePolicy.**return_ok**(*cookie*, *request*)
Return boolean value indicating whether cookie should be returned to server.

cookie is a *Cookie* instance. *request* is an object implementing the interface defined by the documentation for *CookieJar.add_cookie_header()*.

CookiePolicy.**domain_return_ok**(*domain*, *request*)
Return false if cookies should not be returned, given cookie domain.

This method is an optimization. It removes the need for checking every cookie with a particular domain (which might involve reading many files). Returning true from *domain_return_ok()* and *path_return_ok()* leaves all the work to *return_ok()*.

If *domain_return_ok()* returns true for the cookie domain, *path_return_ok()* is called for the cookie path. Otherwise, *path_return_ok()* and *return_ok()* are never called for that cookie domain. If *path_return_ok()* returns true, *return_ok()* is called with the *Cookie* object itself for a full check. Otherwise, *return_ok()* is never called for that cookie path.

Note that *domain_return_ok()* is called for every *cookie* domain, not just for the *request* domain. For example, the function might be called with both `".example.com"` and `"www.example.com"` if the request domain is `"www.example.com"`. The same goes for *path_return_ok()*.

The *request* argument is as documented for *return_ok()*.

CookiePolicy.**path_return_ok**(*path*, *request*)
Return false if cookies should not be returned, given cookie path.

See the documentation for *domain_return_ok()*.

In addition to implementing the methods above, implementations of the *CookiePolicy* interface must also supply the following attributes, indicating which protocols should be used, and how. All of these attributes may be assigned to.

CookiePolicy.**netscape**
Implement Netscape protocol.

CookiePolicy.**rfc2965**
Implement **RFC 2965** protocol.

CookiePolicy.**hide_cookie2**
Don't add *Cookie2* header to requests (the presence of this header indicates to the server that we understand **RFC 2965** cookies).

The most useful way to define a *CookiePolicy* class is by subclassing from *DefaultCookiePolicy* and overriding some or all of the methods above. *CookiePolicy* itself may be used as a 'null policy' to allow setting and receiving any and all cookies (this is unlikely to be useful).

22.24.4 DefaultCookiePolicy Objects

Implements the standard rules for accepting and returning cookies.

Both **RFC 2965** and Netscape cookies are covered. RFC 2965 handling is switched off by default.

The easiest way to provide your own policy is to override this class and call its methods in your overridden implementations before adding your own additional checks:

```
import http.cookiejar
class MyCookiePolicy(http.cookiejar.DefaultCookiePolicy):
    def set_ok(self, cookie, request):
        if not http.cookiejar.DefaultCookiePolicy.set_ok(self, cookie, request):
            return False
        if i_dont_want_to_store_this_cookie(cookie):
            return False
        return True
```

In addition to the features required to implement the *CookiePolicy* interface, this class allows you to block and allow domains from setting and receiving cookies. There are also some strictness switches that allow you to tighten up the rather loose Netscape protocol rules a little bit (at the cost of blocking some benign cookies).

A domain blacklist and whitelist is provided (both off by default). Only domains not in the blacklist and present in the whitelist (if the whitelist is active) participate in cookie setting and returning. Use the *blocked_domains* constructor argument, and `blocked_domains()` and `set_blocked_domains()` methods (and the corresponding argument and methods for *allowed_domains*). If you set a whitelist, you can turn it off again by setting it to *None*.

Domains in block or allow lists that do not start with a dot must equal the cookie domain to be matched. For example, `"example.com"` matches a blacklist entry of `"example.com"`, but `"www.example.com"` does not. Domains that do start with a dot are matched by more specific domains too. For example, both `"www.example.com"` and `"www.coyote.example.com"` match `".example.com"` (but `"example.com"` itself does not). IP addresses are an exception, and must match exactly. For example, if blocked_domains contains `"192.168.1.2"` and `".168.1.2"`, 192.168.1.2 is blocked, but 193.168.1.2 is not.

DefaultCookiePolicy implements the following additional methods:

DefaultCookiePolicy.**blocked_domains**()
Return the sequence of blocked domains (as a tuple).

DefaultCookiePolicy.**set_blocked_domains**(*blocked_domains*)
Set the sequence of blocked domains.

DefaultCookiePolicy.**is_blocked**(*domain*)
Return whether *domain* is on the blacklist for setting or receiving cookies.

DefaultCookiePolicy.**allowed_domains**()
Return *None*, or the sequence of allowed domains (as a tuple).

DefaultCookiePolicy.**set_allowed_domains**(*allowed_domains*)
Set the sequence of allowed domains, or *None*.

DefaultCookiePolicy.**is_not_allowed**(*domain*)
Return whether *domain* is not on the whitelist for setting or receiving cookies.

DefaultCookiePolicy instances have the following attributes, which are all initialised from the constructor arguments of the same name, and which may all be assigned to.

DefaultCookiePolicy.**rfc2109_as_netscape**
If true, request that the *CookieJar* instance downgrade **RFC 2109** cookies (ie. cookies received in a *Set-Cookie* header with a version cookie-attribute of 1) to Netscape cookies by setting the version attribute of the *Cookie* instance to 0. The default value is *None*, in which case RFC 2109 cookies are downgraded if and only if **RFC 2965** handling is turned off. Therefore, RFC 2109 cookies are downgraded by default.

General strictness switches:

DefaultCookiePolicy.**strict_domain**
Don't allow sites to set two-component domains with country-code top-level domains like `.co.uk`, `.gov.uk`, `.co.nz`.etc. This is far from perfect and isn't guaranteed to work!

RFC 2965 protocol strictness switches:

DefaultCookiePolicy.**strict_rfc2965_unverifiable**
Follow **RFC 2965** rules on unverifiable transactions (usually, an unverifiable transaction is one resulting from a redirect or a request for an image hosted on another site). If this is false, cookies are *never* blocked on the basis of verifiability

Netscape protocol strictness switches:

DefaultCookiePolicy.**strict_ns_unverifiable**
Apply **RFC 2965** rules on unverifiable transactions even to Netscape cookies.

DefaultCookiePolicy.**strict_ns_domain**
Flags indicating how strict to be with domain-matching rules for Netscape cookies. See below for acceptable values.

DefaultCookiePolicy.**strict_ns_set_initial_dollar**
Ignore cookies in Set-Cookie: headers that have names starting with `'$'`.

DefaultCookiePolicy.**strict_ns_set_path**
Don't allow setting cookies whose path doesn't path-match request URI.

`strict_ns_domain` is a collection of flags. Its value is constructed by or-ing together (for example, `DomainStrictNoDots|DomainStrictNonDomain` means both flags are set).

DefaultCookiePolicy.**DomainStrictNoDots**
When setting cookies, the 'host prefix' must not contain a dot (eg. `www.foo.bar.com` can't set a cookie for `.bar.com`, because `www.foo` contains a dot).

DefaultCookiePolicy.**DomainStrictNonDomain**
Cookies that did not explicitly specify a `domain` cookie-attribute can only be returned to a domain

equal to the domain that set the cookie (eg. `spam.example.com` won't be returned cookies from `example.com` that had no `domain` cookie-attribute).

`DefaultCookiePolicy.DomainRFC2965Match`
When setting cookies, require a full **RFC 2965** domain-match.

The following attributes are provided for convenience, and are the most useful combinations of the above flags:

`DefaultCookiePolicy.DomainLiberal`
Equivalent to 0 (ie. all of the above Netscape domain strictness flags switched off).

`DefaultCookiePolicy.DomainStrict`
Equivalent to `DomainStrictNoDots|DomainStrictNonDomain`.

22.24.5 Cookie Objects

Cookie instances have Python attributes roughly corresponding to the standard cookie-attributes specified in the various cookie standards. The correspondence is not one-to-one, because there are complicated rules for assigning default values, because the `max-age` and `expires` cookie-attributes contain equivalent information, and because **RFC 2109** cookies may be 'downgraded' by *http.cookiejar* from version 1 to version 0 (Netscape) cookies.

Assignment to these attributes should not be necessary other than in rare circumstances in a *CookiePolicy* method. The class does not enforce internal consistency, so you should know what you're doing if you do that.

`Cookie.version`
Integer or *None*. Netscape cookies have *version* 0. **RFC 2965** and **RFC 2109** cookies have a `version` cookie-attribute of 1. However, note that *http.cookiejar* may 'downgrade' RFC 2109 cookies to Netscape cookies, in which case *version* is 0.

`Cookie.name`
Cookie name (a string).

`Cookie.value`
Cookie value (a string), or *None*.

`Cookie.port`
String representing a port or a set of ports (eg. '80', or '80,8080'), or *None*.

`Cookie.path`
Cookie path (a string, eg. `'/acme/rocket_launchers'`).

`Cookie.secure`
`True` if cookie should only be returned over a secure connection.

`Cookie.expires`
Integer expiry date in seconds since epoch, or *None*. See also the *is_expired()* method.

`Cookie.discard`
`True` if this is a session cookie.

`Cookie.comment`
String comment from the server explaining the function of this cookie, or *None*.

`Cookie.comment_url`
URL linking to a comment from the server explaining the function of this cookie, or *None*.

`Cookie.rfc2109`
`True` if this cookie was received as an **RFC 2109** cookie (ie. the cookie arrived in a *Set-Cookie* header, and the value of the Version cookie-attribute in that header was 1). This attribute is provided because *http.cookiejar* may 'downgrade' RFC 2109 cookies to Netscape cookies, in which case *version* is 0.

Cookie.**port_specified**
: True if a port or set of ports was explicitly specified by the server (in the *Set-Cookie* / *Set-Cookie2* header).

Cookie.**domain_specified**
: True if a domain was explicitly specified by the server.

Cookie.**domain_initial_dot**
: True if the domain explicitly specified by the server began with a dot (`'.'`).

Cookies may have additional non-standard cookie-attributes. These may be accessed using the following methods:

Cookie.**has_nonstandard_attr**(*name*)
: Return true if cookie has the named cookie-attribute.

Cookie.**get_nonstandard_attr**(*name*, *default=None*)
: If cookie has the named cookie-attribute, return its value. Otherwise, return *default*.

Cookie.**set_nonstandard_attr**(*name*, *value*)
: Set the value of the named cookie-attribute.

The *Cookie* class also defines the following method:

Cookie.**is_expired**(*now=None*)
: True if cookie has passed the time at which the server requested it should expire. If *now* is given (in seconds since the epoch), return whether the cookie has expired at the specified time.

22.24.6 Examples

The first example shows the most common usage of *http.cookiejar*:

```
import http.cookiejar, urllib.request
cj = http.cookiejar.CookieJar()
opener = urllib.request.build_opener(urllib.request.HTTPCookieProcessor(cj))
r = opener.open("http://example.com/")
```

This example illustrates how to open a URL using your Netscape, Mozilla, or Lynx cookies (assumes Unix/Netscape convention for location of the cookies file):

```
import os, http.cookiejar, urllib.request
cj = http.cookiejar.MozillaCookieJar()
cj.load(os.path.join(os.path.expanduser("~"), ".netscape", "cookies.txt"))
opener = urllib.request.build_opener(urllib.request.HTTPCookieProcessor(cj))
r = opener.open("http://example.com/")
```

The next example illustrates the use of *DefaultCookiePolicy*. Turn on **RFC 2965** cookies, be more strict about domains when setting and returning Netscape cookies, and block some domains from setting cookies or having them returned:

```
import urllib.request
from http.cookiejar import CookieJar, DefaultCookiePolicy
policy = DefaultCookiePolicy(
    rfc2965=True, strict_ns_domain=Policy.DomainStrict,
    blocked_domains=["ads.net", ".ads.net"])
cj = CookieJar(policy)
opener = urllib.request.build_opener(urllib.request.HTTPCookieProcessor(cj))
r = opener.open("http://example.com/")
```

22.25 xmlrpc — XMLRPC server and client modules

XML-RPC is a Remote Procedure Call method that uses XML passed via HTTP as a transport. With it, a client can call methods with parameters on a remote server (the server is named by a URI) and get back structured data.

`xmlrpc` is a package that collects server and client modules implementing XML-RPC. The modules are:

- *xmlrpc.client*
- *xmlrpc.server*

22.26 xmlrpc.client — XML-RPC client access

Source code: Lib/xmlrpc/client.py

XML-RPC is a Remote Procedure Call method that uses XML passed via HTTP(S) as a transport. With it, a client can call methods with parameters on a remote server (the server is named by a URI) and get back structured data. This module supports writing XML-RPC client code; it handles all the details of translating between conformable Python objects and XML on the wire.

> **Warning:** The *xmlrpc.client* module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see *XML vulnerabilities*.

Changed in version 3.5: For HTTPS URIs, *xmlrpc.client* now performs all the necessary certificate and hostname checks by default.

`class xmlrpc.client.ServerProxy(`*uri*, *transport=None*, *encoding=None*, *verbose=False*, *allow_none=False*, *use_datetime=False*, *use_builtin_types=False*, ***, *context=None*`)`

Changed in version 3.3: The *use_builtin_types* flag was added.

A *ServerProxy* instance is an object that manages communication with a remote XML-RPC server. The required first argument is a URI (Uniform Resource Indicator), and will normally be the URL of the server. The optional second argument is a transport factory instance; by default it is an internal `SafeTransport` instance for https: URLs and an internal HTTP `Transport` instance otherwise. The optional third argument is an encoding, by default UTF-8. The optional fourth argument is a debugging flag.

The following parameters govern the use of the returned proxy instance. If *allow_none* is true, the Python constant `None` will be translated into XML; the default behaviour is for `None` to raise a *TypeError*. This is a commonly-used extension to the XML-RPC specification, but isn't supported by all clients and servers; see http://ontosys.com/xml-rpc/extensions.php for a description. The *use_builtin_types* flag can be used to cause date/time values to be presented as *datetime.datetime* objects and binary data to be presented as *bytes* objects; this flag is false by default. *datetime.datetime*, *bytes* and *bytearray* objects may be passed to calls. The obsolete *use_datetime* flag is similar to *use_builtin_types* but it applies only to date/time values.

Both the HTTP and HTTPS transports support the URL syntax extension for HTTP Basic Authentication: `http://user:pass@host:port/path`. The `user:pass` portion will be base64-encoded as an HTTP 'Authorization' header, and sent to the remote server as part of the connection process when invoking an XML-RPC method. You only need to use this if the remote server requires a Basic Authentication user and password. If an HTTPS URL is provided, *context* may be *ssl.SSLContext* and configures the SSL settings of the underlying HTTPS connection.

The returned instance is a proxy object with methods that can be used to invoke corresponding RPC calls on the remote server. If the remote server supports the introspection API, the proxy can also be used to query the remote server for the methods it supports (service discovery) and fetch other server-associated metadata.

Types that are conformable (e.g. that can be marshalled through XML), include the following (and except where noted, they are unmarshalled as the same Python type):

XML-RPC type	Python type
`boolean`	*bool*
`int`, `i1`, `i2`, `i4`, `i8` or `biginteger`	*int* in range from -2147483648 to 2147483647. Values get the `<int>` tag.
`double` or `float`	*float*. Values get the `<double>` tag.
`string`	*str*
`array`	*list* or *tuple* containing conformable elements. Arrays are returned as *lists*.
`struct`	*dict*. Keys must be strings, values may be any conformable type. Objects of user-defined classes can be passed in; only their *__dict__* attribute is transmitted.
`dateTime.iso8601`	*DateTime* or *datetime.datetime*. Returned type depends on values of *use_builtin_types* and *use_datetime* flags.
`base64`	*Binary*, *bytes* or *bytearray*. Returned type depends on the value of the *use_builtin_types* flag.
`nil`	The `None` constant. Passing is allowed only if *allow_none* is true.
`bigdecimal`	*decimal.Decimal*. Returned type only.

This is the full set of data types supported by XML-RPC. Method calls may also raise a special *Fault* instance, used to signal XML-RPC server errors, or *ProtocolError* used to signal an error in the HTTP/HTTPS transport layer. Both *Fault* and *ProtocolError* derive from a base class called `Error`. Note that the xmlrpc client module currently does not marshal instances of subclasses of built-in types.

When passing strings, characters special to XML such as `<`, `>`, and `&` will be automatically escaped. However, it's the caller's responsibility to ensure that the string is free of characters that aren't allowed in XML, such as the control characters with ASCII values between 0 and 31 (except, of course, tab, newline and carriage return); failing to do this will result in an XML-RPC request that isn't well-formed XML. If you have to pass arbitrary bytes via XML-RPC, use *bytes* or *bytearray* classes or the *Binary* wrapper class described below.

`Server` is retained as an alias for *ServerProxy* for backwards compatibility. New code should use *ServerProxy*.

Changed in version 3.5: Added the *context* argument.

Changed in version 3.6: Added support of type tags with prefixes (e.g. `ex:nil`). Added support of unmarshalling additional types used by Apache XML-RPC implementation for numerics: `i1`, `i2`, `i8`, `biginteger`, `float` and `bigdecimal`. See http://ws.apache.org/xmlrpc/types.html for a description.

See also:

XML-RPC HOWTO A good description of XML-RPC operation and client software in several languages. Contains pretty much everything an XML-RPC client developer needs to know.

XML-RPC Introspection Describes the XML-RPC protocol extension for introspection.

XML-RPC Specification The official specification.

Unofficial XML-RPC Errata Fredrik Lundh's "unofficial errata, intended to clarify certain details in the XML-RPC specification, as well as hint at 'best practices' to use when designing your own XML-RPC implementations."

22.26.1 ServerProxy Objects

A *ServerProxy* instance has a method corresponding to each remote procedure call accepted by the XML-RPC server. Calling the method performs an RPC, dispatched by both name and argument signature (e.g. the same method name can be overloaded with multiple argument signatures). The RPC finishes by returning a value, which may be either returned data in a conformant type or a *Fault* or *ProtocolError* object indicating an error.

Servers that support the XML introspection API support some common methods grouped under the reserved `system` attribute:

`ServerProxy.system.listMethods()`
This method returns a list of strings, one for each (non-system) method supported by the XML-RPC server.

`ServerProxy.system.methodSignature(`*name*`)`
This method takes one parameter, the name of a method implemented by the XML-RPC server. It returns an array of possible signatures for this method. A signature is an array of types. The first of these types is the return type of the method, the rest are parameters.

Because multiple signatures (ie. overloading) is permitted, this method returns a list of signatures rather than a singleton.

Signatures themselves are restricted to the top level parameters expected by a method. For instance if a method expects one array of structs as a parameter, and it returns a string, its signature is simply "string, array". If it expects three integers and returns a string, its signature is "string, int, int, int".

If no signature is defined for the method, a non-array value is returned. In Python this means that the type of the returned value will be something other than list.

`ServerProxy.system.methodHelp(`*name*`)`
This method takes one parameter, the name of a method implemented by the XML-RPC server. It returns a documentation string describing the use of that method. If no such string is available, an empty string is returned. The documentation string may contain HTML markup.

Changed in version 3.5: Instances of *ServerProxy* support the *context manager* protocol for closing the underlying transport.

A working example follows. The server code:

```
from xmlrpc.server import SimpleXMLRPCServer

def is_even(n):
    return n % 2 == 0

server = SimpleXMLRPCServer(("localhost", 8000))
print("Listening on port 8000...")
server.register_function(is_even, "is_even")
server.serve_forever()
```

The client code for the preceding server:

```
import xmlrpc.client

with xmlrpc.client.ServerProxy("http://localhost:8000/") as proxy:
```

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```
    print("3 is even: %s" % str(proxy.is_even(3)))
    print("100 is even: %s" % str(proxy.is_even(100)))
```

22.26.2 DateTime Objects

class xmlrpc.client.DateTime

This class may be initialized with seconds since the epoch, a time tuple, an ISO 8601 time/date string, or a *datetime.datetime* instance. It has the following methods, supported mainly for internal use by the marshalling/unmarshalling code:

decode(*string*)

Accept a string as the instance's new time value.

encode(*out*)

Write the XML-RPC encoding of this *DateTime* item to the *out* stream object.

It also supports certain of Python's built-in operators through rich comparison and `__repr__()` methods.

A working example follows. The server code:

```
import datetime
from xmlrpc.server import SimpleXMLRPCServer
import xmlrpc.client

def today():
    today = datetime.datetime.today()
    return xmlrpc.client.DateTime(today)

server = SimpleXMLRPCServer(("localhost", 8000))
print("Listening on port 8000...")
server.register_function(today, "today")
server.serve_forever()
```

The client code for the preceding server:

```
import xmlrpc.client
import datetime

proxy = xmlrpc.client.ServerProxy("http://localhost:8000/")

today = proxy.today()
# convert the ISO8601 string to a datetime object
converted = datetime.datetime.strptime(today.value, "%Y%m%dT%H:%M:%S")
print("Today: %s" % converted.strftime("%d.%m.%Y, %H:%M"))
```

22.26.3 Binary Objects

class xmlrpc.client.Binary

This class may be initialized from bytes data (which may include NULs). The primary access to the content of a *Binary* object is provided by an attribute:

data

The binary data encapsulated by the *Binary* instance. The data is provided as a *bytes* object.

Binary objects have the following methods, supported mainly for internal use by the marshalling/unmarshalling code:

decode(*bytes*)
Accept a base64 *bytes* object and decode it as the instance's new data.

encode(*out*)
Write the XML-RPC base 64 encoding of this binary item to the *out* stream object.

The encoded data will have newlines every 76 characters as per **RFC 2045 section 6.8**, which was the de facto standard base64 specification when the XML-RPC spec was written.

It also supports certain of Python's built-in operators through `__eq__()` and `__ne__()` methods.

Example usage of the binary objects. We're going to transfer an image over XMLRPC:

```
from xmlrpc.server import SimpleXMLRPCServer
import xmlrpc.client

def python_logo():
    with open("python_logo.jpg", "rb") as handle:
        return xmlrpc.client.Binary(handle.read())

server = SimpleXMLRPCServer(("localhost", 8000))
print("Listening on port 8000...")
server.register_function(python_logo, 'python_logo')

server.serve_forever()
```

The client gets the image and saves it to a file:

```
import xmlrpc.client

proxy = xmlrpc.client.ServerProxy("http://localhost:8000/")
with open("fetched_python_logo.jpg", "wb") as handle:
    handle.write(proxy.python_logo().data)
```

22.26.4 Fault Objects

class xmlrpc.client.**Fault**
A *Fault* object encapsulates the content of an XML-RPC fault tag. Fault objects have the following attributes:

faultCode
A string indicating the fault type.

faultString
A string containing a diagnostic message associated with the fault.

In the following example we're going to intentionally cause a *Fault* by returning a complex type object. The server code:

```
from xmlrpc.server import SimpleXMLRPCServer

# A marshalling error is going to occur because we're returning a
# complex number
def add(x, y):
    return x+y+0j
```

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```
server = SimpleXMLRPCServer(("localhost", 8000))
print("Listening on port 8000...")
server.register_function(add, 'add')

server.serve_forever()
```

The client code for the preceding server:

```
import xmlrpc.client

proxy = xmlrpc.client.ServerProxy("http://localhost:8000/")
try:
    proxy.add(2, 5)
except xmlrpc.client.Fault as err:
    print("A fault occurred")
    print("Fault code: %d" % err.faultCode)
    print("Fault string: %s" % err.faultString)
```

22.26.5 ProtocolError Objects

class xmlrpc.client.ProtocolError

A *ProtocolError* object describes a protocol error in the underlying transport layer (such as a 404 'not found' error if the server named by the URI does not exist). It has the following attributes:

url
The URI or URL that triggered the error.

errcode
The error code.

errmsg
The error message or diagnostic string.

headers
A dict containing the headers of the HTTP/HTTPS request that triggered the error.

In the following example we're going to intentionally cause a *ProtocolError* by providing an invalid URI:

```
import xmlrpc.client

# create a ServerProxy with a URI that doesn't respond to XMLRPC requests
proxy = xmlrpc.client.ServerProxy("http://google.com/")

try:
    proxy.some_method()
except xmlrpc.client.ProtocolError as err:
    print("A protocol error occurred")
    print("URL: %s" % err.url)
    print("HTTP/HTTPS headers: %s" % err.headers)
    print("Error code: %d" % err.errcode)
    print("Error message: %s" % err.errmsg)
```

22.26.6 MultiCall Objects

The *MultiCall* object provides a way to encapsulate multiple calls to a remote server into a single request[1].

class xmlrpc.client.**MultiCall**(*server*)

Create an object used to boxcar method calls. *server* is the eventual target of the call. Calls can be made to the result object, but they will immediately return `None`, and only store the call name and parameters in the *MultiCall* object. Calling the object itself causes all stored calls to be transmitted as a single `system.multicall` request. The result of this call is a *generator*; iterating over this generator yields the individual results.

A usage example of this class follows. The server code:

```
from xmlrpc.server import SimpleXMLRPCServer

def add(x, y):
    return x + y

def subtract(x, y):
    return x - y

def multiply(x, y):
    return x * y

def divide(x, y):
    return x // y

# A simple server with simple arithmetic functions
server = SimpleXMLRPCServer(("localhost", 8000))
print("Listening on port 8000...")
server.register_multicall_functions()
server.register_function(add, 'add')
server.register_function(subtract, 'subtract')
server.register_function(multiply, 'multiply')
server.register_function(divide, 'divide')
server.serve_forever()
```

The client code for the preceding server:

```
import xmlrpc.client

proxy = xmlrpc.client.ServerProxy("http://localhost:8000/")
multicall = xmlrpc.client.MultiCall(proxy)
multicall.add(7, 3)
multicall.subtract(7, 3)
multicall.multiply(7, 3)
multicall.divide(7, 3)
result = multicall()

print("7+3=%d, 7-3=%d, 7*3=%d, 7//3=%d" % tuple(result))
```

[1] This approach has been first presented in a discussion on xmlrpc.com.

22.26.7 Convenience Functions

xmlrpc.client.dumps(*params*, *methodname=None*, *methodresponse=None*, *encoding=None*, *allow_none=False*)

Convert *params* into an XML-RPC request. or into a response if *methodresponse* is true. *params* can be either a tuple of arguments or an instance of the *Fault* exception class. If *methodresponse* is true, only a single value can be returned, meaning that *params* must be of length 1. *encoding*, if supplied, is the encoding to use in the generated XML; the default is UTF-8. Python's *None* value cannot be used in standard XML-RPC; to allow using it via an extension, provide a true value for *allow_none*.

xmlrpc.client.loads(*data*, *use_datetime=False*, *use_builtin_types=False*)

Convert an XML-RPC request or response into Python objects, a `(params, methodname)`. *params* is a tuple of argument; *methodname* is a string, or `None` if no method name is present in the packet. If the XML-RPC packet represents a fault condition, this function will raise a *Fault* exception. The *use_builtin_types* flag can be used to cause date/time values to be presented as *datetime.datetime* objects and binary data to be presented as *bytes* objects; this flag is false by default.

The obsolete *use_datetime* flag is similar to *use_builtin_types* but it applies only to date/time values.

Changed in version 3.3: The *use_builtin_types* flag was added.

22.26.8 Example of Client Usage

```
# simple test program (from the XML-RPC specification)
from xmlrpc.client import ServerProxy, Error

# server = ServerProxy("http://localhost:8000") # local server
with ServerProxy("http://betty.userland.com") as proxy:

    print(proxy)

    try:
        print(proxy.examples.getStateName(41))
    except Error as v:
        print("ERROR", v)
```

To access an XML-RPC server through a HTTP proxy, you need to define a custom transport. The following example shows how:

```
import http.client
import xmlrpc.client

class ProxiedTransport(xmlrpc.client.Transport):

    def set_proxy(self, host, port=None, headers=None):
        self.proxy = host, port
        self.proxy_headers = headers

    def make_connection(self, host):
        connection = http.client.HTTPConnection(*self.proxy)
        connection.set_tunnel(host, headers=self.proxy_headers)
        self._connection = host, connection
        return connection

transport = ProxiedTransport()
transport.set_proxy('proxy-server', 8080)
```

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```
server = xmlrpc.client.ServerProxy('http://betty.userland.com', transport=transport)
print(server.examples.getStateName(41))
```

22.26.9 Example of Client and Server Usage

See *SimpleXMLRPCServer Example*.

22.27 xmlrpc.server — Basic XML-RPC servers

Source code: Lib/xmlrpc/server.py

The *xmlrpc.server* module provides a basic server framework for XML-RPC servers written in Python. Servers can either be free standing, using *SimpleXMLRPCServer*, or embedded in a CGI environment, using *CGIXMLRPCRequestHandler*.

> **Warning:** The *xmlrpc.server* module is not secure against maliciously constructed data. If you need to parse untrusted or unauthenticated data see *XML vulnerabilities*.

class xmlrpc.server.SimpleXMLRPCServer(*addr*, *requestHandler=SimpleXMLRPCRequestHandler*, *logRequests=True*, *allow_none=False*, *encoding=None*, *bind_and_activate=True*, *use_builtin_types=False*)

Create a new server instance. This class provides methods for registration of functions that can be called by the XML-RPC protocol. The *requestHandler* parameter should be a factory for request handler instances; it defaults to *SimpleXMLRPCRequestHandler*. The *addr* and *requestHandler* parameters are passed to the *socketserver.TCPServer* constructor. If *logRequests* is true (the default), requests will be logged; setting this parameter to false will turn off logging. The *allow_none* and *encoding* parameters are passed on to *xmlrpc.client* and control the XML-RPC responses that will be returned from the server. The *bind_and_activate* parameter controls whether `server_bind()` and `server_activate()` are called immediately by the constructor; it defaults to true. Setting it to false allows code to manipulate the *allow_reuse_address* class variable before the address is bound. The *use_builtin_types* parameter is passed to the *loads()* function and controls which types are processed when date/times values or binary data are received; it defaults to false.

Changed in version 3.3: The *use_builtin_types* flag was added.

class xmlrpc.server.CGIXMLRPCRequestHandler(*allow_none=False*, *encoding=None*, *use_builtin_types=False*)

Create a new instance to handle XML-RPC requests in a CGI environment. The *allow_none* and *encoding* parameters are passed on to *xmlrpc.client* and control the XML-RPC responses that will be returned from the server. The *use_builtin_types* parameter is passed to the *loads()* function and controls which types are processed when date/times values or binary data are received; it defaults to false.

Changed in version 3.3: The *use_builtin_types* flag was added.

class xmlrpc.server.SimpleXMLRPCRequestHandler

Create a new request handler instance. This request handler supports `POST` requests and modifies logging so that the *logRequests* parameter to the *SimpleXMLRPCServer* constructor parameter is honored.

22.27.1 SimpleXMLRPCServer Objects

The *SimpleXMLRPCServer* class is based on *socketserver.TCPServer* and provides a means of creating simple, stand alone XML-RPC servers.

SimpleXMLRPCServer.**register_function**(*function=None*, *name=None*)
Register a function that can respond to XML-RPC requests. If *name* is given, it will be the method name associated with *function*, otherwise `function.__name__` will be used. *name* is a string, and may contain characters not legal in Python identifiers, including the period character.

This method can also be used as a decorator. When used as a decorator, *name* can only be given as a keyword argument to register *function* under *name*. If no *name* is given, `function.__name__` will be used.

Changed in version 3.7: *register_function()* can be used as a decorator.

SimpleXMLRPCServer.**register_instance**(*instance*, *allow_dotted_names=False*)
Register an object which is used to expose method names which have not been registered using *register_function()*. If *instance* contains a `_dispatch()` method, it is called with the requested method name and the parameters from the request. Its API is `def _dispatch(self, method, params)` (note that *params* does not represent a variable argument list). If it calls an underlying function to perform its task, that function is called as `func(*params)`, expanding the parameter list. The return value from `_dispatch()` is returned to the client as the result. If *instance* does not have a `_dispatch()` method, it is searched for an attribute matching the name of the requested method.

If the optional *allow_dotted_names* argument is true and the instance does not have a `_dispatch()` method, then if the requested method name contains periods, each component of the method name is searched for individually, with the effect that a simple hierarchical search is performed. The value found from this search is then called with the parameters from the request, and the return value is passed back to the client.

> **Warning:** Enabling the *allow_dotted_names* option allows intruders to access your module's global variables and may allow intruders to execute arbitrary code on your machine. Only use this option on a secure, closed network.

SimpleXMLRPCServer.**register_introspection_functions**()
Registers the XML-RPC introspection functions `system.listMethods`, `system.methodHelp` and `system.methodSignature`.

SimpleXMLRPCServer.**register_multicall_functions**()
Registers the XML-RPC multicall function system.multicall.

SimpleXMLRPCRequestHandler.**rpc_paths**
An attribute value that must be a tuple listing valid path portions of the URL for receiving XML-RPC requests. Requests posted to other paths will result in a 404 "no such page" HTTP error. If this tuple is empty, all paths will be considered valid. The default value is `('/', '/RPC2')`.

SimpleXMLRPCServer Example

Server code:

```
from xmlrpc.server import SimpleXMLRPCServer
from xmlrpc.server import SimpleXMLRPCRequestHandler

# Restrict to a particular path.
class RequestHandler(SimpleXMLRPCRequestHandler):
```

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```
    rpc_paths = ('/RPC2',)

# Create server
with SimpleXMLRPCServer(('localhost', 8000),
                        requestHandler=RequestHandler) as server:
    server.register_introspection_functions()

    # Register pow() function; this will use the value of
    # pow.__name__ as the name, which is just 'pow'.
    server.register_function(pow)

    # Register a function under a different name
    def adder_function(x, y):
        return x + y
    server.register_function(adder_function, 'add')

    # Register an instance; all the methods of the instance are
    # published as XML-RPC methods (in this case, just 'mul').
    class MyFuncs:
        def mul(self, x, y):
            return x * y

    server.register_instance(MyFuncs())

    # Run the server's main loop
    server.serve_forever()
```

The following client code will call the methods made available by the preceding server:

```
import xmlrpc.client

s = xmlrpc.client.ServerProxy('http://localhost:8000')
print(s.pow(2,3))  # Returns 2**3 = 8
print(s.add(2,3))  # Returns 5
print(s.mul(5,2))  # Returns 5*2 = 10

# Print list of available methods
print(s.system.listMethods())
```

`register_function()` can also be used as a decorator. The previous server example can register functions in a decorator way:

```
from xmlrpc.server import SimpleXMLRPCServer
from xmlrpc.server import SimpleXMLRPCRequestHandler

class RequestHandler(SimpleXMLRPCRequestHandler):
    rpc_paths = ('/RPC2',)

with SimpleXMLRPCServer(('localhost', 8000),
                        requestHandler=RequestHandler) as server:
    server.register_introspection_functions()

    # Register pow() function; this will use the value of
    # pow.__name__ as the name, which is just 'pow'.
    server.register_function(pow)
```

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```
    # Register a function under a different name, using
    # register_function as a decorator. *name* can only be given
    # as a keyword argument.
    @server.register_function(name='add')
    def adder_function(x, y):
        return x + y

    # Register a function under function.__name__.
    @server.register_function
    def mul(x, y):
        return x * y

    server.serve_forever()
```

The following example included in the `Lib/xmlrpc/server.py` module shows a server allowing dotted names and registering a multicall function.

Warning: Enabling the *allow_dotted_names* option allows intruders to access your module's global variables and may allow intruders to execute arbitrary code on your machine. Only use this example only within a secure, closed network.

```
import datetime

class ExampleService:
    def getData(self):
        return '42'

    class currentTime:
        @staticmethod
        def getCurrentTime():
            return datetime.datetime.now()

with SimpleXMLRPCServer(("localhost", 8000)) as server:
    server.register_function(pow)
    server.register_function(lambda x,y: x+y, 'add')
    server.register_instance(ExampleService(), allow_dotted_names=True)
    server.register_multicall_functions()
    print('Serving XML-RPC on localhost port 8000')
    try:
        server.serve_forever()
    except KeyboardInterrupt:
        print("\nKeyboard interrupt received, exiting.")
        sys.exit(0)
```

This ExampleService demo can be invoked from the command line:

```
python -m xmlrpc.server
```

The client that interacts with the above server is included in *Lib/xmlrpc/client.py*:

```
server = ServerProxy("http://localhost:8000")

try:
    print(server.currentTime.getCurrentTime())
```

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```
except Error as v:
    print("ERROR", v)

multi = MultiCall(server)
multi.getData()
multi.pow(2,9)
multi.add(1,2)
try:
    for response in multi():
        print(response)
except Error as v:
    print("ERROR", v)
```

This client which interacts with the demo XMLRPC server can be invoked as:

```
python -m xmlrpc.client
```

22.27.2 CGIXMLRPCRequestHandler

The *CGIXMLRPCRequestHandler* class can be used to handle XML-RPC requests sent to Python CGI scripts.

CGIXMLRPCRequestHandler.register_function(*function=None*, *name=None*)
Register a function that can respond to XML-RPC requests. If *name* is given, it will be the method name associated with *function*, otherwise `function.__name__` will be used. *name* is a string, and may contain characters not legal in Python identifiers, including the period character.

This method can also be used as a decorator. When used as a decorator, *name* can only be given as a keyword argument to register *function* under *name*. If no *name* is given, `function.__name__` will be used.

Changed in version 3.7: *register_function()* can be used as a decorator.

CGIXMLRPCRequestHandler.register_instance(*instance*)
Register an object which is used to expose method names which have not been registered using *register_function()*. If instance contains a `_dispatch()` method, it is called with the requested method name and the parameters from the request; the return value is returned to the client as the result. If instance does not have a `_dispatch()` method, it is searched for an attribute matching the name of the requested method; if the requested method name contains periods, each component of the method name is searched for individually, with the effect that a simple hierarchical search is performed. The value found from this search is then called with the parameters from the request, and the return value is passed back to the client.

CGIXMLRPCRequestHandler.register_introspection_functions()
Register the XML-RPC introspection functions `system.listMethods`, `system.methodHelp` and `system.methodSignature`.

CGIXMLRPCRequestHandler.register_multicall_functions()
Register the XML-RPC multicall function `system.multicall`.

CGIXMLRPCRequestHandler.handle_request(*request_text=None*)
Handle an XML-RPC request. If *request_text* is given, it should be the POST data provided by the HTTP server, otherwise the contents of stdin will be used.

Example:

```
class MyFuncs:
    def mul(self, x, y):
        return x * y


handler = CGIXMLRPCRequestHandler()
handler.register_function(pow)
handler.register_function(lambda x,y: x+y, 'add')
handler.register_introspection_functions()
handler.register_instance(MyFuncs())
handler.handle_request()
```

22.27.3 Documenting XMLRPC server

These classes extend the above classes to serve HTML documentation in response to HTTP GET requests. Servers can either be free standing, using *DocXMLRPCServer*, or embedded in a CGI environment, using *DocCGIXMLRPCRequestHandler*.

class xmlrpc.server.**DocXMLRPCServer**(*addr*, *requestHandler=DocXMLRPCRequestHandler*, *logRequests=True*, *allow_none=False*, *encoding=None*, *bind_and_activate=True*, *use_builtin_types=True*)

Create a new server instance. All parameters have the same meaning as for *SimpleXMLRPCServer*; *requestHandler* defaults to *DocXMLRPCRequestHandler*.

Changed in version 3.3: The *use_builtin_types* flag was added.

class xmlrpc.server.**DocCGIXMLRPCRequestHandler**

Create a new instance to handle XML-RPC requests in a CGI environment.

class xmlrpc.server.**DocXMLRPCRequestHandler**

Create a new request handler instance. This request handler supports XML-RPC POST requests, documentation GET requests, and modifies logging so that the *logRequests* parameter to the *DocXMLRPCServer* constructor parameter is honored.

22.27.4 DocXMLRPCServer Objects

The *DocXMLRPCServer* class is derived from *SimpleXMLRPCServer* and provides a means of creating self-documenting, stand alone XML-RPC servers. HTTP POST requests are handled as XML-RPC method calls. HTTP GET requests are handled by generating pydoc-style HTML documentation. This allows a server to provide its own web-based documentation.

DocXMLRPCServer.**set_server_title**(*server_title*)

Set the title used in the generated HTML documentation. This title will be used inside the HTML "title" element.

DocXMLRPCServer.**set_server_name**(*server_name*)

Set the name used in the generated HTML documentation. This name will appear at the top of the generated documentation inside a "h1" element.

DocXMLRPCServer.**set_server_documentation**(*server_documentation*)

Set the description used in the generated HTML documentation. This description will appear as a paragraph, below the server name, in the documentation.

22.27.5 DocCGIXMLRPCRequestHandler

The *DocCGIXMLRPCRequestHandler* class is derived from *CGIXMLRPCRequestHandler* and provides a means of creating self-documenting, XML-RPC CGI scripts. HTTP POST requests are handled as XML-RPC method calls. HTTP GET requests are handled by generating pydoc-style HTML documentation. This allows a server to provide its own web-based documentation.

DocCGIXMLRPCRequestHandler.set_server_title(*server_title*)
Set the title used in the generated HTML documentation. This title will be used inside the HTML "title" element.

DocCGIXMLRPCRequestHandler.set_server_name(*server_name*)
Set the name used in the generated HTML documentation. This name will appear at the top of the generated documentation inside a "h1" element.

DocCGIXMLRPCRequestHandler.set_server_documentation(*server_documentation*)
Set the description used in the generated HTML documentation. This description will appear as a paragraph, below the server name, in the documentation.

22.28 ipaddress — IPv4/IPv6 manipulation library

Source code: Lib/ipaddress.py

---

ipaddress provides the capabilities to create, manipulate and operate on IPv4 and IPv6 addresses and networks.

The functions and classes in this module make it straightforward to handle various tasks related to IP addresses, including checking whether or not two hosts are on the same subnet, iterating over all hosts in a particular subnet, checking whether or not a string represents a valid IP address or network definition, and so on.

This is the full module API reference—for an overview and introduction, see ipaddress-howto.

New in version 3.3.

22.28.1 Convenience factory functions

The *ipaddress* module provides factory functions to conveniently create IP addresses, networks and interfaces:

ipaddress.ip_address(*address*)
Return an *IPv4Address* or *IPv6Address* object depending on the IP address passed as argument. Either IPv4 or IPv6 addresses may be supplied; integers less than 2**32 will be considered to be IPv4 by default. A *ValueError* is raised if *address* does not represent a valid IPv4 or IPv6 address.

```
>>> ipaddress.ip_address('192.168.0.1')
IPv4Address('192.168.0.1')
>>> ipaddress.ip_address('2001:db8::')
IPv6Address('2001:db8::')
```

ipaddress.ip_network(*address*, *strict=True*)
Return an *IPv4Network* or *IPv6Network* object depending on the IP address passed as argument. *address* is a string or integer representing the IP network. Either IPv4 or IPv6 networks may be supplied; integers less than 2**32 will be considered to be IPv4 by default. *strict* is passed to *IPv4Network* or *IPv6Network* constructor. A *ValueError* is raised if *address* does not represent a valid IPv4 or IPv6 address, or if the network has host bits set.

```
>>> ipaddress.ip_network('192.168.0.0/28')
IPv4Network('192.168.0.0/28')
```

ipaddress.ip_interface(*address*)
Return an *IPv4Interface* or *IPv6Interface* object depending on the IP address passed as argument. *address* is a string or integer representing the IP address. Either IPv4 or IPv6 addresses may be supplied; integers less than 2**32 will be considered to be IPv4 by default. A *ValueError* is raised if *address* does not represent a valid IPv4 or IPv6 address.

One downside of these convenience functions is that the need to handle both IPv4 and IPv6 formats means that error messages provide minimal information on the precise error, as the functions don't know whether the IPv4 or IPv6 format was intended. More detailed error reporting can be obtained by calling the appropriate version specific class constructors directly.

22.28.2 IP Addresses

Address objects

The *IPv4Address* and *IPv6Address* objects share a lot of common attributes. Some attributes that are only meaningful for IPv6 addresses are also implemented by *IPv4Address* objects, in order to make it easier to write code that handles both IP versions correctly. Address objects are *hashable*, so they can be used as keys in dictionaries.

class ipaddress.IPv4Address(*address*)
Construct an IPv4 address. An *AddressValueError* is raised if *address* is not a valid IPv4 address.

The following constitutes a valid IPv4 address:

1. A string in decimal-dot notation, consisting of four decimal integers in the inclusive range 0–255, separated by dots (e.g. `192.168.0.1`). Each integer represents an octet (byte) in the address. Leading zeroes are tolerated only for values less than 8 (as there is no ambiguity between the decimal and octal interpretations of such strings).
2. An integer that fits into 32 bits.
3. An integer packed into a *bytes* object of length 4 (most significant octet first).

```
>>> ipaddress.IPv4Address('192.168.0.1')
IPv4Address('192.168.0.1')
>>> ipaddress.IPv4Address(3232235521)
IPv4Address('192.168.0.1')
>>> ipaddress.IPv4Address(b'\xC0\xA8\x00\x01')
IPv4Address('192.168.0.1')
```

version
The appropriate version number: `4` for IPv4, `6` for IPv6.

max_prefixlen
The total number of bits in the address representation for this version: `32` for IPv4, `128` for IPv6.

The prefix defines the number of leading bits in an address that are compared to determine whether or not an address is part of a network.

compressed

exploded
The string representation in dotted decimal notation. Leading zeroes are never included in the representation.

As IPv4 does not define a shorthand notation for addresses with octets set to zero, these two attributes are always the same as `str(addr)` for IPv4 addresses. Exposing these attributes makes it easier to write display code that can handle both IPv4 and IPv6 addresses.

packed
The binary representation of this address - a *bytes* object of the appropriate length (most significant octet first). This is 4 bytes for IPv4 and 16 bytes for IPv6.

reverse_pointer
The name of the reverse DNS PTR record for the IP address, e.g.:

```
>>> ipaddress.ip_address("127.0.0.1").reverse_pointer
'1.0.0.127.in-addr.arpa'
>>> ipaddress.ip_address("2001:db8::1").reverse_pointer
'1.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.8.b.d.0.1.0.0.2.ip6.arpa'
```

This is the name that could be used for performing a PTR lookup, not the resolved hostname itself.

New in version 3.5.

is_multicast
`True` if the address is reserved for multicast use. See **RFC 3171** (for IPv4) or **RFC 2373** (for IPv6).

is_private
`True` if the address is allocated for private networks. See iana-ipv4-special-registry (for IPv4) or iana-ipv6-special-registry (for IPv6).

is_global
`True` if the address is allocated for public networks. See iana-ipv4-special-registry (for IPv4) or iana-ipv6-special-registry (for IPv6).

New in version 3.4.

is_unspecified
`True` if the address is unspecified. See **RFC 5735** (for IPv4) or **RFC 2373** (for IPv6).

is_reserved
`True` if the address is otherwise IETF reserved.

is_loopback
`True` if this is a loopback address. See **RFC 3330** (for IPv4) or **RFC 2373** (for IPv6).

is_link_local
`True` if the address is reserved for link-local usage. See **RFC 3927**.

class ipaddress.IPv6Address(*address*)
Construct an IPv6 address. An *AddressValueError* is raised if *address* is not a valid IPv6 address.

The following constitutes a valid IPv6 address:

1. A string consisting of eight groups of four hexadecimal digits, each group representing 16 bits. The groups are separated by colons. This describes an *exploded* (longhand) notation. The string can also be *compressed* (shorthand notation) by various means. See **RFC 4291** for details. For example, `"0000:0000:0000:0000:0000:0abc:0007:0def"` can be compressed to `"::abc:7:def"`.
2. An integer that fits into 128 bits.
3. An integer packed into a *bytes* object of length 16, big-endian.

```
>>> ipaddress.IPv6Address('2001:db8::1000')
IPv6Address('2001:db8::1000')
```

compressed

The short form of the address representation, with leading zeroes in groups omitted and the longest sequence of groups consisting entirely of zeroes collapsed to a single empty group.

This is also the value returned by `str(addr)` for IPv6 addresses.

exploded

The long form of the address representation, with all leading zeroes and groups consisting entirely of zeroes included.

For the following attributes, see the corresponding documentation of the *IPv4Address* class:

packed

reverse_pointer

version

max_prefixlen

is_multicast

is_private

is_global

is_unspecified

is_reserved

is_loopback

is_link_local
New in version 3.4: is_global

is_site_local
`True` if the address is reserved for site-local usage. Note that the site-local address space has been deprecated by **RFC 3879**. Use *is_private* to test if this address is in the space of unique local addresses as defined by **RFC 4193**.

ipv4_mapped
For addresses that appear to be IPv4 mapped addresses (starting with `::FFFF/96`), this property will report the embedded IPv4 address. For any other address, this property will be `None`.

sixtofour
For addresses that appear to be 6to4 addresses (starting with `2002::/16`) as defined by **RFC 3056**, this property will report the embedded IPv4 address. For any other address, this property will be `None`.

teredo
For addresses that appear to be Teredo addresses (starting with `2001::/32`) as defined by **RFC 4380**, this property will report the embedded `(server, client)` IP address pair. For any other address, this property will be `None`.

Conversion to Strings and Integers

To interoperate with networking interfaces such as the socket module, addresses must be converted to strings or integers. This is handled using the *str()* and *int()* builtin functions:

```
>>> str(ipaddress.IPv4Address('192.168.0.1'))
'192.168.0.1'
>>> int(ipaddress.IPv4Address('192.168.0.1'))
3232235521
```

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```
>>> str(ipaddress.IPv6Address('::1'))
'::1'
>>> int(ipaddress.IPv6Address('::1'))
1
```

Operators

Address objects support some operators. Unless stated otherwise, operators can only be applied between compatible objects (i.e. IPv4 with IPv4, IPv6 with IPv6).

Comparison operators

Address objects can be compared with the usual set of comparison operators. Some examples:

```
>>> IPv4Address('127.0.0.2') > IPv4Address('127.0.0.1')
True
>>> IPv4Address('127.0.0.2') == IPv4Address('127.0.0.1')
False
>>> IPv4Address('127.0.0.2') != IPv4Address('127.0.0.1')
True
```

Arithmetic operators

Integers can be added to or subtracted from address objects. Some examples:

```
>>> IPv4Address('127.0.0.2') + 3
IPv4Address('127.0.0.5')
>>> IPv4Address('127.0.0.2') - 3
IPv4Address('126.255.255.255')
>>> IPv4Address('255.255.255.255') + 1
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ipaddress.AddressValueError: 4294967296 (>= 2**32) is not permitted as an IPv4 address
```

22.28.3 IP Network definitions

The *IPv4Network* and *IPv6Network* objects provide a mechanism for defining and inspecting IP network definitions. A network definition consists of a *mask* and a *network address*, and as such defines a range of IP addresses that equal the network address when masked (binary AND) with the mask. For example, a network definition with the mask `255.255.255.0` and the network address `192.168.1.0` consists of IP addresses in the inclusive range `192.168.1.0` to `192.168.1.255`.

Prefix, net mask and host mask

There are several equivalent ways to specify IP network masks. A *prefix* `/<nbits>` is a notation that denotes how many high-order bits are set in the network mask. A *net mask* is an IP address with some number of high-order bits set. Thus the prefix `/24` is equivalent to the net mask `255.255.255.0` in IPv4, or `ffff:ff00::` in IPv6. In addition, a *host mask* is the logical inverse of a *net mask*, and is sometimes used (for example in Cisco access control lists) to denote a network mask. The host mask equivalent to `/24` in IPv4 is `0.0.0.255`.

Network objects

All attributes implemented by address objects are implemented by network objects as well. In addition, network objects implement additional attributes. All of these are common between *IPv4Network* and *IPv6Network*, so to avoid duplication they are only documented for *IPv4Network*. Network objects are *hashable*, so they can be used as keys in dictionaries.

class ipaddress.IPv4Network(*address*, *strict=True*)

Construct an IPv4 network definition. *address* can be one of the following:

1. A string consisting of an IP address and an optional mask, separated by a slash (`/`). The IP address is the network address, and the mask can be either a single number, which means it's a *prefix*, or a string representation of an IPv4 address. If it's the latter, the mask is interpreted as a *net mask* if it starts with a non-zero field, or as a *host mask* if it starts with a zero field, with the single exception of an all-zero mask which is treated as a *net mask*. If no mask is provided, it's considered to be `/32`.

   For example, the following *address* specifications are equivalent: `192.168.1.0/24`, `192.168.1.0/255.255.255.0` and `192.168.1.0/0.0.0.255`.

2. An integer that fits into 32 bits. This is equivalent to a single-address network, with the network address being *address* and the mask being `/32`.

3. An integer packed into a *bytes* object of length 4, big-endian. The interpretation is similar to an integer *address*.

4. A two-tuple of an address description and a netmask, where the address description is either a string, a 32-bits integer, a 4-bytes packed integer, or an existing IPv4Address object; and the netmask is either an integer representing the prefix length (e.g. `24`) or a string representing the prefix mask (e.g. `255.255.255.0`).

An *AddressValueError* is raised if *address* is not a valid IPv4 address. A *NetmaskValueError* is raised if the mask is not valid for an IPv4 address.

If *strict* is `True` and host bits are set in the supplied address, then *ValueError* is raised. Otherwise, the host bits are masked out to determine the appropriate network address.

Unless stated otherwise, all network methods accepting other network/address objects will raise *TypeError* if the argument's IP version is incompatible to `self`.

Changed in version 3.5: Added the two-tuple form for the *address* constructor parameter.

version

max_prefixlen

Refer to the corresponding attribute documentation in *IPv4Address*.

is_multicast

is_private

is_unspecified

is_reserved

is_loopback

is_link_local

These attributes are true for the network as a whole if they are true for both the network address and the broadcast address.

network_address

The network address for the network. The network address and the prefix length together uniquely define a network.

broadcast_address
The broadcast address for the network. Packets sent to the broadcast address should be received by every host on the network.

hostmask
The host mask, as an *IPv4Address* object.

netmask
The net mask, as an *IPv4Address* object.

with_prefixlen

compressed

exploded
A string representation of the network, with the mask in prefix notation.

`with_prefixlen` and `compressed` are always the same as `str(network)`. `exploded` uses the exploded form the network address.

with_netmask
A string representation of the network, with the mask in net mask notation.

with_hostmask
A string representation of the network, with the mask in host mask notation.

num_addresses
The total number of addresses in the network.

prefixlen
Length of the network prefix, in bits.

hosts()
Returns an iterator over the usable hosts in the network. The usable hosts are all the IP addresses that belong to the network, except the network address itself and the network broadcast address. For networks with a mask length of 31, the network address and network broadcast address are also included in the result.

```
>>> list(ip_network('192.0.2.0/29').hosts())
[IPv4Address('192.0.2.1'), IPv4Address('192.0.2.2'),
 IPv4Address('192.0.2.3'), IPv4Address('192.0.2.4'),
 IPv4Address('192.0.2.5'), IPv4Address('192.0.2.6')]
>>> list(ip_network('192.0.2.0/31').hosts())
[IPv4Address('192.0.2.0'), IPv4Address('192.0.2.1')]
```

overlaps(*other*)
`True` if this network is partly or wholly contained in *other* or *other* is wholly contained in this network.

address_exclude(*network*)
Computes the network definitions resulting from removing the given *network* from this one. Returns an iterator of network objects. Raises *ValueError* if *network* is not completely contained in this network.

```
>>> n1 = ip_network('192.0.2.0/28')
>>> n2 = ip_network('192.0.2.1/32')
>>> list(n1.address_exclude(n2))
[IPv4Network('192.0.2.8/29'), IPv4Network('192.0.2.4/30'),
 IPv4Network('192.0.2.2/31'), IPv4Network('192.0.2.0/32')]
```

subnets(*prefixlen_diff=1*, *new_prefix=None*)
The subnets that join to make the current network definition, depending on the argument values.

prefixlen_diff is the amount our prefix length should be increased by. *new_prefix* is the desired new prefix of the subnets; it must be larger than our prefix. One and only one of *prefixlen_diff* and *new_prefix* must be set. Returns an iterator of network objects.

```
>>> list(ip_network('192.0.2.0/24').subnets())
[IPv4Network('192.0.2.0/25'), IPv4Network('192.0.2.128/25')]
>>> list(ip_network('192.0.2.0/24').subnets(prefixlen_diff=2))
[IPv4Network('192.0.2.0/26'), IPv4Network('192.0.2.64/26'),
 IPv4Network('192.0.2.128/26'), IPv4Network('192.0.2.192/26')]
>>> list(ip_network('192.0.2.0/24').subnets(new_prefix=26))
[IPv4Network('192.0.2.0/26'), IPv4Network('192.0.2.64/26'),
 IPv4Network('192.0.2.128/26'), IPv4Network('192.0.2.192/26')]
>>> list(ip_network('192.0.2.0/24').subnets(new_prefix=23))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
    raise ValueError('new prefix must be longer')
ValueError: new prefix must be longer
>>> list(ip_network('192.0.2.0/24').subnets(new_prefix=25))
[IPv4Network('192.0.2.0/25'), IPv4Network('192.0.2.128/25')]
```

supernet(*prefixlen_diff=1*, *new_prefix=None*)

The supernet containing this network definition, depending on the argument values. *prefixlen_diff* is the amount our prefix length should be decreased by. *new_prefix* is the desired new prefix of the supernet; it must be smaller than our prefix. One and only one of *prefixlen_diff* and *new_prefix* must be set. Returns a single network object.

```
>>> ip_network('192.0.2.0/24').supernet()
IPv4Network('192.0.2.0/23')
>>> ip_network('192.0.2.0/24').supernet(prefixlen_diff=2)
IPv4Network('192.0.0.0/22')
>>> ip_network('192.0.2.0/24').supernet(new_prefix=20)
IPv4Network('192.0.0.0/20')
```

subnet_of(*other*)

Returns *True* if this network is a subnet of *other*.

```
>>> a = ip_network('192.168.1.0/24')
>>> b = ip_network('192.168.1.128/30')
>>> b.subnet_of(a)
True
```

New in version 3.7.

supernet_of(*other*)

Returns *True* if this network is a supernet of *other*.

```
>>> a = ip_network('192.168.1.0/24')
>>> b = ip_network('192.168.1.128/30')
>>> a.supernet_of(b)
True
```

New in version 3.7.

compare_networks(*other*)

Compare this network to *other*. In this comparison only the network addresses are considered; host bits aren't. Returns either `-1`, `0` or `1`.

```
>>> ip_network('192.0.2.1/32').compare_networks(ip_network('192.0.2.2/32'))
-1
>>> ip_network('192.0.2.1/32').compare_networks(ip_network('192.0.2.0/32'))
1
>>> ip_network('192.0.2.1/32').compare_networks(ip_network('192.0.2.1/32'))
0
```

Deprecated since version 3.7: It uses the same ordering and comparison algorithm as "<", "==", and ">"

class ipaddress.IPv6Network(*address*, *strict=True*)

Construct an IPv6 network definition. *address* can be one of the following:

1. A string consisting of an IP address and an optional prefix length, separated by a slash (/). The IP address is the network address, and the prefix length must be a single number, the *prefix*. If no prefix length is provided, it's considered to be /128.

   Note that currently expanded netmasks are not supported. That means 2001:db00::0/24 is a valid argument while 2001:db00::0/ffff:ff00:: not.

2. An integer that fits into 128 bits. This is equivalent to a single-address network, with the network address being *address* and the mask being /128.

3. An integer packed into a *bytes* object of length 16, big-endian. The interpretation is similar to an integer *address*.

4. A two-tuple of an address description and a netmask, where the address description is either a string, a 128-bits integer, a 16-bytes packed integer, or an existing IPv6Address object; and the netmask is an integer representing the prefix length.

An *AddressValueError* is raised if *address* is not a valid IPv6 address. A *NetmaskValueError* is raised if the mask is not valid for an IPv6 address.

If *strict* is True and host bits are set in the supplied address, then *ValueError* is raised. Otherwise, the host bits are masked out to determine the appropriate network address.

Changed in version 3.5: Added the two-tuple form for the *address* constructor parameter.

version

max_prefixlen

is_multicast

is_private

is_unspecified

is_reserved

is_loopback

is_link_local

network_address

broadcast_address

hostmask

netmask

with_prefixlen

compressed

exploded

with_netmask

with_hostmask

num_addresses

prefixlen

hosts()
Returns an iterator over the usable hosts in the network. The usable hosts are all the IP addresses that belong to the network, except the Subnet-Router anycast address. For networks with a mask length of 127, the Subnet-Router anycast address is also included in the result.

overlaps(*other*)

address_exclude(*network*)

subnets(*prefixlen_diff=1*, *new_prefix=None*)

supernet(*prefixlen_diff=1*, *new_prefix=None*)

subnet_of(*other*)

supernet_of(*other*)

compare_networks(*other*)
Refer to the corresponding attribute documentation in *IPv4Network*.

is_site_local
These attribute is true for the network as a whole if it is true for both the network address and the broadcast address.

Operators

Network objects support some operators. Unless stated otherwise, operators can only be applied between compatible objects (i.e. IPv4 with IPv4, IPv6 with IPv6).

Logical operators

Network objects can be compared with the usual set of logical operators. Network objects are ordered first by network address, then by net mask.

Iteration

Network objects can be iterated to list all the addresses belonging to the network. For iteration, *all* hosts are returned, including unusable hosts (for usable hosts, use the *hosts()* method). An example:

```
>>> for addr in IPv4Network('192.0.2.0/28'):
...     addr
...
IPv4Address('192.0.2.0')
IPv4Address('192.0.2.1')
IPv4Address('192.0.2.2')
IPv4Address('192.0.2.3')
IPv4Address('192.0.2.4')
IPv4Address('192.0.2.5')
IPv4Address('192.0.2.6')
IPv4Address('192.0.2.7')
IPv4Address('192.0.2.8')
```

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```
IPv4Address('192.0.2.9')
IPv4Address('192.0.2.10')
IPv4Address('192.0.2.11')
IPv4Address('192.0.2.12')
IPv4Address('192.0.2.13')
IPv4Address('192.0.2.14')
IPv4Address('192.0.2.15')
```

Networks as containers of addresses

Network objects can act as containers of addresses. Some examples:

```
>>> IPv4Network('192.0.2.0/28')[0]
IPv4Address('192.0.2.0')
>>> IPv4Network('192.0.2.0/28')[15]
IPv4Address('192.0.2.15')
>>> IPv4Address('192.0.2.6') in IPv4Network('192.0.2.0/28')
True
>>> IPv4Address('192.0.3.6') in IPv4Network('192.0.2.0/28')
False
```

22.28.4 Interface objects

Interface objects are *hashable*, so they can be used as keys in dictionaries.

class ipaddress.**IPv4Interface**(*address*)

Construct an IPv4 interface. The meaning of *address* is as in the constructor of *IPv4Network*, except that arbitrary host addresses are always accepted.

IPv4Interface is a subclass of *IPv4Address*, so it inherits all the attributes from that class. In addition, the following attributes are available:

ip

The address (*IPv4Address*) without network information.

```
>>> interface = IPv4Interface('192.0.2.5/24')
>>> interface.ip
IPv4Address('192.0.2.5')
```

network

The network (*IPv4Network*) this interface belongs to.

```
>>> interface = IPv4Interface('192.0.2.5/24')
>>> interface.network
IPv4Network('192.0.2.0/24')
```

with_prefixlen

A string representation of the interface with the mask in prefix notation.

```
>>> interface = IPv4Interface('192.0.2.5/24')
>>> interface.with_prefixlen
'192.0.2.5/24'
```

with_netmask

A string representation of the interface with the network as a net mask.

```
>>> interface = IPv4Interface('192.0.2.5/24')
>>> interface.with_netmask
'192.0.2.5/255.255.255.0'
```

with_hostmask
A string representation of the interface with the network as a host mask.

```
>>> interface = IPv4Interface('192.0.2.5/24')
>>> interface.with_hostmask
'192.0.2.5/0.0.0.255'
```

class ipaddress.IPv6Interface(*address*)
Construct an IPv6 interface. The meaning of *address* is as in the constructor of *IPv6Network*, except that arbitrary host addresses are always accepted.

IPv6Interface is a subclass of *IPv6Address*, so it inherits all the attributes from that class. In addition, the following attributes are available:

ip

network

with_prefixlen

with_netmask

with_hostmask
Refer to the corresponding attribute documentation in *IPv4Interface*.

Operators

Interface objects support some operators. Unless stated otherwise, operators can only be applied between compatible objects (i.e. IPv4 with IPv4, IPv6 with IPv6).

Logical operators

Interface objects can be compared with the usual set of logical operators.

For equality comparison (== and !=), both the IP address and network must be the same for the objects to be equal. An interface will not compare equal to any address or network object.

For ordering (<, >, etc) the rules are different. Interface and address objects with the same IP version can be compared, and the address objects will always sort before the interface objects. Two interface objects are first compared by their networks and, if those are the same, then by their IP addresses.

22.28.5 Other Module Level Functions

The module also provides the following module level functions:

ipaddress.v4_int_to_packed(*address*)
Represent an address as 4 packed bytes in network (big-endian) order. *address* is an integer representation of an IPv4 IP address. A *ValueError* is raised if the integer is negative or too large to be an IPv4 IP address.

```
>>> ipaddress.ip_address(3221225985)
IPv4Address('192.0.2.1')
>>> ipaddress.v4_int_to_packed(3221225985)
b'\xc0\x00\x02\x01'
```

ipaddress.v6_int_to_packed(*address*)
Represent an address as 16 packed bytes in network (big-endian) order. *address* is an integer representation of an IPv6 IP address. A *ValueError* is raised if the integer is negative or too large to be an IPv6 IP address.

ipaddress.summarize_address_range(*first*, *last*)
Return an iterator of the summarized network range given the first and last IP addresses. *first* is the first *IPv4Address* or *IPv6Address* in the range and *last* is the last *IPv4Address* or *IPv6Address* in the range. A *TypeError* is raised if *first* or *last* are not IP addresses or are not of the same version. A *ValueError* is raised if *last* is not greater than *first* or if *first* address version is not 4 or 6.

```
>>> [ipaddr for ipaddr in ipaddress.summarize_address_range(
...    ipaddress.IPv4Address('192.0.2.0'),
...    ipaddress.IPv4Address('192.0.2.130'))]
[IPv4Network('192.0.2.0/25'), IPv4Network('192.0.2.128/31'), IPv4Network('192.0.2.130/32')]
```

ipaddress.collapse_addresses(*addresses*)
Return an iterator of the collapsed *IPv4Network* or *IPv6Network* objects. *addresses* is an iterator of *IPv4Network* or *IPv6Network* objects. A *TypeError* is raised if *addresses* contains mixed version objects.

```
>>> [ipaddr for ipaddr in
... ipaddress.collapse_addresses([ipaddress.IPv4Network('192.0.2.0/25'),
... ipaddress.IPv4Network('192.0.2.128/25')])]
[IPv4Network('192.0.2.0/24')]
```

ipaddress.get_mixed_type_key(*obj*)
Return a key suitable for sorting between networks and addresses. Address and Network objects are not sortable by default; they're fundamentally different, so the expression:

```
IPv4Address('192.0.2.0') <= IPv4Network('192.0.2.0/24')
```

doesn't make sense. There are some times however, where you may wish to have *ipaddress* sort these anyway. If you need to do this, you can use this function as the *key* argument to *sorted()*.

obj is either a network or address object.

22.28.6 Custom Exceptions

To support more specific error reporting from class constructors, the module defines the following exceptions:

exception ipaddress.AddressValueError(*ValueError*)
Any value error related to the address.

exception ipaddress.NetmaskValueError(*ValueError*)
Any value error related to the net mask.

CHAPTER

TWENTYTHREE

MULTIMEDIA SERVICES

The modules described in this chapter implement various algorithms or interfaces that are mainly useful for multimedia applications. They are available at the discretion of the installation. Here's an overview:

23.1 audioop — Manipulate raw audio data

The *audioop* module contains some useful operations on sound fragments. It operates on sound fragments consisting of signed integer samples 8, 16, 24 or 32 bits wide, stored in *bytes-like objects*. All scalar items are integers, unless specified otherwise.

Changed in version 3.4: Support for 24-bit samples was added. All functions now accept any *bytes-like object*. String input now results in an immediate error.

This module provides support for a-LAW, u-LAW and Intel/DVI ADPCM encodings.

A few of the more complicated operations only take 16-bit samples, otherwise the sample size (in bytes) is always a parameter of the operation.

The module defines the following variables and functions:

exception audioop.error
This exception is raised on all errors, such as unknown number of bytes per sample, etc.

audioop.add(*fragment1*, *fragment2*, *width*)
Return a fragment which is the addition of the two samples passed as parameters. *width* is the sample width in bytes, either `1`, `2`, `3` or `4`. Both fragments should have the same length. Samples are truncated in case of overflow.

audioop.adpcm2lin(*adpcmfragment*, *width*, *state*)
Decode an Intel/DVI ADPCM coded fragment to a linear fragment. See the description of *lin2adpcm()* for details on ADPCM coding. Return a tuple `(sample, newstate)` where the sample has the width specified in *width*.

audioop.alaw2lin(*fragment*, *width*)
Convert sound fragments in a-LAW encoding to linearly encoded sound fragments. a-LAW encoding always uses 8 bits samples, so *width* refers only to the sample width of the output fragment here.

audioop.avg(*fragment*, *width*)
Return the average over all samples in the fragment.

audioop.avgpp(*fragment*, *width*)
Return the average peak-peak value over all samples in the fragment. No filtering is done, so the usefulness of this routine is questionable.

audioop.**bias**(*fragment*, *width*, *bias*)
Return a fragment that is the original fragment with a bias added to each sample. Samples wrap around in case of overflow.

audioop.**byteswap**(*fragment*, *width*)
"Byteswap" all samples in a fragment and returns the modified fragment. Converts big-endian samples to little-endian and vice versa.

New in version 3.4.

audioop.**cross**(*fragment*, *width*)
Return the number of zero crossings in the fragment passed as an argument.

audioop.**findfactor**(*fragment*, *reference*)
Return a factor *F* such that `rms(add(fragment, mul(reference, -F)))` is minimal, i.e., return the factor with which you should multiply *reference* to make it match as well as possible to *fragment*. The fragments should both contain 2-byte samples.

The time taken by this routine is proportional to `len(fragment)`.

audioop.**findfit**(*fragment*, *reference*)
Try to match *reference* as well as possible to a portion of *fragment* (which should be the longer fragment). This is (conceptually) done by taking slices out of *fragment*, using *findfactor()* to compute the best match, and minimizing the result. The fragments should both contain 2-byte samples. Return a tuple `(offset, factor)` where *offset* is the (integer) offset into *fragment* where the optimal match started and *factor* is the (floating-point) factor as per *findfactor()*.

audioop.**findmax**(*fragment*, *length*)
Search *fragment* for a slice of length *length* samples (not bytes!) with maximum energy, i.e., return *i* for which `rms(fragment[i*2:(i+length)*2])` is maximal. The fragments should both contain 2-byte samples.

The routine takes time proportional to `len(fragment)`.

audioop.**getsample**(*fragment*, *width*, *index*)
Return the value of sample *index* from the fragment.

audioop.**lin2adpcm**(*fragment*, *width*, *state*)
Convert samples to 4 bit Intel/DVI ADPCM encoding. ADPCM coding is an adaptive coding scheme, whereby each 4 bit number is the difference between one sample and the next, divided by a (varying) step. The Intel/DVI ADPCM algorithm has been selected for use by the IMA, so it may well become a standard.

state is a tuple containing the state of the coder. The coder returns a tuple `(adpcmfrag, newstate)`, and the *newstate* should be passed to the next call of *lin2adpcm()*. In the initial call, `None` can be passed as the state. *adpcmfrag* is the ADPCM coded fragment packed 2 4-bit values per byte.

audioop.**lin2alaw**(*fragment*, *width*)
Convert samples in the audio fragment to a-LAW encoding and return this as a bytes object. a-LAW is an audio encoding format whereby you get a dynamic range of about 13 bits using only 8 bit samples. It is used by the Sun audio hardware, among others.

audioop.**lin2lin**(*fragment*, *width*, *newwidth*)
Convert samples between 1-, 2-, 3- and 4-byte formats.

Note: In some audio formats, such as .WAV files, 16, 24 and 32 bit samples are signed, but 8 bit samples are unsigned. So when converting to 8 bit wide samples for these formats, you need to also add 128 to the result:

```
new_frames = audioop.lin2lin(frames, old_width, 1)
new_frames = audioop.bias(new_frames, 1, 128)
```

The same, in reverse, has to be applied when converting from 8 to 16, 24 or 32 bit width samples.

audioop.lin2ulaw(*fragment*, *width*)
Convert samples in the audio fragment to u-LAW encoding and return this as a bytes object. u-LAW is an audio encoding format whereby you get a dynamic range of about 14 bits using only 8 bit samples. It is used by the Sun audio hardware, among others.

audioop.max(*fragment*, *width*)
Return the maximum of the *absolute value* of all samples in a fragment.

audioop.maxpp(*fragment*, *width*)
Return the maximum peak-peak value in the sound fragment.

audioop.minmax(*fragment*, *width*)
Return a tuple consisting of the minimum and maximum values of all samples in the sound fragment.

audioop.mul(*fragment*, *width*, *factor*)
Return a fragment that has all samples in the original fragment multiplied by the floating-point value *factor*. Samples are truncated in case of overflow.

audioop.ratecv(*fragment*, *width*, *nchannels*, *inrate*, *outrate*, *state*[, *weightA*[, *weightB*]])
Convert the frame rate of the input fragment.

state is a tuple containing the state of the converter. The converter returns a tuple `(newfragment, newstate)`, and *newstate* should be passed to the next call of *ratecv()*. The initial call should pass `None` as the state.

The *weightA* and *weightB* arguments are parameters for a simple digital filter and default to `1` and `0` respectively.

audioop.reverse(*fragment*, *width*)
Reverse the samples in a fragment and returns the modified fragment.

audioop.rms(*fragment*, *width*)
Return the root-mean-square of the fragment, i.e. `sqrt(sum(S_i^2)/n)`.

This is a measure of the power in an audio signal.

audioop.tomono(*fragment*, *width*, *lfactor*, *rfactor*)
Convert a stereo fragment to a mono fragment. The left channel is multiplied by *lfactor* and the right channel by *rfactor* before adding the two channels to give a mono signal.

audioop.tostereo(*fragment*, *width*, *lfactor*, *rfactor*)
Generate a stereo fragment from a mono fragment. Each pair of samples in the stereo fragment are computed from the mono sample, whereby left channel samples are multiplied by *lfactor* and right channel samples by *rfactor*.

audioop.ulaw2lin(*fragment*, *width*)
Convert sound fragments in u-LAW encoding to linearly encoded sound fragments. u-LAW encoding always uses 8 bits samples, so *width* refers only to the sample width of the output fragment here.

Note that operations such as *mul()* or *max()* make no distinction between mono and stereo fragments, i.e. all samples are treated equal. If this is a problem the stereo fragment should be split into two mono fragments first and recombined later. Here is an example of how to do that:

```
def mul_stereo(sample, width, lfactor, rfactor):
    lsample = audioop.tomono(sample, width, 1, 0)
    rsample = audioop.tomono(sample, width, 0, 1)
    lsample = audioop.mul(lsample, width, lfactor)
    rsample = audioop.mul(rsample, width, rfactor)
    lsample = audioop.tostereo(lsample, width, 1, 0)
```

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```
    rsample = audioop.tostereo(rsample, width, 0, 1)
    return audioop.add(lsample, rsample, width)
```

If you use the ADPCM coder to build network packets and you want your protocol to be stateless (i.e. to be able to tolerate packet loss) you should not only transmit the data but also the state. Note that you should send the *initial* state (the one you passed to *lin2adpcm()*) along to the decoder, not the final state (as returned by the coder). If you want to use *struct.Struct* to store the state in binary you can code the first element (the predicted value) in 16 bits and the second (the delta index) in 8.

The ADPCM coders have never been tried against other ADPCM coders, only against themselves. It could well be that I misinterpreted the standards in which case they will not be interoperable with the respective standards.

The `find*()` routines might look a bit funny at first sight. They are primarily meant to do echo cancellation. A reasonably fast way to do this is to pick the most energetic piece of the output sample, locate that in the input sample and subtract the whole output sample from the input sample:

```
def echocancel(outputdata, inputdata):
    pos = audioop.findmax(outputdata, 800)    # one tenth second
    out_test = outputdata[pos*2:]
    in_test = inputdata[pos*2:]
    ipos, factor = audioop.findfit(in_test, out_test)
    # Optional (for better cancellation):
    # factor = audioop.findfactor(in_test[ipos*2:ipos*2+len(out_test)],
    #              out_test)
    prefill = '\0'*(pos+ipos)*2
    postfill = '\0'*(len(inputdata)-len(prefill)-len(outputdata))
    outputdata = prefill + audioop.mul(outputdata, 2, -factor) + postfill
    return audioop.add(inputdata, outputdata, 2)
```

23.2 aifc — Read and write AIFF and AIFC files

Source code: Lib/aifc.py

This module provides support for reading and writing AIFF and AIFF-C files. AIFF is Audio Interchange File Format, a format for storing digital audio samples in a file. AIFF-C is a newer version of the format that includes the ability to compress the audio data.

Audio files have a number of parameters that describe the audio data. The sampling rate or frame rate is the number of times per second the sound is sampled. The number of channels indicate if the audio is mono, stereo, or quadro. Each frame consists of one sample per channel. The sample size is the size in bytes of each sample. Thus a frame consists of `nchannels * samplesize` bytes, and a second's worth of audio consists of `nchannels * samplesize * framerate` bytes.

For example, CD quality audio has a sample size of two bytes (16 bits), uses two channels (stereo) and has a frame rate of 44,100 frames/second. This gives a frame size of 4 bytes (2*2), and a second's worth occupies 2*2*44100 bytes (176,400 bytes).

Module *aifc* defines the following function:

`aifc.open`(*file*, *mode=None*)

Open an AIFF or AIFF-C file and return an object instance with methods that are described below. The argument *file* is either a string naming a file or a *file object*. *mode* must be `'r'` or `'rb'` when the file must be opened for reading, or `'w'` or `'wb'` when the file must be opened for writing. If omitted,

`file.mode` is used if it exists, otherwise `'rb'` is used. When used for writing, the file object should be seekable, unless you know ahead of time how many samples you are going to write in total and use `writeframesraw()` and `setnframes()`. The *open()* function may be used in a `with` statement. When the `with` block completes, the *close()* method is called.

Changed in version 3.4: Support for the `with` statement was added.

Objects returned by *open()* when a file is opened for reading have the following methods:

aifc.getnchannels()
Return the number of audio channels (1 for mono, 2 for stereo).

aifc.getsampwidth()
Return the size in bytes of individual samples.

aifc.getframerate()
Return the sampling rate (number of audio frames per second).

aifc.getnframes()
Return the number of audio frames in the file.

aifc.getcomptype()
Return a bytes array of length 4 describing the type of compression used in the audio file. For AIFF files, the returned value is `b'NONE'`.

aifc.getcompname()
Return a bytes array convertible to a human-readable description of the type of compression used in the audio file. For AIFF files, the returned value is `b'not compressed'`.

aifc.getparams()
Returns a *namedtuple()* `(nchannels, sampwidth, framerate, nframes, comptype, compname)`, equivalent to output of the `get*()` methods.

aifc.getmarkers()
Return a list of markers in the audio file. A marker consists of a tuple of three elements. The first is the mark ID (an integer), the second is the mark position in frames from the beginning of the data (an integer), the third is the name of the mark (a string).

aifc.getmark(*id*)
Return the tuple as described in *getmarkers()* for the mark with the given *id*.

aifc.readframes(*nframes*)
Read and return the next *nframes* frames from the audio file. The returned data is a string containing for each frame the uncompressed samples of all channels.

aifc.rewind()
Rewind the read pointer. The next *readframes()* will start from the beginning.

aifc.setpos(*pos*)
Seek to the specified frame number.

aifc.tell()
Return the current frame number.

aifc.close()
Close the AIFF file. After calling this method, the object can no longer be used.

Objects returned by *open()* when a file is opened for writing have all the above methods, except for `readframes()` and `setpos()`. In addition the following methods exist. The `get*()` methods can only be called after the corresponding `set*()` methods have been called. Before the first `writeframes()` or `writeframesraw()`, all parameters except for the number of frames must be filled in.

aifc.aiff()
Create an AIFF file. The default is that an AIFF-C file is created, unless the name of the file ends in `'.aiff'` in which case the default is an AIFF file.

aifc.aifc()
Create an AIFF-C file. The default is that an AIFF-C file is created, unless the name of the file ends in `'.aiff'` in which case the default is an AIFF file.

aifc.setnchannels(*nchannels*)
Specify the number of channels in the audio file.

aifc.setsampwidth(*width*)
Specify the size in bytes of audio samples.

aifc.setframerate(*rate*)
Specify the sampling frequency in frames per second.

aifc.setnframes(*nframes*)
Specify the number of frames that are to be written to the audio file. If this parameter is not set, or not set correctly, the file needs to support seeking.

aifc.setcomptype(*type*, *name*)
Specify the compression type. If not specified, the audio data will not be compressed. In AIFF files, compression is not possible. The name parameter should be a human-readable description of the compression type as a bytes array, the type parameter should be a bytes array of length 4. Currently the following compression types are supported: `b'NONE'`, `b'ULAW'`, `b'ALAW'`, `b'G722'`.

aifc.setparams(*nchannels*, *sampwidth*, *framerate*, *comptype*, *compname*)
Set all the above parameters at once. The argument is a tuple consisting of the various parameters. This means that it is possible to use the result of a *getparams()* call as argument to *setparams()*.

aifc.setmark(*id*, *pos*, *name*)
Add a mark with the given id (larger than 0), and the given name at the given position. This method can be called at any time before *close()*.

aifc.tell()
Return the current write position in the output file. Useful in combination with *setmark()*.

aifc.writeframes(*data*)
Write data to the output file. This method can only be called after the audio file parameters have been set.

Changed in version 3.4: Any *bytes-like object* is now accepted.

aifc.writeframesraw(*data*)
Like *writeframes()*, except that the header of the audio file is not updated.

Changed in version 3.4: Any *bytes-like object* is now accepted.

aifc.close()
Close the AIFF file. The header of the file is updated to reflect the actual size of the audio data. After calling this method, the object can no longer be used.

23.3 sunau — Read and write Sun AU files

Source code: Lib/sunau.py

The *sunau* module provides a convenient interface to the Sun AU sound format. Note that this module is interface-compatible with the modules *aifc* and *wave*.

An audio file consists of a header followed by the data. The fields of the header are:

Field	Contents
magic word	The four bytes `.snd`.
header size	Size of the header, including info, in bytes.
data size	Physical size of the data, in bytes.
encoding	Indicates how the audio samples are encoded.
sample rate	The sampling rate.
# of channels	The number of channels in the samples.
info	ASCII string giving a description of the audio file (padded with null bytes).

Apart from the info field, all header fields are 4 bytes in size. They are all 32-bit unsigned integers encoded in big-endian byte order.

The *sunau* module defines the following functions:

sunau.open(*file*, *mode*)
If *file* is a string, open the file by that name, otherwise treat it as a seekable file-like object. *mode* can be any of

'r' Read only mode.

'w' Write only mode.

Note that it does not allow read/write files.

A *mode* of **'r'** returns an **AU_read** object, while a *mode* of **'w'** or **'wb'** returns an **AU_write** object.

sunau.openfp(*file*, *mode*)
A synonym for *open()*, maintained for backwards compatibility.

Deprecated since version 3.7, will be removed in version 3.9.

The *sunau* module defines the following exception:

exception sunau.Error
An error raised when something is impossible because of Sun AU specs or implementation deficiency.

The *sunau* module defines the following data items:

sunau.AUDIO_FILE_MAGIC
An integer every valid Sun AU file begins with, stored in big-endian form. This is the string `.snd` interpreted as an integer.

sunau.AUDIO_FILE_ENCODING_MULAW_8
sunau.AUDIO_FILE_ENCODING_LINEAR_8
sunau.AUDIO_FILE_ENCODING_LINEAR_16
sunau.AUDIO_FILE_ENCODING_LINEAR_24
sunau.AUDIO_FILE_ENCODING_LINEAR_32
sunau.AUDIO_FILE_ENCODING_ALAW_8
Values of the encoding field from the AU header which are supported by this module.

sunau.AUDIO_FILE_ENCODING_FLOAT
sunau.AUDIO_FILE_ENCODING_DOUBLE
sunau.AUDIO_FILE_ENCODING_ADPCM_G721
sunau.AUDIO_FILE_ENCODING_ADPCM_G722
sunau.AUDIO_FILE_ENCODING_ADPCM_G723_3
sunau.AUDIO_FILE_ENCODING_ADPCM_G723_5
Additional known values of the encoding field from the AU header, but which are not supported by this module.

23.3.1 AU_read Objects

AU_read objects, as returned by *open()* above, have the following methods:

AU_read.close()
Close the stream, and make the instance unusable. (This is called automatically on deletion.)

AU_read.getnchannels()
Returns number of audio channels (1 for mono, 2 for stereo).

AU_read.getsampwidth()
Returns sample width in bytes.

AU_read.getframerate()
Returns sampling frequency.

AU_read.getnframes()
Returns number of audio frames.

AU_read.getcomptype()
Returns compression type. Supported compression types are `'ULAW'`, `'ALAW'` and `'NONE'`.

AU_read.getcompname()
Human-readable version of *getcomptype()*. The supported types have the respective names `'CCITT G.711 u-law'`, `'CCITT G.711 A-law'` and `'not compressed'`.

AU_read.getparams()
Returns a *namedtuple()* `(nchannels, sampwidth, framerate, nframes, comptype, compname)`, equivalent to output of the `get*()` methods.

AU_read.readframes(*n*)
Reads and returns at most *n* frames of audio, as a *bytes* object. The data will be returned in linear format. If the original data is in u-LAW format, it will be converted.

AU_read.rewind()
Rewind the file pointer to the beginning of the audio stream.

The following two methods define a term "position" which is compatible between them, and is otherwise implementation dependent.

AU_read.setpos(*pos*)
Set the file pointer to the specified position. Only values returned from *tell()* should be used for *pos*.

AU_read.tell()
Return current file pointer position. Note that the returned value has nothing to do with the actual position in the file.

The following two functions are defined for compatibility with the *aifc*, and don't do anything interesting.

AU_read.getmarkers()
Returns `None`.

AU_read.getmark(*id*)
Raise an error.

23.3.2 AU_write Objects

AU_write objects, as returned by *open()* above, have the following methods:

AU_write.setnchannels(*n*)
Set the number of channels.

AU_write.setsampwidth(*n*)
Set the sample width (in bytes.)

Changed in version 3.4: Added support for 24-bit samples.

AU_write.setframerate(*n*)
Set the frame rate.

AU_write.setnframes(*n*)
Set the number of frames. This can be later changed, when and if more frames are written.

AU_write.setcomptype(*type*, *name*)
Set the compression type and description. Only `'NONE'` and `'ULAW'` are supported on output.

AU_write.setparams(*tuple*)
The *tuple* should be `(nchannels, sampwidth, framerate, nframes, comptype, compname)`, with values valid for the `set*()` methods. Set all parameters.

AU_write.tell()
Return current position in the file, with the same disclaimer for the *AU_read.tell()* and *AU_read.setpos()* methods.

AU_write.writeframesraw(*data*)
Write audio frames, without correcting *nframes*.

Changed in version 3.4: Any *bytes-like object* is now accepted.

AU_write.writeframes(*data*)
Write audio frames and make sure *nframes* is correct.

Changed in version 3.4: Any *bytes-like object* is now accepted.

AU_write.close()
Make sure *nframes* is correct, and close the file.

This method is called upon deletion.

Note that it is invalid to set any parameters after calling `writeframes()` or `writeframesraw()`.

23.4 `wave` — Read and write WAV files

Source code: Lib/wave.py

The *wave* module provides a convenient interface to the WAV sound format. It does not support compression/decompression, but it does support mono/stereo.

The *wave* module defines the following function and exception:

wave.open(*file*, *mode=None*)
If *file* is a string, open the file by that name, otherwise treat it as a file-like object. *mode* can be:

`'rb'` Read only mode.

`'wb'` Write only mode.

Note that it does not allow read/write WAV files.

A *mode* of `'rb'` returns a `Wave_read` object, while a *mode* of `'wb'` returns a `Wave_write` object. If *mode* is omitted and a file-like object is passed as *file*, `file.mode` is used as the default value for *mode*.

If you pass in a file-like object, the wave object will not close it when its `close()` method is called; it is the caller's responsibility to close the file object.

The *open()* function may be used in a `with` statement. When the `with` block completes, the *Wave_read.close()* or *Wave_write.close()* method is called.

Changed in version 3.4: Added support for unseekable files.

`wave.openfp`(*file*, *mode*)
A synonym for *open()*, maintained for backwards compatibility.

Deprecated since version 3.7, will be removed in version 3.9.

exception `wave.Error`
An error raised when something is impossible because it violates the WAV specification or hits an implementation deficiency.

23.4.1 Wave_read Objects

Wave_read objects, as returned by *open()*, have the following methods:

`Wave_read.close()`
Close the stream if it was opened by *wave*, and make the instance unusable. This is called automatically on object collection.

`Wave_read.getnchannels()`
Returns number of audio channels (`1` for mono, `2` for stereo).

`Wave_read.getsampwidth()`
Returns sample width in bytes.

`Wave_read.getframerate()`
Returns sampling frequency.

`Wave_read.getnframes()`
Returns number of audio frames.

`Wave_read.getcomptype()`
Returns compression type (`'NONE'` is the only supported type).

`Wave_read.getcompname()`
Human-readable version of *getcomptype()*. Usually `'not compressed'` parallels `'NONE'`.

`Wave_read.getparams()`
Returns a *namedtuple()* `(nchannels, sampwidth, framerate, nframes, comptype, compname)`, equivalent to output of the `get*()` methods.

`Wave_read.readframes`(*n*)
Reads and returns at most *n* frames of audio, as a *bytes* object.

`Wave_read.rewind()`
Rewind the file pointer to the beginning of the audio stream.

The following two methods are defined for compatibility with the *aifc* module, and don't do anything interesting.

`Wave_read.getmarkers()`
Returns `None`.

`Wave_read.getmark`(*id*)
Raise an error.

The following two methods define a term "position" which is compatible between them, and is otherwise implementation dependent.

`Wave_read.setpos`(*pos*)
Set the file pointer to the specified position.

`Wave_read.tell()`
Return current file pointer position.

23.4.2 Wave_write Objects

For seekable output streams, the `wave` header will automatically be updated to reflect the number of frames actually written. For unseekable streams, the *nframes* value must be accurate when the first frame data is written. An accurate *nframes* value can be achieved either by calling *setnframes()* or *setparams()* with the number of frames that will be written before *close()* is called and then using *writeframesraw()* to write the frame data, or by calling *writeframes()* with all of the frame data to be written. In the latter case *writeframes()* will calculate the number of frames in the data and set *nframes* accordingly before writing the frame data.

Wave_write objects, as returned by *open()*, have the following methods:

Changed in version 3.4: Added support for unseekable files.

`Wave_write.close()`
Make sure *nframes* is correct, and close the file if it was opened by *wave*. This method is called upon object collection. It will raise an exception if the output stream is not seekable and *nframes* does not match the number of frames actually written.

`Wave_write.setnchannels(`*n*`)`
Set the number of channels.

`Wave_write.setsampwidth(`*n*`)`
Set the sample width to *n* bytes.

`Wave_write.setframerate(`*n*`)`
Set the frame rate to *n*.

Changed in version 3.2: A non-integral input to this method is rounded to the nearest integer.

`Wave_write.setnframes(`*n*`)`
Set the number of frames to *n*. This will be changed later if the number of frames actually written is different (this update attempt will raise an error if the output stream is not seekable).

`Wave_write.setcomptype(`*type*, *name*`)`
Set the compression type and description. At the moment, only compression type `NONE` is supported, meaning no compression.

`Wave_write.setparams(`*tuple*`)`
The *tuple* should be `(nchannels, sampwidth, framerate, nframes, comptype, compname)`, with values valid for the `set*()` methods. Sets all parameters.

`Wave_write.tell()`
Return current position in the file, with the same disclaimer for the *Wave_read.tell()* and *Wave_read.setpos()* methods.

`Wave_write.writeframesraw(`*data*`)`
Write audio frames, without correcting *nframes*.

Changed in version 3.4: Any *bytes-like object* is now accepted.

`Wave_write.writeframes(`*data*`)`
Write audio frames and make sure *nframes* is correct. It will raise an error if the output stream is not seekable and the total number of frames that have been written after *data* has been written does not match the previously set value for *nframes*.

Changed in version 3.4: Any *bytes-like object* is now accepted.

Note that it is invalid to set any parameters after calling `writeframes()` or `writeframesraw()`, and any attempt to do so will raise *wave.Error*.

23.5 chunk — Read IFF chunked data

Source code: Lib/chunk.py

This module provides an interface for reading files that use EA IFF 85 chunks.[1] This format is used in at least the Audio Interchange File Format (AIFF/AIFF-C) and the Real Media File Format (RMFF). The WAVE audio file format is closely related and can also be read using this module.

A chunk has the following structure:

Offset	Length	Contents
0	4	Chunk ID
4	4	Size of chunk in big-endian byte order, not including the header
8	*n*	Data bytes, where *n* is the size given in the preceding field
8 + *n*	0 or 1	Pad byte needed if *n* is odd and chunk alignment is used

The ID is a 4-byte string which identifies the type of chunk.

The size field (a 32-bit value, encoded using big-endian byte order) gives the size of the chunk data, not including the 8-byte header.

Usually an IFF-type file consists of one or more chunks. The proposed usage of the *Chunk* class defined here is to instantiate an instance at the start of each chunk and read from the instance until it reaches the end, after which a new instance can be instantiated. At the end of the file, creating a new instance will fail with an *EOFError* exception.

class chunk.Chunk(*file*, *align=True*, *bigendian=True*, *inclheader=False*)

Class which represents a chunk. The *file* argument is expected to be a file-like object. An instance of this class is specifically allowed. The only method that is needed is `read()`. If the methods *seek()* and *tell()* are present and don't raise an exception, they are also used. If these methods are present and raise an exception, they are expected to not have altered the object. If the optional argument *align* is true, chunks are assumed to be aligned on 2-byte boundaries. If *align* is false, no alignment is assumed. The default value is true. If the optional argument *bigendian* is false, the chunk size is assumed to be in little-endian order. This is needed for WAVE audio files. The default value is true. If the optional argument *inclheader* is true, the size given in the chunk header includes the size of the header. The default value is false.

A *Chunk* object supports the following methods:

getname()

Returns the name (ID) of the chunk. This is the first 4 bytes of the chunk.

getsize()

Returns the size of the chunk.

close()

Close and skip to the end of the chunk. This does not close the underlying file.

The remaining methods will raise *OSError* if called after the *close()* method has been called. Before Python 3.3, they used to raise *IOError*, now an alias of *OSError*.

isatty()

Returns `False`.

seek(*pos*, *whence=0*)

Set the chunk's current position. The *whence* argument is optional and defaults to `0` (absolute file positioning); other values are `1` (seek relative to the current position) and `2` (seek relative to

[1] "EA IFF 85" Standard for Interchange Format Files, Jerry Morrison, Electronic Arts, January 1985.

the file's end). There is no return value. If the underlying file does not allow seek, only forward seeks are allowed.

tell()
Return the current position into the chunk.

read(*size=-1*)
Read at most *size* bytes from the chunk (less if the read hits the end of the chunk before obtaining *size* bytes). If the *size* argument is negative or omitted, read all data until the end of the chunk. An empty bytes object is returned when the end of the chunk is encountered immediately.

skip()
Skip to the end of the chunk. All further calls to *read()* for the chunk will return `b''`. If you are not interested in the contents of the chunk, this method should be called so that the file points to the start of the next chunk.

23.6 colorsys — Conversions between color systems

Source code: Lib/colorsys.py

The *colorsys* module defines bidirectional conversions of color values between colors expressed in the RGB (Red Green Blue) color space used in computer monitors and three other coordinate systems: YIQ, HLS (Hue Lightness Saturation) and HSV (Hue Saturation Value). Coordinates in all of these color spaces are floating point values. In the YIQ space, the Y coordinate is between 0 and 1, but the I and Q coordinates can be positive or negative. In all other spaces, the coordinates are all between 0 and 1.

See also:

More information about color spaces can be found at http://poynton.ca/ColorFAQ.html and https://www.cambridgeincolour.com/tutorials/color-spaces.htm.

The *colorsys* module defines the following functions:

colorsys.**rgb_to_yiq**(*r*, *g*, *b*)
Convert the color from RGB coordinates to YIQ coordinates.

colorsys.**yiq_to_rgb**(*y*, *i*, *q*)
Convert the color from YIQ coordinates to RGB coordinates.

colorsys.**rgb_to_hls**(*r*, *g*, *b*)
Convert the color from RGB coordinates to HLS coordinates.

colorsys.**hls_to_rgb**(*h*, *l*, *s*)
Convert the color from HLS coordinates to RGB coordinates.

colorsys.**rgb_to_hsv**(*r*, *g*, *b*)
Convert the color from RGB coordinates to HSV coordinates.

colorsys.**hsv_to_rgb**(*h*, *s*, *v*)
Convert the color from HSV coordinates to RGB coordinates.

Example:

```
>>> import colorsys
>>> colorsys.rgb_to_hsv(0.2, 0.4, 0.4)
(0.5, 0.5, 0.4)
>>> colorsys.hsv_to_rgb(0.5, 0.5, 0.4)
(0.2, 0.4, 0.4)
```

23.7 imghdr — Determine the type of an image

Source code: Lib/imghdr.py

The *imghdr* module determines the type of image contained in a file or byte stream.

The *imghdr* module defines the following function:

imghdr.what(*filename*, *h=None*)
: Tests the image data contained in the file named by *filename*, and returns a string describing the image type. If optional *h* is provided, the *filename* is ignored and *h* is assumed to contain the byte stream to test.

  Changed in version 3.6: Accepts a *path-like object*.

The following image types are recognized, as listed below with the return value from *what()*:

Value	Image format
'rgb'	SGI ImgLib Files
'gif'	GIF 87a and 89a Files
'pbm'	Portable Bitmap Files
'pgm'	Portable Graymap Files
'ppm'	Portable Pixmap Files
'tiff'	TIFF Files
'rast'	Sun Raster Files
'xbm'	X Bitmap Files
'jpeg'	JPEG data in JFIF or Exif formats
'bmp'	BMP files
'png'	Portable Network Graphics
'webp'	WebP files
'exr'	OpenEXR Files

New in version 3.5: The *exr* and *webp* formats were added.

You can extend the list of file types *imghdr* can recognize by appending to this variable:

imghdr.tests
: A list of functions performing the individual tests. Each function takes two arguments: the byte-stream and an open file-like object. When *what()* is called with a byte-stream, the file-like object will be None.

  The test function should return a string describing the image type if the test succeeded, or None if it failed.

Example:

```
>>> import imghdr
>>> imghdr.what('bass.gif')
'gif'
```

23.8 sndhdr — Determine type of sound file

Source code: Lib/sndhdr.py

The *sndhdr* provides utility functions which attempt to determine the type of sound data which is in a file. When these functions are able to determine what type of sound data is stored in a file, they return a *namedtuple()*, containing five attributes: (`filetype`, `framerate`, `nchannels`, `nframes`, `sampwidth`). The value for *type* indicates the data type and will be one of the strings `'aifc'`, `'aiff'`, `'au'`, `'hcom'`, `'sndr'`, `'sndt'`, `'voc'`, `'wav'`, `'8svx'`, `'sb'`, `'ub'`, or `'ul'`. The *sampling_rate* will be either the actual value or `0` if unknown or difficult to decode. Similarly, *channels* will be either the number of channels or `0` if it cannot be determined or if the value is difficult to decode. The value for *frames* will be either the number of frames or `-1`. The last item in the tuple, *bits_per_sample*, will either be the sample size in bits or `'A'` for A-LAW or `'U'` for u-LAW.

`sndhdr.what`(*filename*)
: Determines the type of sound data stored in the file *filename* using *whathdr()*. If it succeeds, returns a namedtuple as described above, otherwise `None` is returned.

  Changed in version 3.5: Result changed from a tuple to a namedtuple.

`sndhdr.whathdr`(*filename*)
: Determines the type of sound data stored in a file based on the file header. The name of the file is given by *filename*. This function returns a namedtuple as described above on success, or `None`.

  Changed in version 3.5: Result changed from a tuple to a namedtuple.

23.9 `ossaudiodev` — Access to OSS-compatible audio devices

This module allows you to access the OSS (Open Sound System) audio interface. OSS is available for a wide range of open-source and commercial Unices, and is the standard audio interface for Linux and recent versions of FreeBSD.

Changed in version 3.3: Operations in this module now raise *OSError* where *IOError* was raised.

See also:

Open Sound System Programmer's Guide the official documentation for the OSS C API

The module defines a large number of constants supplied by the OSS device driver; see `<sys/soundcard.h>` on either Linux or FreeBSD for a listing.

ossaudiodev defines the following variables and functions:

`exception ossaudiodev.OSSAudioError`
: This exception is raised on certain errors. The argument is a string describing what went wrong.

  (If *ossaudiodev* receives an error from a system call such as `open()`, `write()`, or `ioctl()`, it raises *OSError*. Errors detected directly by *ossaudiodev* result in *OSSAudioError*.)

  (For backwards compatibility, the exception class is also available as `ossaudiodev.error`.)

`ossaudiodev.open`(*mode*)
`ossaudiodev.open`(*device*, *mode*)
: Open an audio device and return an OSS audio device object. This object supports many file-like methods, such as `read()`, `write()`, and `fileno()` (although there are subtle differences between conventional Unix read/write semantics and those of OSS audio devices). It also supports a number of audio-specific methods; see below for the complete list of methods.

  device is the audio device filename to use. If it is not specified, this module first looks in the environment variable `AUDIODEV` for a device to use. If not found, it falls back to `/dev/dsp`.

  mode is one of `'r'` for read-only (record) access, `'w'` for write-only (playback) access and `'rw'` for both. Since many sound cards only allow one process to have the recorder or player open at a time, it is

a good idea to open the device only for the activity needed. Further, some sound cards are half-duplex: they can be opened for reading or writing, but not both at once.

Note the unusual calling syntax: the *first* argument is optional, and the second is required. This is a historical artifact for compatibility with the older `linuxaudiodev` module which *ossaudiodev* supersedes.

`ossaudiodev.openmixer([device])`
Open a mixer device and return an OSS mixer device object. *device* is the mixer device filename to use. If it is not specified, this module first looks in the environment variable `MIXERDEV` for a device to use. If not found, it falls back to `/dev/mixer`.

23.9.1 Audio Device Objects

Before you can write to or read from an audio device, you must call three methods in the correct order:

1. `setfmt()` to set the output format
2. `channels()` to set the number of channels
3. `speed()` to set the sample rate

Alternately, you can use the `setparameters()` method to set all three audio parameters at once. This is more convenient, but may not be as flexible in all cases.

The audio device objects returned by *open()* define the following methods and (read-only) attributes:

`oss_audio_device.close()`
Explicitly close the audio device. When you are done writing to or reading from an audio device, you should explicitly close it. A closed device cannot be used again.

`oss_audio_device.fileno()`
Return the file descriptor associated with the device.

`oss_audio_device.read(size)`
Read *size* bytes from the audio input and return them as a Python string. Unlike most Unix device drivers, OSS audio devices in blocking mode (the default) will block *read()* until the entire requested amount of data is available.

`oss_audio_device.write(data)`
Write a *bytes-like object* *data* to the audio device and return the number of bytes written. If the audio device is in blocking mode (the default), the entire data is always written (again, this is different from usual Unix device semantics). If the device is in non-blocking mode, some data may not be written —see *writeall()*.

Changed in version 3.5: Writable *bytes-like object* is now accepted.

`oss_audio_device.writeall(data)`
Write a *bytes-like object* *data* to the audio device: waits until the audio device is able to accept data, writes as much data as it will accept, and repeats until *data* has been completely written. If the device is in blocking mode (the default), this has the same effect as *write()*; *writeall()* is only useful in non-blocking mode. Has no return value, since the amount of data written is always equal to the amount of data supplied.

Changed in version 3.5: Writable *bytes-like object* is now accepted.

Changed in version 3.2: Audio device objects also support the context management protocol, i.e. they can be used in a `with` statement.

The following methods each map to exactly one `ioctl()` system call. The correspondence is obvious: for example, `setfmt()` corresponds to the `SNDCTL_DSP_SETFMT` ioctl, and `sync()` to `SNDCTL_DSP_SYNC` (this can

be useful when consulting the OSS documentation). If the underlying `ioctl()` fails, they all raise *OSError*.

`oss_audio_device.nonblock()`
Put the device into non-blocking mode. Once in non-blocking mode, there is no way to return it to blocking mode.

`oss_audio_device.getfmts()`
Return a bitmask of the audio output formats supported by the soundcard. Some of the formats supported by OSS are:

Format	Description
`AFMT_MU_LAW`	a logarithmic encoding (used by Sun `.au` files and `/dev/audio`)
`AFMT_A_LAW`	a logarithmic encoding
`AFMT_IMA_ADPCM`	a 4:1 compressed format defined by the Interactive Multimedia Association
`AFMT_U8`	Unsigned, 8-bit audio
`AFMT_S16_LE`	Signed, 16-bit audio, little-endian byte order (as used by Intel processors)
`AFMT_S16_BE`	Signed, 16-bit audio, big-endian byte order (as used by 68k, PowerPC, Sparc)
`AFMT_S8`	Signed, 8 bit audio
`AFMT_U16_LE`	Unsigned, 16-bit little-endian audio
`AFMT_U16_BE`	Unsigned, 16-bit big-endian audio

Consult the OSS documentation for a full list of audio formats, and note that most devices support only a subset of these formats. Some older devices only support `AFMT_U8`; the most common format used today is `AFMT_S16_LE`.

`oss_audio_device.setfmt(`*format*`)`
Try to set the current audio format to *format*—see *getfmts()* for a list. Returns the audio format that the device was set to, which may not be the requested format. May also be used to return the current audio format—do this by passing an "audio format" of `AFMT_QUERY`.

`oss_audio_device.channels(`*nchannels*`)`
Set the number of output channels to *nchannels*. A value of 1 indicates monophonic sound, 2 stereophonic. Some devices may have more than 2 channels, and some high-end devices may not support mono. Returns the number of channels the device was set to.

`oss_audio_device.speed(`*samplerate*`)`
Try to set the audio sampling rate to *samplerate* samples per second. Returns the rate actually set. Most sound devices don't support arbitrary sampling rates. Common rates are:

Rate	Description
8000	default rate for `/dev/audio`
11025	speech recording
22050	
44100	CD quality audio (at 16 bits/sample and 2 channels)
96000	DVD quality audio (at 24 bits/sample)

`oss_audio_device.sync()`
Wait until the sound device has played every byte in its buffer. (This happens implicitly when the device is closed.) The OSS documentation recommends closing and re-opening the device rather than using *sync()*.

`oss_audio_device.reset()`
Immediately stop playing or recording and return the device to a state where it can accept commands. The OSS documentation recommends closing and re-opening the device after calling *reset()*.

oss_audio_device.post()
: Tell the driver that there is likely to be a pause in the output, making it possible for the device to handle the pause more intelligently. You might use this after playing a spot sound effect, before waiting for user input, or before doing disk I/O.

The following convenience methods combine several ioctls, or one ioctl and some simple calculations.

oss_audio_device.setparameters(*format*, *nchannels*, *samplerate*[, *strict=False*])
: Set the key audio sampling parameters—sample format, number of channels, and sampling rate—in one method call. *format*, *nchannels*, and *samplerate* should be as specified in the *setfmt()*, *channels()*, and *speed()* methods. If *strict* is true, *setparameters()* checks to see if each parameter was actually set to the requested value, and raises *OSSAudioError* if not. Returns a tuple (*format*, *nchannels*, *samplerate*) indicating the parameter values that were actually set by the device driver (i.e., the same as the return values of *setfmt()*, *channels()*, and *speed()*).

  For example,

```
(fmt, channels, rate) = dsp.setparameters(fmt, channels, rate)
```

  is equivalent to

```
fmt = dsp.setfmt(fmt)
channels = dsp.channels(channels)
rate = dsp.rate(rate)
```

oss_audio_device.bufsize()
: Returns the size of the hardware buffer, in samples.

oss_audio_device.obufcount()
: Returns the number of samples that are in the hardware buffer yet to be played.

oss_audio_device.obuffree()
: Returns the number of samples that could be queued into the hardware buffer to be played without blocking.

Audio device objects also support several read-only attributes:

oss_audio_device.closed
: Boolean indicating whether the device has been closed.

oss_audio_device.name
: String containing the name of the device file.

oss_audio_device.mode
: The I/O mode for the file, either `"r"`, `"rw"`, or `"w"`.

23.9.2 Mixer Device Objects

The mixer object provides two file-like methods:

oss_mixer_device.close()
: This method closes the open mixer device file. Any further attempts to use the mixer after this file is closed will raise an *OSError*.

oss_mixer_device.fileno()
: Returns the file handle number of the open mixer device file.

Changed in version 3.2: Mixer objects also support the context management protocol.

The remaining methods are specific to audio mixing:

oss_mixer_device.controls()
: This method returns a bitmask specifying the available mixer controls ("Control" being a specific mixable "channel", such as SOUND_MIXER_PCM or SOUND_MIXER_SYNTH). This bitmask indicates a subset of all available mixer controls—the SOUND_MIXER_* constants defined at module level. To determine if, for example, the current mixer object supports a PCM mixer, use the following Python code:

```
mixer=ossaudiodev.openmixer()
if mixer.controls() & (1 << ossaudiodev.SOUND_MIXER_PCM):
    # PCM is supported
    ... code ...
```

For most purposes, the SOUND_MIXER_VOLUME (master volume) and SOUND_MIXER_PCM controls should suffice—but code that uses the mixer should be flexible when it comes to choosing mixer controls. On the Gravis Ultrasound, for example, SOUND_MIXER_VOLUME does not exist.

oss_mixer_device.stereocontrols()
: Returns a bitmask indicating stereo mixer controls. If a bit is set, the corresponding control is stereo; if it is unset, the control is either monophonic or not supported by the mixer (use in combination with *controls()* to determine which).

See the code example for the *controls()* function for an example of getting data from a bitmask.

oss_mixer_device.reccontrols()
: Returns a bitmask specifying the mixer controls that may be used to record. See the code example for *controls()* for an example of reading from a bitmask.

oss_mixer_device.get(*control*)
: Returns the volume of a given mixer control. The returned volume is a 2-tuple (left_volume, right_volume). Volumes are specified as numbers from 0 (silent) to 100 (full volume). If the control is monophonic, a 2-tuple is still returned, but both volumes are the same.

Raises *OSSAudioError* if an invalid control is specified, or *OSError* if an unsupported control is specified.

oss_mixer_device.set(*control*, *(left*, *right)*)
: Sets the volume for a given mixer control to (left,right). left and right must be ints and between 0 (silent) and 100 (full volume). On success, the new volume is returned as a 2-tuple. Note that this may not be exactly the same as the volume specified, because of the limited resolution of some soundcard's mixers.

Raises *OSSAudioError* if an invalid mixer control was specified, or if the specified volumes were out-of-range.

oss_mixer_device.get_recsrc()
: This method returns a bitmask indicating which control(s) are currently being used as a recording source.

oss_mixer_device.set_recsrc(*bitmask*)
: Call this function to specify a recording source. Returns a bitmask indicating the new recording source (or sources) if successful; raises *OSError* if an invalid source was specified. To set the current recording source to the microphone input:

```
mixer.setrecsrc (1 << ossaudiodev.SOUND_MIXER_MIC)
```

CHAPTER

TWENTYFOUR

INTERNATIONALIZATION

The modules described in this chapter help you write software that is independent of language and locale by providing mechanisms for selecting a language to be used in program messages or by tailoring output to match local conventions.

The list of modules described in this chapter is:

24.1 gettext — Multilingual internationalization services

Source code: Lib/gettext.py

The *gettext* module provides internationalization (I18N) and localization (L10N) services for your Python modules and applications. It supports both the GNU `gettext` message catalog API and a higher level, class-based API that may be more appropriate for Python files. The interface described below allows you to write your module and application messages in one natural language, and provide a catalog of translated messages for running under different natural languages.

Some hints on localizing your Python modules and applications are also given.

24.1.1 GNU gettext API

The *gettext* module defines the following API, which is very similar to the GNU **gettext** API. If you use this API you will affect the translation of your entire application globally. Often this is what you want if your application is monolingual, with the choice of language dependent on the locale of your user. If you are localizing a Python module, or if your application needs to switch languages on the fly, you probably want to use the class-based API instead.

`gettext.bindtextdomain`(*domain*, *localedir=None*)

Bind the *domain* to the locale directory *localedir*. More concretely, *gettext* will look for binary `.mo` files for the given domain using the path (on Unix): `localedir/language/LC_MESSAGES/domain.mo`, where *languages* is searched for in the environment variables `LANGUAGE`, `LC_ALL`, `LC_MESSAGES`, and `LANG` respectively.

If *localedir* is omitted or `None`, then the current binding for *domain* is returned.[1]

`gettext.bind_textdomain_codeset`(*domain*, *codeset=None*)

Bind the *domain* to *codeset*, changing the encoding of byte strings returned by the *lgettext()*, *ldgettext()*, *lngettext()* and *ldngettext()* functions. If *codeset* is omitted, then the current binding is returned.

[1] The default locale directory is system dependent; for example, on RedHat Linux it is `/usr/share/locale`, but on Solaris it is `/usr/lib/locale`. The *gettext* module does not try to support these system dependent defaults; instead its default is `sys.prefix/share/locale`. For this reason, it is always best to call *bindtextdomain()* with an explicit absolute path at the start of your application.

gettext.**textdomain**(*domain=None*)
Change or query the current global domain. If *domain* is `None`, then the current global domain is returned, otherwise the global domain is set to *domain*, which is returned.

gettext.**gettext**(*message*)
Return the localized translation of *message*, based on the current global domain, language, and locale directory. This function is usually aliased as `_()` in the local namespace (see examples below).

gettext.**dgettext**(*domain*, *message*)
Like *gettext()*, but look the message up in the specified *domain*.

gettext.**ngettext**(*singular*, *plural*, *n*)
Like *gettext()*, but consider plural forms. If a translation is found, apply the plural formula to *n*, and return the resulting message (some languages have more than two plural forms). If no translation is found, return *singular* if *n* is 1; return *plural* otherwise.

The Plural formula is taken from the catalog header. It is a C or Python expression that has a free variable *n*; the expression evaluates to the index of the plural in the catalog. See the GNU gettext documentation for the precise syntax to be used in `.po` files and the formulas for a variety of languages.

gettext.**dngettext**(*domain*, *singular*, *plural*, *n*)
Like *ngettext()*, but look the message up in the specified *domain*.

gettext.**lgettext**(*message*)

gettext.**ldgettext**(*domain*, *message*)

gettext.**lngettext**(*singular*, *plural*, *n*)

gettext.**ldngettext**(*domain*, *singular*, *plural*, *n*)
Equivalent to the corresponding functions without the `l` prefix (*gettext()*, *dgettext()*, *ngettext()* and *dngettext()*), but the translation is returned as a byte string encoded in the preferred system encoding if no other encoding was explicitly set with *bind_textdomain_codeset()*.

> **Warning:** These functions should be avoided in Python 3, because they return encoded bytes. It's much better to use alternatives which return Unicode strings instead, since most Python applications will want to manipulate human readable text as strings instead of bytes. Further, it's possible that you may get unexpected Unicode-related exceptions if there are encoding problems with the translated strings. It is possible that the `l*()` functions will be deprecated in future Python versions due to their inherent problems and limitations.

Note that GNU **gettext** also defines a `dcgettext()` method, but this was deemed not useful and so it is currently unimplemented.

Here's an example of typical usage for this API:

```
import gettext
gettext.bindtextdomain('myapplication', '/path/to/my/language/directory')
gettext.textdomain('myapplication')
_ = gettext.gettext
# ...
print(_('This is a translatable string.'))
```

24.1.2 Class-based API

The class-based API of the *gettext* module gives you more flexibility and greater convenience than the GNU **gettext** API. It is the recommended way of localizing your Python applications and modules. **gettext** defines a "translations" class which implements the parsing of GNU `.mo` format files, and has methods for

returning strings. Instances of this "translations" class can also install themselves in the built-in namespace as the function `_()`.

`gettext.find`(*domain*, *localedir=None*, *languages=None*, *all=False*)

This function implements the standard `.mo` file search algorithm. It takes a *domain*, identical to what *textdomain()* takes. Optional *localedir* is as in *bindtextdomain()* Optional *languages* is a list of strings, where each string is a language code.

If *localedir* is not given, then the default system locale directory is used.[2] If *languages* is not given, then the following environment variables are searched: `LANGUAGE`, `LC_ALL`, `LC_MESSAGES`, and `LANG`. The first one returning a non-empty value is used for the *languages* variable. The environment variables should contain a colon separated list of languages, which will be split on the colon to produce the expected list of language code strings.

find() then expands and normalizes the languages, and then iterates through them, searching for an existing file built of these components:

localedir/*language*/LC_MESSAGES/*domain*.mo

The first such file name that exists is returned by *find()*. If no such file is found, then `None` is returned. If *all* is given, it returns a list of all file names, in the order in which they appear in the languages list or the environment variables.

`gettext.translation`(*domain*, *localedir=None*, *languages=None*, *class_=None*, *fallback=False*, *codeset=None*)

Return a `Translations` instance based on the *domain*, *localedir*, and *languages*, which are first passed to *find()* to get a list of the associated `.mo` file paths. Instances with identical `.mo` file names are cached. The actual class instantiated is either *class_* if provided, otherwise *GNUTranslations*. The class's constructor must take a single *file object* argument. If provided, *codeset* will change the charset used to encode translated strings in the *lgettext()* and *lngettext()* methods.

If multiple files are found, later files are used as fallbacks for earlier ones. To allow setting the fallback, *copy.copy()* is used to clone each translation object from the cache; the actual instance data is still shared with the cache.

If no `.mo` file is found, this function raises *OSError* if *fallback* is false (which is the default), and returns a *NullTranslations* instance if *fallback* is true.

Changed in version 3.3: *IOError* used to be raised instead of *OSError*.

`gettext.install`(*domain*, *localedir=None*, *codeset=None*, *names=None*)

This installs the function `_()` in Python's builtins namespace, based on *domain*, *localedir*, and *codeset* which are passed to the function *translation()*.

For the *names* parameter, please see the description of the translation object's *install()* method.

As seen below, you usually mark the strings in your application that are candidates for translation, by wrapping them in a call to the `_()` function, like this:

```
print(_('This string will be translated.'))
```

For convenience, you want the `_()` function to be installed in Python's builtins namespace, so it is easily accessible in all modules of your application.

The `NullTranslations` class

Translation classes are what actually implement the translation of original source file message strings to translated message strings. The base class used by all translation classes is *NullTranslations*; this provides the basic interface you can use to write your own specialized translation classes. Here are the methods of `NullTranslations`:

[2] See the footnote for *bindtextdomain()* above.

class gettext.**NullTranslations**(*fp=None*)

Takes an optional *file object* *fp*, which is ignored by the base class. Initializes "protected" instance variables *_info* and *_charset* which are set by derived classes, as well as *_fallback*, which is set through *add_fallback()*. It then calls `self._parse(fp)` if *fp* is not `None`.

_parse(*fp*)

No-op'd in the base class, this method takes file object *fp*, and reads the data from the file, initializing its message catalog. If you have an unsupported message catalog file format, you should override this method to parse your format.

add_fallback(*fallback*)

Add *fallback* as the fallback object for the current translation object. A translation object should consult the fallback if it cannot provide a translation for a given message.

gettext(*message*)

If a fallback has been set, forward `gettext()` to the fallback. Otherwise, return *message*. Overridden in derived classes.

ngettext(*singular*, *plural*, *n*)

If a fallback has been set, forward `ngettext()` to the fallback. Otherwise, return *singular* if *n* is 1; return *plural* otherwise. Overridden in derived classes.

lgettext(*message*)

lngettext(*singular*, *plural*, *n*)

Equivalent to *gettext()* and *ngettext()*, but the translation is returned as a byte string encoded in the preferred system encoding if no encoding was explicitly set with *set_output_charset()*. Overridden in derived classes.

> **Warning:** These methods should be avoided in Python 3. See the warning for the *lgettext()* function.

info()

Return the "protected" `_info` variable.

charset()

Return the encoding of the message catalog file.

output_charset()

Return the encoding used to return translated messages in *lgettext()* and *lngettext()*.

set_output_charset(*charset*)

Change the encoding used to return translated messages.

install(*names=None*)

This method installs *gettext()* into the built-in namespace, binding it to `_`.

If the *names* parameter is given, it must be a sequence containing the names of functions you want to install in the builtins namespace in addition to `_()`. Supported names are `'gettext'`, `'ngettext'`, `'lgettext'` and `'lngettext'`.

Note that this is only one way, albeit the most convenient way, to make the `_()` function available to your application. Because it affects the entire application globally, and specifically the built-in namespace, localized modules should never install `_()`. Instead, they should use this code to make `_()` available to their module:

```
import gettext
t = gettext.translation('mymodule', ...)
_ = t.gettext
```

This puts `_()` only in the module's global namespace and so only affects calls within this module.

The `GNUTranslations` class

The *gettext* module provides one additional class derived from *NullTranslations*: *GNUTranslations*. This class overrides `_parse()` to enable reading GNU **gettext** format `.mo` files in both big-endian and little-endian format.

GNUTranslations parses optional meta-data out of the translation catalog. It is convention with GNU **gettext** to include meta-data as the translation for the empty string. This meta-data is in **RFC 822**-style `key: value` pairs, and should contain the `Project-Id-Version` key. If the key `Content-Type` is found, then the `charset` property is used to initialize the "protected" `_charset` instance variable, defaulting to `None` if not found. If the charset encoding is specified, then all message ids and message strings read from the catalog are converted to Unicode using this encoding, else ASCII encoding is assumed.

Since message ids are read as Unicode strings too, all `*gettext()` methods will assume message ids as Unicode strings, not byte strings.

The entire set of key/value pairs are placed into a dictionary and set as the "protected" `_info` instance variable.

If the `.mo` file's magic number is invalid, the major version number is unexpected, or if other problems occur while reading the file, instantiating a *GNUTranslations* class can raise *OSError*.

class gettext.**GNUTranslations**

The following methods are overridden from the base class implementation:

gettext(*message*)

Look up the *message* id in the catalog and return the corresponding message string, as a Unicode string. If there is no entry in the catalog for the *message* id, and a fallback has been set, the look up is forwarded to the fallback's *gettext()* method. Otherwise, the *message* id is returned.

ngettext(*singular*, *plural*, *n*)

Do a plural-forms lookup of a message id. *singular* is used as the message id for purposes of lookup in the catalog, while *n* is used to determine which plural form to use. The returned message string is a Unicode string.

If the message id is not found in the catalog, and a fallback is specified, the request is forwarded to the fallback's *ngettext()* method. Otherwise, when *n* is 1 *singular* is returned, and *plural* is returned in all other cases.

Here is an example:

```
n = len(os.listdir('.'))
cat = GNUTranslations(somefile)
message = cat.ngettext(
    'There is %(num)d file in this directory',
    'There are %(num)d files in this directory',
    n) % {'num': n}
```

lgettext(*message*)

lngettext(*singular*, *plural*, *n*)

Equivalent to *gettext()* and *ngettext()*, but the translation is returned as a byte string encoded in the preferred system encoding if no encoding was explicitly set with *set_output_charset()*.

> **Warning:** These methods should be avoided in Python 3. See the warning for the *lgettext()* function.

Solaris message catalog support

The Solaris operating system defines its own binary `.mo` file format, but since no documentation can be found on this format, it is not supported at this time.

The Catalog constructor

GNOME uses a version of the *gettext* module by James Henstridge, but this version has a slightly different API. Its documented usage was:

```
import gettext
cat = gettext.Catalog(domain, localedir)
_ = cat.gettext
print(_('hello world'))
```

For compatibility with this older module, the function `Catalog()` is an alias for the *translation()* function described above.

One difference between this module and Henstridge's: his catalog objects supported access through a mapping API, but this appears to be unused and so is not currently supported.

24.1.3 Internationalizing your programs and modules

Internationalization (I18N) refers to the operation by which a program is made aware of multiple languages. Localization (L10N) refers to the adaptation of your program, once internationalized, to the local language and cultural habits. In order to provide multilingual messages for your Python programs, you need to take the following steps:

1. prepare your program or module by specially marking translatable strings
2. run a suite of tools over your marked files to generate raw messages catalogs
3. create language specific translations of the message catalogs
4. use the *gettext* module so that message strings are properly translated

In order to prepare your code for I18N, you need to look at all the strings in your files. Any string that needs to be translated should be marked by wrapping it in `_('...')` — that is, a call to the function `_()`. For example:

```
filename = 'mylog.txt'
message = _('writing a log message')
fp = open(filename, 'w')
fp.write(message)
fp.close()
```

In this example, the string `'writing a log message'` is marked as a candidate for translation, while the strings `'mylog.txt'` and `'w'` are not.

There are a few tools to extract the strings meant for translation. The original GNU **gettext** only supported C or C++ source code but its extended version **xgettext** scans code written in a number of languages, including Python, to find strings marked as translatable. Babel is a Python internationalization library that includes a `pybabel` script to extract and compile message catalogs. François Pinard's program called **xpot** does a similar job and is available as part of his po-utils package.

(Python also includes pure-Python versions of these programs, called **pygettext.py** and **msgfmt.py**; some Python distributions will install them for you. **pygettext.py** is similar to **xgettext**, but only understands Python source code and cannot handle other programming languages such as C or C++. **pygettext.py** supports a command-line interface similar to **xgettext**; for details on its use, run `pygettext.py --help`.

msgfmt.py is binary compatible with GNU **msgfmt**. With these two programs, you may not need the GNU **gettext** package to internationalize your Python applications.)

xgettext, **pygettext**, and similar tools generate `.po` files that are message catalogs. They are structured human-readable files that contain every marked string in the source code, along with a placeholder for the translated versions of these strings.

Copies of these `.po` files are then handed over to the individual human translators who write translations for every supported natural language. They send back the completed language-specific versions as a `<language-name>.po` file that's compiled into a machine-readable `.mo` binary catalog file using the **msgfmt** program. The `.mo` files are used by the *gettext* module for the actual translation processing at run-time.

How you use the *gettext* module in your code depends on whether you are internationalizing a single module or your entire application. The next two sections will discuss each case.

Localizing your module

If you are localizing your module, you must take care not to make global changes, e.g. to the built-in namespace. You should not use the GNU `gettext` API but instead the class-based API.

Let's say your module is called "spam" and the module's various natural language translation `.mo` files reside in `/usr/share/locale` in GNU **gettext** format. Here's what you would put at the top of your module:

```
import gettext
t = gettext.translation('spam', '/usr/share/locale')
_ = t.gettext
```

Localizing your application

If you are localizing your application, you can install the `_()` function globally into the built-in namespace, usually in the main driver file of your application. This will let all your application-specific files just use `_('...')` without having to explicitly install it in each file.

In the simple case then, you need only add the following bit of code to the main driver file of your application:

```
import gettext
gettext.install('myapplication')
```

If you need to set the locale directory, you can pass it into the *install()* function:

```
import gettext
gettext.install('myapplication', '/usr/share/locale')
```

Changing languages on the fly

If your program needs to support many languages at the same time, you may want to create multiple translation instances and then switch between them explicitly, like so:

```
import gettext

lang1 = gettext.translation('myapplication', languages=['en'])
lang2 = gettext.translation('myapplication', languages=['fr'])
lang3 = gettext.translation('myapplication', languages=['de'])

# start by using language1
```

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```
lang1.install()

# ... time goes by, user selects language 2
lang2.install()

# ... more time goes by, user selects language 3
lang3.install()
```

Deferred translations

In most coding situations, strings are translated where they are coded. Occasionally however, you need to mark strings for translation, but defer actual translation until later. A classic example is:

```
animals = ['mollusk',
           'albatross',
           'rat',
           'penguin',
           'python', ]
# ...
for a in animals:
    print(a)
```

Here, you want to mark the strings in the `animals` list as being translatable, but you don't actually want to translate them until they are printed.

Here is one way you can handle this situation:

```
def _(message): return message

animals = [_('mollusk'),
           _('albatross'),
           _('rat'),
           _('penguin'),
           _('python'), ]

del _

# ...
for a in animals:
    print(_(a))
```

This works because the dummy definition of `_()` simply returns the string unchanged. And this dummy definition will temporarily override any definition of `_()` in the built-in namespace (until the `del` command). Take care, though if you have a previous definition of `_()` in the local namespace.

Note that the second use of `_()` will not identify "a" as being translatable to the **gettext** program, because the parameter is not a string literal.

Another way to handle this is with the following example:

```
def N_(message): return message

animals = [N_('mollusk'),
           N_('albatross'),
           N_('rat'),
           N_('penguin'),
```

(continues on next page)

(continued from previous page)

```
          N_('python'), ]

# ...
for a in animals:
    print(_(a))
```

In this case, you are marking translatable strings with the function `N_()`, which won't conflict with any definition of `_()`. However, you will need to teach your message extraction program to look for translatable strings marked with `N_()`. **xgettext**, **pygettext**, `pybabel extract`, and **xpot** all support this through the use of the `-k` command-line switch. The choice of `N_()` here is totally arbitrary; it could have just as easily been `MarkThisStringForTranslation()`.

24.1.4 Acknowledgements

The following people contributed code, feedback, design suggestions, previous implementations, and valuable experience to the creation of this module:

- Peter Funk
- James Henstridge
- Juan David Ibáñez Palomar
- Marc-André Lemburg
- Martin von Löwis
- François Pinard
- Barry Warsaw
- Gustavo Niemeyer

24.2 `locale` — Internationalization services

Source code: Lib/locale.py

The *locale* module opens access to the POSIX locale database and functionality. The POSIX locale mechanism allows programmers to deal with certain cultural issues in an application, without requiring the programmer to know all the specifics of each country where the software is executed.

The *locale* module is implemented on top of the `_locale` module, which in turn uses an ANSI C locale implementation if available.

The *locale* module defines the following exception and functions:

exception locale.**Error**
: Exception raised when the locale passed to *setlocale()* is not recognized.

locale.**setlocale**(*category*, *locale=None*)
: If *locale* is given and not `None`, *setlocale()* modifies the locale setting for the *category*. The available categories are listed in the data description below. *locale* may be a string, or an iterable of two strings (language code and encoding). If it's an iterable, it's converted to a locale name using the locale aliasing engine. An empty string specifies the user's default settings. If the modification of the locale fails, the exception *Error* is raised. If successful, the new locale setting is returned.

  If *locale* is omitted or `None`, the current setting for *category* is returned.

setlocale() is not thread-safe on most systems. Applications typically start with a call of

```
import locale
locale.setlocale(locale.LC_ALL, '')
```

This sets the locale for all categories to the user's default setting (typically specified in the `LANG` environment variable). If the locale is not changed thereafter, using multithreading should not cause problems.

`locale.localeconv()`

Returns the database of the local conventions as a dictionary. This dictionary has the following strings as keys:

Category	Key	Meaning
LC_NUMERIC	`'decimal_point'`	Decimal point character.
	`'grouping'`	Sequence of numbers specifying which relative positions the `'thousands_sep'` is expected. If the sequence is terminated with *CHAR_MAX*, no further grouping is performed. If the sequence terminates with a `0`, the last group size is repeatedly used.
	`'thousands_sep'`	Character used between groups.
LC_MONETARY	`'int_curr_symbol'`	International currency symbol.
	`'currency_symbol'`	Local currency symbol.
	`'p_cs_precedes/n_cs_precedes'`	Whether the currency symbol precedes the value (for positive resp. negative values).
	`'p_sep_by_space/n_sep_by_space'`	Whether the currency symbol is separated from the value by a space (for positive resp. negative values).
	`'mon_decimal_point'`	Decimal point used for monetary values.
	`'frac_digits'`	Number of fractional digits used in local formatting of monetary values.
	`'int_frac_digits'`	Number of fractional digits used in international formatting of monetary values.
	`'mon_thousands_sep'`	Group separator used for monetary values.
	`'mon_grouping'`	Equivalent to `'grouping'`, used for monetary values.
	`'positive_sign'`	Symbol used to annotate a positive monetary value.
	`'negative_sign'`	Symbol used to annotate a negative monetary value.
	`'p_sign_posn/n_sign_posn'`	The position of the sign (for positive resp. negative values), see below.

All numeric values can be set to *CHAR_MAX* to indicate that there is no value specified in this locale.

The possible values for `'p_sign_posn'` and `'n_sign_posn'` are given below.

Value	Explanation
0	Currency and value are surrounded by parentheses.
1	The sign should precede the value and currency symbol.
2	The sign should follow the value and currency symbol.
3	The sign should immediately precede the value.
4	The sign should immediately follow the value.
CHAR_MAX	Nothing is specified in this locale.

The function sets temporarily the LC_CTYPE locale to the LC_NUMERIC locale to decode decimal_point and thousands_sep byte strings if they are non-ASCII or longer than 1 byte, and the LC_NUMERIC locale is different than the LC_CTYPE locale. This temporary change affects other threads.

Changed in version 3.7: The function now sets temporarily the LC_CTYPE locale to the LC_NUMERIC locale in some cases.

locale.nl_langinfo(*option*)

Return some locale-specific information as a string. This function is not available on all systems, and the set of possible options might also vary across platforms. The possible argument values are numbers, for which symbolic constants are available in the locale module.

The *nl_langinfo()* function accepts one of the following keys. Most descriptions are taken from the corresponding description in the GNU C library.

locale.CODESET

Get a string with the name of the character encoding used in the selected locale.

locale.D_T_FMT

Get a string that can be used as a format string for *time.strftime()* to represent date and time in a locale-specific way.

locale.D_FMT

Get a string that can be used as a format string for *time.strftime()* to represent a date in a locale-specific way.

locale.T_FMT

Get a string that can be used as a format string for *time.strftime()* to represent a time in a locale-specific way.

locale.T_FMT_AMPM

Get a format string for *time.strftime()* to represent time in the am/pm format.

DAY_1 ... DAY_7

Get the name of the n-th day of the week.

Note: This follows the US convention of DAY_1 being Sunday, not the international convention (ISO 8601) that Monday is the first day of the week.

ABDAY_1 ... ABDAY_7

Get the abbreviated name of the n-th day of the week.

MON_1 ... MON_12

Get the name of the n-th month.

ABMON_1 ... ABMON_12

Get the abbreviated name of the n-th month.

locale.RADIXCHAR

Get the radix character (decimal dot, decimal comma, etc.).

locale.**THOUSEP**
Get the separator character for thousands (groups of three digits).

locale.**YESEXPR**
Get a regular expression that can be used with the regex function to recognize a positive response to a yes/no question.

Note: The expression is in the syntax suitable for the `regex()` function from the C library, which might differ from the syntax used in *re*.

---

locale.**NOEXPR**
Get a regular expression that can be used with the regex(3) function to recognize a negative response to a yes/no question.

locale.**CRNCYSTR**
Get the currency symbol, preceded by "-" if the symbol should appear before the value, "+" if the symbol should appear after the value, or "." if the symbol should replace the radix character.

locale.**ERA**
Get a string that represents the era used in the current locale.

Most locales do not define this value. An example of a locale which does define this value is the Japanese one. In Japan, the traditional representation of dates includes the name of the era corresponding to the then-emperor's reign.

Normally it should not be necessary to use this value directly. Specifying the `E` modifier in their format strings causes the *time.strftime()* function to use this information. The format of the returned string is not specified, and therefore you should not assume knowledge of it on different systems.

locale.**ERA_D_T_FMT**
Get a format string for *time.strftime()* to represent date and time in a locale-specific era-based way.

locale.**ERA_D_FMT**
Get a format string for *time.strftime()* to represent a date in a locale-specific era-based way.

locale.**ERA_T_FMT**
Get a format string for *time.strftime()* to represent a time in a locale-specific era-based way.

locale.**ALT_DIGITS**
Get a representation of up to 100 values used to represent the values 0 to 99.

locale.**getdefaultlocale**([*envvars*])
Tries to determine the default locale settings and returns them as a tuple of the form `(language code, encoding)`.

According to POSIX, a program which has not called `setlocale(LC_ALL, '')` runs using the portable `'C'` locale. Calling `setlocale(LC_ALL, '')` lets it use the default locale as defined by the `LANG` variable. Since we do not want to interfere with the current locale setting we thus emulate the behavior in the way described above.

To maintain compatibility with other platforms, not only the `LANG` variable is tested, but a list of variables given as envvars parameter. The first found to be defined will be used. *envvars* defaults to the search path used in GNU gettext; it must always contain the variable name `'LANG'`. The GNU gettext search path contains `'LC_ALL'`, `'LC_CTYPE'`, `'LANG'` and `'LANGUAGE'`, in that order.

Except for the code `'C'`, the language code corresponds to **RFC 1766**. *language code* and *encoding* may be `None` if their values cannot be determined.

locale.**getlocale**(*category=LC_CTYPE*)
Returns the current setting for the given locale category as sequence containing *language code*, *encoding*. *category* may be one of the `LC_*` values except *LC_ALL*. It defaults to *LC_CTYPE*.

Except for the code `'C'`, the language code corresponds to **RFC 1766**. *language code* and *encoding* may be `None` if their values cannot be determined.

locale.**getpreferredencoding**(*do_setlocale=True*)
Return the encoding used for text data, according to user preferences. User preferences are expressed differently on different systems, and might not be available programmatically on some systems, so this function only returns a guess.

On some systems, it is necessary to invoke *setlocale()* to obtain the user preferences, so this function is not thread-safe. If invoking setlocale is not necessary or desired, *do_setlocale* should be set to `False`.

On Android or in the UTF-8 mode (`-X utf8` option), always return `'UTF-8'`, the locale and the *do_setlocale* argument are ignored.

Changed in version 3.7: The function now always returns `UTF-8` on Android or if the UTF-8 mode is enabled.

locale.**normalize**(*localename*)
Returns a normalized locale code for the given locale name. The returned locale code is formatted for use with *setlocale()*. If normalization fails, the original name is returned unchanged.

If the given encoding is not known, the function defaults to the default encoding for the locale code just like *setlocale()*.

locale.**resetlocale**(*category=LC_ALL*)
Sets the locale for *category* to the default setting.

The default setting is determined by calling *getdefaultlocale()*. *category* defaults to *LC_ALL*.

locale.**strcoll**(*string1*, *string2*)
Compares two strings according to the current *LC_COLLATE* setting. As any other compare function, returns a negative, or a positive value, or `0`, depending on whether *string1* collates before or after *string2* or is equal to it.

locale.**strxfrm**(*string*)
Transforms a string to one that can be used in locale-aware comparisons. For example, `strxfrm(s1) < strxfrm(s2)` is equivalent to `strcoll(s1, s2) < 0`. This function can be used when the same string is compared repeatedly, e.g. when collating a sequence of strings.

locale.**format_string**(*format*, *val*, *grouping=False*, *monetary=False*)
Formats a number *val* according to the current *LC_NUMERIC* setting. The format follows the conventions of the `%` operator. For floating point values, the decimal point is modified if appropriate. If *grouping* is true, also takes the grouping into account.

If *monetary* is true, the conversion uses monetary thousands separator and grouping strings.

Processes formatting specifiers as in `format % val`, but takes the current locale settings into account.

Changed in version 3.7: The *monetary* keyword parameter was added.

locale.**format**(*format*, *val*, *grouping=False*, *monetary=False*)
Please note that this function works like *format_string()* but will only work for exactly one `%char` specifier. For example, `'%f'` and `'%.0f'` are both valid specifiers, but `'%f KiB'` is not.

For whole format strings, use *format_string()*.

Deprecated since version 3.7: Use *format_string()* instead.

locale.**currency**(*val*, *symbol=True*, *grouping=False*, *international=False*)
Formats a number *val* according to the current *LC_MONETARY* settings.

The returned string includes the currency symbol if *symbol* is true, which is the default. If *grouping* is true (which is not the default), grouping is done with the value. If *international* is true (which is not the default), the international currency symbol is used.

Note that this function will not work with the 'C' locale, so you have to set a locale via *setlocale()* first.

`locale.str(`*float*`)`
Formats a floating point number using the same format as the built-in function `str(float)`, but takes the decimal point into account.

`locale.delocalize(`*string*`)`
Converts a string into a normalized number string, following the *LC_NUMERIC* settings.

New in version 3.5.

`locale.atof(`*string*`)`
Converts a string to a floating point number, following the *LC_NUMERIC* settings.

`locale.atoi(`*string*`)`
Converts a string to an integer, following the *LC_NUMERIC* conventions.

`locale.LC_CTYPE`
Locale category for the character type functions. Depending on the settings of this category, the functions of module *string* dealing with case change their behaviour.

`locale.LC_COLLATE`
Locale category for sorting strings. The functions *strcoll()* and *strxfrm()* of the *locale* module are affected.

`locale.LC_TIME`
Locale category for the formatting of time. The function *time.strftime()* follows these conventions.

`locale.LC_MONETARY`
Locale category for formatting of monetary values. The available options are available from the *localeconv()* function.

`locale.LC_MESSAGES`
Locale category for message display. Python currently does not support application specific locale-aware messages. Messages displayed by the operating system, like those returned by *os.strerror()* might be affected by this category.

`locale.LC_NUMERIC`
Locale category for formatting numbers. The functions *format()*, *atoi()*, *atof()* and *str()* of the *locale* module are affected by that category. All other numeric formatting operations are not affected.

`locale.LC_ALL`
Combination of all locale settings. If this flag is used when the locale is changed, setting the locale for all categories is attempted. If that fails for any category, no category is changed at all. When the locale is retrieved using this flag, a string indicating the setting for all categories is returned. This string can be later used to restore the settings.

`locale.CHAR_MAX`
This is a symbolic constant used for different values returned by *localeconv()*.

Example:

```
>>> import locale
>>> loc = locale.getlocale()  # get current locale
# use German locale; name might vary with platform
>>> locale.setlocale(locale.LC_ALL, 'de_DE')
>>> locale.strcoll('f\xe4n', 'foo')  # compare a string containing an umlaut
```

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```
>>> locale.setlocale(locale.LC_ALL, '')   # use user's preferred locale
>>> locale.setlocale(locale.LC_ALL, 'C')  # use default (C) locale
>>> locale.setlocale(locale.LC_ALL, loc)  # restore saved locale
```

24.2.1 Background, details, hints, tips and caveats

The C standard defines the locale as a program-wide property that may be relatively expensive to change. On top of that, some implementation are broken in such a way that frequent locale changes may cause core dumps. This makes the locale somewhat painful to use correctly.

Initially, when a program is started, the locale is the `C` locale, no matter what the user's preferred locale is. There is one exception: the *LC_CTYPE* category is changed at startup to set the current locale encoding to the user's preferred locale encoding. The program must explicitly say that it wants the user's preferred locale settings for other categories by calling `setlocale(LC_ALL, '')`.

It is generally a bad idea to call *setlocale()* in some library routine, since as a side effect it affects the entire program. Saving and restoring it is almost as bad: it is expensive and affects other threads that happen to run before the settings have been restored.

If, when coding a module for general use, you need a locale independent version of an operation that is affected by the locale (such as certain formats used with *time.strftime()*), you will have to find a way to do it without using the standard library routine. Even better is convincing yourself that using locale settings is okay. Only as a last resort should you document that your module is not compatible with non-`C` locale settings.

The only way to perform numeric operations according to the locale is to use the special functions defined by this module: *atof()*, *atoi()*, *format()*, *str()*.

There is no way to perform case conversions and character classifications according to the locale. For (Unicode) text strings these are done according to the character value only, while for byte strings, the conversions and classifications are done according to the ASCII value of the byte, and bytes whose high bit is set (i.e., non-ASCII bytes) are never converted or considered part of a character class such as letter or whitespace.

24.2.2 For extension writers and programs that embed Python

Extension modules should never call *setlocale()*, except to find out what the current locale is. But since the return value can only be used portably to restore it, that is not very useful (except perhaps to find out whether or not the locale is `C`).

When Python code uses the *locale* module to change the locale, this also affects the embedding application. If the embedding application doesn't want this to happen, it should remove the `_locale` extension module (which does all the work) from the table of built-in modules in the `config.c` file, and make sure that the `_locale` module is not accessible as a shared library.

24.2.3 Access to message catalogs

`locale.`**`gettext`**`(`*msg*`)`

`locale.`**`dgettext`**`(`*domain*, *msg*`)`

`locale.`**`dcgettext`**`(`*domain*, *msg*, *category*`)`

`locale.`**`textdomain`**`(`*domain*`)`

`locale.`**`bindtextdomain`**`(`*domain*, *dir*`)`

The locale module exposes the C library's gettext interface on systems that provide this interface. It consists of the functions `gettext()`, `dgettext()`, `dcgettext()`, `textdomain()`, `bindtextdomain()`, and `bind_textdomain_codeset()`. These are similar to the same functions in the *gettext* module, but use the C library's binary format for message catalogs, and the C library's search algorithms for locating message catalogs.

Python applications should normally find no need to invoke these functions, and should use *gettext* instead. A known exception to this rule are applications that link with additional C libraries which internally invoke `gettext()` or `dcgettext()`. For these applications, it may be necessary to bind the text domain, so that the libraries can properly locate their message catalogs.

CHAPTER

TWENTYFIVE

PROGRAM FRAMEWORKS

The modules described in this chapter are frameworks that will largely dictate the structure of your program. Currently the modules described here are all oriented toward writing command-line interfaces.

The full list of modules described in this chapter is:

25.1 `turtle` — Turtle graphics

Source code: Lib/turtle.py

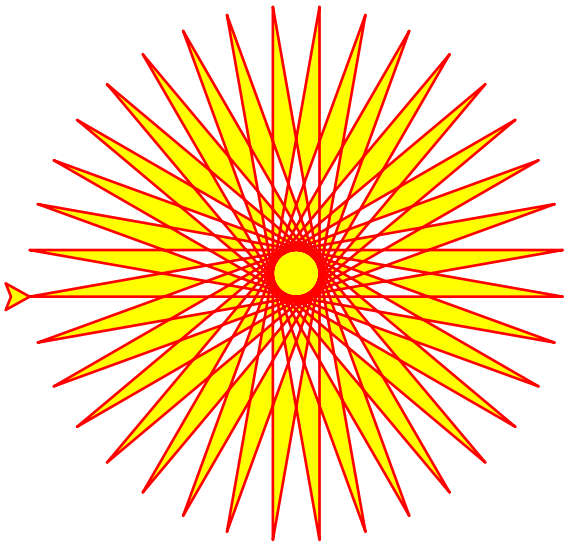
25.1.1 Introduction

Turtle graphics is a popular way for introducing programming to kids. It was part of the original Logo programming language developed by Wally Feurzig and Seymour Papert in 1966.

Imagine a robotic turtle starting at (0, 0) in the x-y plane. After an `import turtle`, give it the command `turtle.forward(15)`, and it moves (on-screen!) 15 pixels in the direction it is facing, drawing a line as it moves. Give it the command `turtle.right(25)`, and it rotates in-place 25 degrees clockwise.

Turtle star

Turtle can draw intricate shapes using programs that repeat simple moves.



```
from turtle import *
color('red', 'yellow')
begin_fill()
while True:
    forward(200)
    left(170)
    if abs(pos()) < 1:
        break
end_fill()
done()
```

By combining together these and similar commands, intricate shapes and pictures can easily be drawn.

The *turtle* module is an extended reimplementation of the same-named module from the Python standard distribution up to version Python 2.5.

It tries to keep the merits of the old turtle module and to be (nearly) 100% compatible with it. This means in the first place to enable the learning programmer to use all the commands, classes and methods interactively when using the module from within IDLE run with the `-n` switch.

The turtle module provides turtle graphics primitives, in both object-oriented and procedure-oriented ways. Because it uses *tkinter* for the underlying graphics, it needs a version of Python installed with Tk support.

The object-oriented interface uses essentially two+two classes:

1. The *TurtleScreen* class defines graphics windows as a playground for the drawing turtles. Its constructor needs a `tkinter.Canvas` or a *ScrolledCanvas* as argument. It should be used when *turtle* is used as part of some application.

   The function *Screen()* returns a singleton object of a *TurtleScreen* subclass. This function should be used when *turtle* is used as a standalone tool for doing graphics. As a singleton object, inheriting from its class is not possible.

   All methods of TurtleScreen/Screen also exist as functions, i.e. as part of the procedure-oriented interface.

2. *RawTurtle* (alias: *RawPen*) defines Turtle objects which draw on a *TurtleScreen*. Its constructor needs a Canvas, ScrolledCanvas or TurtleScreen as argument, so the RawTurtle objects know where to

draw.

Derived from RawTurtle is the subclass *Turtle* (alias: `Pen`), which draws on "the" *Screen* instance which is automatically created, if not already present.

All methods of RawTurtle/Turtle also exist as functions, i.e. part of the procedure-oriented interface.

The procedural interface provides functions which are derived from the methods of the classes *Screen* and *Turtle*. They have the same names as the corresponding methods. A screen object is automatically created whenever a function derived from a Screen method is called. An (unnamed) turtle object is automatically created whenever any of the functions derived from a Turtle method is called.

To use multiple turtles on a screen one has to use the object-oriented interface.

Note: In the following documentation the argument list for functions is given. Methods, of course, have the additional first argument *self* which is omitted here.

25.1.2 Overview of available Turtle and Screen methods

Turtle methods

Turtle motion

Move and draw

forward() | *fd()*
backward() | *bk()* | *back()*
right() | *rt()*
left() | *lt()*
goto() | *setpos()* | *setposition()*
setx()
sety()
setheading() | *seth()*
home()
circle()
dot()
stamp()
clearstamp()
clearstamps()
undo()
speed()

Tell Turtle's state

position() | *pos()*
towards()
xcor()
ycor()
heading()
distance()

Setting and measurement

degrees()

radians()

Pen control

Drawing state

pendown() | *pd()* | *down()*
penup() | *pu()* | *up()*
pensize() | *width()*
pen()
isdown()

Color control

color()
pencolor()
fillcolor()

Filling

filling()
begin_fill()
end_fill()

More drawing control

reset()
clear()
write()

Turtle state

Visibility

showturtle() | *st()*
hideturtle() | *ht()*
isvisible()

Appearance

shape()
resizemode()
shapesize() | *turtlesize()*
shearfactor()
settiltangle()
tiltangle()
tilt()
shapetransform()
get_shapepoly()

Using events

onclick()
onrelease()
ondrag()

Special Turtle methods

begin_poly()
end_poly()
get_poly()

clone()
getturtle() | *getpen()*
getscreen()
setundobuffer()
undobufferentries()

Methods of TurtleScreen/Screen

Window control

bgcolor()
bgpic()
clear() | *clearscreen()*
reset() | *resetscreen()*
screensize()
setworldcoordinates()

Animation control

delay()
tracer()
update()

Using screen events

listen()
onkey() | *onkeyrelease()*
onkeypress()
onclick() | *onscreenclick()*
ontimer()
mainloop() | *done()*

Settings and special methods

mode()
colormode()
getcanvas()
getshapes()
register_shape() | *addshape()*
turtles()
window_height()
window_width()

Input methods

textinput()
numinput()

Methods specific to Screen

bye()
exitonclick()
setup()
title()

25.1.3 Methods of RawTurtle/Turtle and corresponding functions

Most of the examples in this section refer to a Turtle instance called `turtle`.

Turtle motion

`turtle.forward(`*distance*`)`
`turtle.fd(`*distance*`)`

Parameters `distance` – a number (integer or float)

Move the turtle forward by the specified *distance*, in the direction the turtle is headed.

```
>>> turtle.position()
(0.00,0.00)
>>> turtle.forward(25)
>>> turtle.position()
(25.00,0.00)
>>> turtle.forward(-75)
>>> turtle.position()
(-50.00,0.00)
```

`turtle.back(`*distance*`)`
`turtle.bk(`*distance*`)`
`turtle.backward(`*distance*`)`

Parameters `distance` – a number

Move the turtle backward by *distance*, opposite to the direction the turtle is headed. Do not change the turtle's heading.

```
>>> turtle.position()
(0.00,0.00)
>>> turtle.backward(30)
>>> turtle.position()
(-30.00,0.00)
```

`turtle.right(`*angle*`)`
`turtle.rt(`*angle*`)`

Parameters `angle` – a number (integer or float)

Turn turtle right by *angle* units. (Units are by default degrees, but can be set via the *degrees()* and *radians()* functions.) Angle orientation depends on the turtle mode, see *mode()*.

```
>>> turtle.heading()
22.0
>>> turtle.right(45)
>>> turtle.heading()
337.0
```

`turtle.left(`*angle*`)`
`turtle.lt(`*angle*`)`

Parameters `angle` – a number (integer or float)

Turn turtle left by *angle* units. (Units are by default degrees, but can be set via the *degrees()* and *radians()* functions.) Angle orientation depends on the turtle mode, see *mode()*.

```
>>> turtle.heading()
22.0
>>> turtle.left(45)
>>> turtle.heading()
67.0
```

turtle.goto(*x*, *y=None*)
turtle.setpos(*x*, *y=None*)
turtle.setposition(*x*, *y=None*)

Parameters

- **x** – a number or a pair/vector of numbers
- **y** – a number or None

If *y* is None, *x* must be a pair of coordinates or a *Vec2D* (e.g. as returned by *pos()*).

Move turtle to an absolute position. If the pen is down, draw line. Do not change the turtle's orientation.

```
>>> tp = turtle.pos()
>>> tp
(0.00,0.00)
>>> turtle.setpos(60,30)
>>> turtle.pos()
(60.00,30.00)
>>> turtle.setpos((20,80))
>>> turtle.pos()
(20.00,80.00)
>>> turtle.setpos(tp)
>>> turtle.pos()
(0.00,0.00)
```

turtle.setx(*x*)

Parameters **x** – a number (integer or float)

Set the turtle's first coordinate to *x*, leave second coordinate unchanged.

```
>>> turtle.position()
(0.00,240.00)
>>> turtle.setx(10)
>>> turtle.position()
(10.00,240.00)
```

turtle.sety(*y*)

Parameters **y** – a number (integer or float)

Set the turtle's second coordinate to *y*, leave first coordinate unchanged.

```
>>> turtle.position()
(0.00,40.00)
>>> turtle.sety(-10)
>>> turtle.position()
(0.00,-10.00)
```

turtle.setheading(*to_angle*)
turtle.seth(*to_angle*)

Parameters **to_angle** – a number (integer or float)

Set the orientation of the turtle to *to_angle*. Here are some common directions in degrees:

standard mode	logo mode
0 - east	0 - north
90 - north	90 - east
180 - west	180 - south
270 - south	270 - west

```
>>> turtle.setheading(90)
>>> turtle.heading()
90.0
```

`turtle.home()`

Move turtle to the origin – coordinates (0,0) – and set its heading to its start-orientation (which depends on the mode, see *mode()*).

```
>>> turtle.heading()
90.0
>>> turtle.position()
(0.00,-10.00)
>>> turtle.home()
>>> turtle.position()
(0.00,0.00)
>>> turtle.heading()
0.0
```

`turtle.circle`(*radius*, *extent=None*, *steps=None*)

Parameters

- **radius** – a number
- **extent** – a number (or None)
- **steps** – an integer (or None)

Draw a circle with given *radius*. The center is *radius* units left of the turtle; *extent* – an angle – determines which part of the circle is drawn. If *extent* is not given, draw the entire circle. If *extent* is not a full circle, one endpoint of the arc is the current pen position. Draw the arc in counterclockwise direction if *radius* is positive, otherwise in clockwise direction. Finally the direction of the turtle is changed by the amount of *extent*.

As the circle is approximated by an inscribed regular polygon, *steps* determines the number of steps to use. If not given, it will be calculated automatically. May be used to draw regular polygons.

```
>>> turtle.home()
>>> turtle.position()
(0.00,0.00)
>>> turtle.heading()
0.0
>>> turtle.circle(50)
>>> turtle.position()
(-0.00,0.00)
>>> turtle.heading()
0.0
>>> turtle.circle(120, 180)  # draw a semicircle
>>> turtle.position()
(0.00,240.00)
```

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```
>>> turtle.heading()
180.0
```

`turtle.dot`(*size=None*, **color*)

Parameters

- **size** – an integer >= 1 (if given)
- **color** – a colorstring or a numeric color tuple

Draw a circular dot with diameter *size*, using *color*. If *size* is not given, the maximum of pensize+4 and 2*pensize is used.

```
>>> turtle.home()
>>> turtle.dot()
>>> turtle.fd(50); turtle.dot(20, "blue"); turtle.fd(50)
>>> turtle.position()
(100.00,-0.00)
>>> turtle.heading()
0.0
```

`turtle.stamp`()

Stamp a copy of the turtle shape onto the canvas at the current turtle position. Return a stamp_id for that stamp, which can be used to delete it by calling `clearstamp(stamp_id)`.

```
>>> turtle.color("blue")
>>> turtle.stamp()
11
>>> turtle.fd(50)
```

`turtle.clearstamp`(*stampid*)

Parameters **stampid** – an integer, must be return value of previous *stamp()* call

Delete stamp with given *stampid*.

```
>>> turtle.position()
(150.00,-0.00)
>>> turtle.color("blue")
>>> astamp = turtle.stamp()
>>> turtle.fd(50)
>>> turtle.position()
(200.00,-0.00)
>>> turtle.clearstamp(astamp)
>>> turtle.position()
(200.00,-0.00)
```

`turtle.clearstamps`(*n=None*)

Parameters **n** – an integer (or `None`)

Delete all or first/last n of turtle's stamps. If n is `None`, delete all stamps, if $n > 0$ delete first n stamps, else if $n < 0$ delete last n stamps.

```
>>> for i in range(8):
...     turtle.stamp(); turtle.fd(30)
13
14
15
```

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```
16
17
18
19
20
>>> turtle.clearstamps(2)
>>> turtle.clearstamps(-2)
>>> turtle.clearstamps()
```

turtle.undo()

Undo (repeatedly) the last turtle action(s). Number of available undo actions is determined by the size of the undobuffer.

```
>>> for i in range(4):
...     turtle.fd(50); turtle.lt(80)
...
>>> for i in range(8):
...     turtle.undo()
```

turtle.speed(*speed=None*)

Parameters **speed** – an integer in the range 0..10 or a speedstring (see below)

Set the turtle's speed to an integer value in the range 0..10. If no argument is given, return current speed.

If input is a number greater than 10 or smaller than 0.5, speed is set to 0. Speedstrings are mapped to speedvalues as follows:

- "fastest": 0
- "fast": 10
- "normal": 6
- "slow": 3
- "slowest": 1

Speeds from 1 to 10 enforce increasingly faster animation of line drawing and turtle turning.

Attention: *speed* = 0 means that *no* animation takes place. forward/back makes turtle jump and likewise left/right make the turtle turn instantly.

```
>>> turtle.speed()
3
>>> turtle.speed('normal')
>>> turtle.speed()
6
>>> turtle.speed(9)
>>> turtle.speed()
9
```

Tell Turtle's state

turtle.position()
turtle.pos()

Return the turtle's current location (x,y) (as a *Vec2D* vector).

```
>>> turtle.pos()
(440.00,-0.00)
```

turtle.towards(*x*, *y=None*)

Parameters

- **x** – a number or a pair/vector of numbers or a turtle instance
- **y** – a number if *x* is a number, else None

Return the angle between the line from turtle position to position specified by (x,y), the vector or the other turtle. This depends on the turtle's start orientation which depends on the mode - "standard"/"world" or "logo").

```
>>> turtle.goto(10, 10)
>>> turtle.towards(0,0)
225.0
```

turtle.xcor()

Return the turtle's x coordinate.

```
>>> turtle.home()
>>> turtle.left(50)
>>> turtle.forward(100)
>>> turtle.pos()
(64.28,76.60)
>>> print(round(turtle.xcor(), 5))
64.27876
```

turtle.ycor()

Return the turtle's y coordinate.

```
>>> turtle.home()
>>> turtle.left(60)
>>> turtle.forward(100)
>>> print(turtle.pos())
(50.00,86.60)
>>> print(round(turtle.ycor(), 5))
86.60254
```

turtle.heading()

Return the turtle's current heading (value depends on the turtle mode, see *mode()*).

```
>>> turtle.home()
>>> turtle.left(67)
>>> turtle.heading()
67.0
```

turtle.distance(*x*, *y=None*)

Parameters

- **x** – a number or a pair/vector of numbers or a turtle instance
- **y** – a number if *x* is a number, else None

Return the distance from the turtle to (x,y), the given vector, or the given other turtle, in turtle step units.

```
>>> turtle.home()
>>> turtle.distance(30,40)
50.0
>>> turtle.distance((30,40))
50.0
>>> joe = Turtle()
>>> joe.forward(77)
>>> turtle.distance(joe)
77.0
```

Settings for measurement

turtle.degrees(*fullcircle=360.0*)

Parameters **fullcircle** – a number

Set angle measurement units, i.e. set number of "degrees" for a full circle. Default value is 360 degrees.

```
>>> turtle.home()
>>> turtle.left(90)
>>> turtle.heading()
90.0

Change angle measurement unit to grad (also known as gon,
grade, or gradian and equals 1/100-th of the right angle.)
>>> turtle.degrees(400.0)
>>> turtle.heading()
100.0
>>> turtle.degrees(360)
>>> turtle.heading()
90.0
```

turtle.radians()

Set the angle measurement units to radians. Equivalent to `degrees(2*math.pi)`.

```
>>> turtle.home()
>>> turtle.left(90)
>>> turtle.heading()
90.0
>>> turtle.radians()
>>> turtle.heading()
1.5707963267948966
```

Pen control

Drawing state

turtle.pendown()
turtle.pd()
turtle.down()

Pull the pen down – drawing when moving.

turtle.penup()
turtle.pu()
turtle.up()

Pull the pen up – no drawing when moving.

turtle.**pensize**(*width=None*)
turtle.**width**(*width=None*)

Parameters **width** – a positive number

Set the line thickness to *width* or return it. If resizemode is set to "auto" and turtleshape is a polygon, that polygon is drawn with the same line thickness. If no argument is given, the current pensize is returned.

```
>>> turtle.pensize()
1
>>> turtle.pensize(10)   # from here on lines of width 10 are drawn
```

turtle.**pen**(*pen=None*, ***pendict*)

Parameters

- **pen** – a dictionary with some or all of the below listed keys
- **pendict** – one or more keyword-arguments with the below listed keys as keywords

Return or set the pen's attributes in a "pen-dictionary" with the following key/value pairs:

- "shown": True/False
- "pendown": True/False
- "pencolor": color-string or color-tuple
- "fillcolor": color-string or color-tuple
- "pensize": positive number
- "speed": number in range 0..10
- "resizemode": "auto" or "user" or "noresize"
- "stretchfactor": (positive number, positive number)
- "outline": positive number
- "tilt": number

This dictionary can be used as argument for a subsequent call to *pen()* to restore the former pen-state. Moreover one or more of these attributes can be provided as keyword-arguments. This can be used to set several pen attributes in one statement.

```
>>> turtle.pen(fillcolor="black", pencolor="red", pensize=10)
>>> sorted(turtle.pen().items())
[('fillcolor', 'black'), ('outline', 1), ('pencolor', 'red'),
 ('pendown', True), ('pensize', 10), ('resizemode', 'noresize'),
 ('shearfactor', 0.0), ('shown', True), ('speed', 9),
 ('stretchfactor', (1.0, 1.0)), ('tilt', 0.0)]
>>> penstate=turtle.pen()
>>> turtle.color("yellow", "")
>>> turtle.penup()
>>> sorted(turtle.pen().items())[:3]
[('fillcolor', ''), ('outline', 1), ('pencolor', 'yellow')]
>>> turtle.pen(penstate, fillcolor="green")
>>> sorted(turtle.pen().items())[:3]
[('fillcolor', 'green'), ('outline', 1), ('pencolor', 'red')]
```

turtle.**isdown**()

Return `True` if pen is down, `False` if it's up.

```
>>> turtle.penup()
>>> turtle.isdown()
False
>>> turtle.pendown()
>>> turtle.isdown()
True
```

Color control

turtle.**pencolor**(**args*)

Return or set the pencolor.

Four input formats are allowed:

pencolor() Return the current pencolor as color specification string or as a tuple (see example). May be used as input to another color/pencolor/fillcolor call.

pencolor(colorstring) Set pencolor to *colorstring*, which is a Tk color specification string, such as `"red"`, `"yellow"`, or `"#33cc8c"`.

pencolor((r, g, b)) Set pencolor to the RGB color represented by the tuple of *r*, *g*, and *b*. Each of *r*, *g*, and *b* must be in the range 0..colormode, where colormode is either 1.0 or 255 (see *colormode()*).

pencolor(r, g, b)

Set pencolor to the RGB color represented by *r*, *g*, and *b*. Each of *r*, *g*, and *b* must be in the range 0..colormode.

If turtleshape is a polygon, the outline of that polygon is drawn with the newly set pencolor.

```
>>> colormode()
1.0
>>> turtle.pencolor()
'red'
>>> turtle.pencolor("brown")
>>> turtle.pencolor()
'brown'
>>> tup = (0.2, 0.8, 0.55)
>>> turtle.pencolor(tup)
>>> turtle.pencolor()
(0.2, 0.8, 0.5490196078431373)
>>> colormode(255)
>>> turtle.pencolor()
(51.0, 204.0, 140.0)
>>> turtle.pencolor('#32c18f')
>>> turtle.pencolor()
(50.0, 193.0, 143.0)
```

turtle.**fillcolor**(**args*)

Return or set the fillcolor.

Four input formats are allowed:

fillcolor() Return the current fillcolor as color specification string, possibly in tuple format (see example). May be used as input to another color/pencolor/fillcolor call.

fillcolor(colorstring) Set fillcolor to *colorstring*, which is a Tk color specification string, such as `"red"`, `"yellow"`, or `"#33cc8c"`.

fillcolor((r, g, b)) Set fillcolor to the RGB color represented by the tuple of *r*, *g*, and *b*. Each of *r*, *g*, and *b* must be in the range 0..colormode, where colormode is either 1.0 or 255 (see *colormode()*).

fillcolor(r, g, b)

Set fillcolor to the RGB color represented by *r*, *g*, and *b*. Each of *r*, *g*, and *b* must be in the range 0..colormode.

If turtleshape is a polygon, the interior of that polygon is drawn with the newly set fillcolor.

```
>>> turtle.fillcolor("violet")
>>> turtle.fillcolor()
'violet'
>>> turtle.pencolor()
(50.0, 193.0, 143.0)
>>> turtle.fillcolor((50, 193, 143))  # Integers, not floats
>>> turtle.fillcolor()
(50.0, 193.0, 143.0)
>>> turtle.fillcolor('#ffffff')
>>> turtle.fillcolor()
(255.0, 255.0, 255.0)
```

turtle.color(**args*)

Return or set pencolor and fillcolor.

Several input formats are allowed. They use 0 to 3 arguments as follows:

color() Return the current pencolor and the current fillcolor as a pair of color specification strings or tuples as returned by *pencolor()* and *fillcolor()*.

color(colorstring), color((r,g,b)), color(r,g,b) Inputs as in *pencolor()*, set both, fillcolor and pencolor, to the given value.

color(colorstring1, colorstring2), color((r1,g1,b1), (r2,g2,b2))

Equivalent to `pencolor(colorstring1)` and `fillcolor(colorstring2)` and analogously if the other input format is used.

If turtleshape is a polygon, outline and interior of that polygon is drawn with the newly set colors.

```
>>> turtle.color("red", "green")
>>> turtle.color()
('red', 'green')
>>> color("#285078", "#a0c8f0")
>>> color()
((40.0, 80.0, 120.0), (160.0, 200.0, 240.0))
```

See also: Screen method *colormode()*.

Filling

turtle.filling()

Return fillstate (`True` if filling, `False` else).

```
>>> turtle.begin_fill()
>>> if turtle.filling():
...     turtle.pensize(5)
... else:
...     turtle.pensize(3)
```

turtle.**begin_fill**()
To be called just before drawing a shape to be filled.

turtle.**end_fill**()
Fill the shape drawn after the last call to *begin_fill()*.

```
>>> turtle.color("black", "red")
>>> turtle.begin_fill()
>>> turtle.circle(80)
>>> turtle.end_fill()
```

More drawing control

turtle.**reset**()
Delete the turtle's drawings from the screen, re-center the turtle and set variables to the default values.

```
>>> turtle.goto(0,-22)
>>> turtle.left(100)
>>> turtle.position()
(0.00,-22.00)
>>> turtle.heading()
100.0
>>> turtle.reset()
>>> turtle.position()
(0.00,0.00)
>>> turtle.heading()
0.0
```

turtle.**clear**()
Delete the turtle's drawings from the screen. Do not move turtle. State and position of the turtle as well as drawings of other turtles are not affected.

turtle.**write**(*arg*, *move=False*, *align="left"*, *font=("Arial", 8, "normal")*)

Parameters

- **arg** – object to be written to the TurtleScreen
- **move** – True/False
- **align** – one of the strings "left", "center" or right"
- **font** – a triple (fontname, fontsize, fonttype)

Write text - the string representation of *arg* - at the current turtle position according to *align* ("left", "center" or right") and with the given font. If *move* is true, the pen is moved to the bottom-right corner of the text. By default, *move* is `False`.

```
>>> turtle.write("Home = ", True, align="center")
>>> turtle.write((0,0), True)
```

Turtle state

Visibility

turtle.**hideturtle**()

turtle.**ht**()
Make the turtle invisible. It's a good idea to do this while you're in the middle of doing some complex drawing, because hiding the turtle speeds up the drawing observably.

```
>>> turtle.hideturtle()
```

turtle.**showturtle**()
turtle.**st**()
Make the turtle visible.

```
>>> turtle.showturtle()
```

turtle.**isvisible**()
Return `True` if the Turtle is shown, `False` if it's hidden.

```
>>> turtle.hideturtle()
>>> turtle.isvisible()
False
>>> turtle.showturtle()
>>> turtle.isvisible()
True
```

Appearance

turtle.**shape**(*name=None*)

Parameters **name** – a string which is a valid shapename

Set turtle shape to shape with given *name* or, if name is not given, return name of current shape. Shape with *name* must exist in the TurtleScreen's shape dictionary. Initially there are the following polygon shapes: "arrow", "turtle", "circle", "square", "triangle", "classic". To learn about how to deal with shapes see Screen method *register_shape()*.

```
>>> turtle.shape()
'classic'
>>> turtle.shape("turtle")
>>> turtle.shape()
'turtle'
```

turtle.**resizemode**(*rmode=None*)

Parameters **rmode** – one of the strings "auto", "user", "noresize"

Set resizemode to one of the values: "auto", "user", "noresize". If *rmode* is not given, return current resizemode. Different resizemodes have the following effects:

- "auto": adapts the appearance of the turtle corresponding to the value of pensize.
- "user": adapts the appearance of the turtle according to the values of stretchfactor and outlinewidth (outline), which are set by *shapesize()*.
- "noresize": no adaption of the turtle's appearance takes place.

resizemode("user") is called by *shapesize()* when used with arguments.

```
>>> turtle.resizemode()
'noresize'
>>> turtle.resizemode("auto")
>>> turtle.resizemode()
'auto'
```

turtle.**shapesize**(*stretch_wid=None*, *stretch_len=None*, *outline=None*)
turtle.**turtlesize**(*stretch_wid=None*, *stretch_len=None*, *outline=None*)

Parameters

- **stretch_wid** – positive number
- **stretch_len** – positive number
- **outline** – positive number

Return or set the pen's attributes x/y-stretchfactors and/or outline. Set resizemode to "user". If and only if resizemode is set to "user", the turtle will be displayed stretched according to its stretchfactors: *stretch_wid* is stretchfactor perpendicular to its orientation, *stretch_len* is stretchfactor in direction of its orientation, *outline* determines the width of the shapes's outline.

```
>>> turtle.shapesize()
(1.0, 1.0, 1)
>>> turtle.resizemode("user")
>>> turtle.shapesize(5, 5, 12)
>>> turtle.shapesize()
(5, 5, 12)
>>> turtle.shapesize(outline=8)
>>> turtle.shapesize()
(5, 5, 8)
```

turtle.**shearfactor**(*shear=None*)

Parameters **shear** – number (optional)

Set or return the current shearfactor. Shear the turtleshape according to the given shearfactor shear, which is the tangent of the shear angle. Do *not* change the turtle's heading (direction of movement). If shear is not given: return the current shearfactor, i. e. the tangent of the shear angle, by which lines parallel to the heading of the turtle are sheared.

```
>>> turtle.shape("circle")
>>> turtle.shapesize(5,2)
>>> turtle.shearfactor(0.5)
>>> turtle.shearfactor()
0.5
```

turtle.**tilt**(*angle*)

Parameters **angle** – a number

Rotate the turtleshape by *angle* from its current tilt-angle, but do *not* change the turtle's heading (direction of movement).

```
>>> turtle.reset()
>>> turtle.shape("circle")
>>> turtle.shapesize(5,2)
>>> turtle.tilt(30)
>>> turtle.fd(50)
>>> turtle.tilt(30)
>>> turtle.fd(50)
```

turtle.**settiltangle**(*angle*)

Parameters **angle** – a number

Rotate the turtleshape to point in the direction specified by *angle*, regardless of its current tilt-angle. *Do not* change the turtle's heading (direction of movement).

```
>>> turtle.reset()
>>> turtle.shape("circle")
>>> turtle.shapesize(5,2)
>>> turtle.settiltangle(45)
>>> turtle.fd(50)
>>> turtle.settiltangle(-45)
>>> turtle.fd(50)
```

Deprecated since version 3.1.

turtle.tiltangle(*angle=None*)

Parameters **angle** – a number (optional)

Set or return the current tilt-angle. If angle is given, rotate the turtleshape to point in the direction specified by angle, regardless of its current tilt-angle. Do *not* change the turtle's heading (direction of movement). If angle is not given: return the current tilt-angle, i. e. the angle between the orientation of the turtleshape and the heading of the turtle (its direction of movement).

```
>>> turtle.reset()
>>> turtle.shape("circle")
>>> turtle.shapesize(5,2)
>>> turtle.tilt(45)
>>> turtle.tiltangle()
45.0
```

turtle.shapetransform(*t11=None*, *t12=None*, *t21=None*, *t22=None*)

Parameters

- **t11** – a number (optional)
- **t12** – a number (optional)
- **t21** – a number (optional)
- **t12** – a number (optional)

Set or return the current transformation matrix of the turtle shape.

If none of the matrix elements are given, return the transformation matrix as a tuple of 4 elements. Otherwise set the given elements and transform the turtleshape according to the matrix consisting of first row t11, t12 and second row t21, 22. The determinant t11 * t22 - t12 * t21 must not be zero, otherwise an error is raised. Modify stretchfactor, shearfactor and tiltangle according to the given matrix.

```
>>> turtle = Turtle()
>>> turtle.shape("square")
>>> turtle.shapesize(4,2)
>>> turtle.shearfactor(-0.5)
>>> turtle.shapetransform()
(4.0, -1.0, -0.0, 2.0)
```

turtle.get_shapepoly()

Return the current shape polygon as tuple of coordinate pairs. This can be used to define a new shape or components of a compound shape.

```
>>> turtle.shape("square")
>>> turtle.shapetransform(4, -1, 0, 2)
>>> turtle.get_shapepoly()
((50, -20), (30, 20), (-50, 20), (-30, -20))
```

Using events

`turtle.onclick`(*fun*, *btn=1*, *add=None*)

Parameters

- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults to 1 (left mouse button)
- **add** – `True` or `False` – if `True`, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-click events on this turtle. If *fun* is `None`, existing bindings are removed. Example for the anonymous turtle, i.e. the procedural way:

```
>>> def turn(x, y):
...     left(180)
...
>>> onclick(turn)  # Now clicking into the turtle will turn it.
>>> onclick(None)  # event-binding will be removed
```

`turtle.onrelease`(*fun*, *btn=1*, *add=None*)

Parameters

- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults to 1 (left mouse button)
- **add** – `True` or `False` – if `True`, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-button-release events on this turtle. If *fun* is `None`, existing bindings are removed.

```
>>> class MyTurtle(Turtle):
...     def glow(self,x,y):
...         self.fillcolor("red")
...     def unglow(self,x,y):
...         self.fillcolor("")
...
>>> turtle = MyTurtle()
>>> turtle.onclick(turtle.glow)     # clicking on turtle turns fillcolor red,
>>> turtle.onrelease(turtle.unglow) # releasing turns it to transparent.
```

`turtle.ondrag`(*fun*, *btn=1*, *add=None*)

Parameters

- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults to 1 (left mouse button)
- **add** – `True` or `False` – if `True`, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-move events on this turtle. If *fun* is `None`, existing bindings are removed.

Remark: Every sequence of mouse-move-events on a turtle is preceded by a mouse-click event on that turtle.

```
>>> turtle.ondrag(turtle.goto)
```

Subsequently, clicking and dragging the Turtle will move it across the screen thereby producing handdrawings (if pen is down).

Special Turtle methods

turtle.begin_poly()
Start recording the vertices of a polygon. Current turtle position is first vertex of polygon.

turtle.end_poly()
Stop recording the vertices of a polygon. Current turtle position is last vertex of polygon. This will be connected with the first vertex.

turtle.get_poly()
Return the last recorded polygon.

```
>>> turtle.home()
>>> turtle.begin_poly()
>>> turtle.fd(100)
>>> turtle.left(20)
>>> turtle.fd(30)
>>> turtle.left(60)
>>> turtle.fd(50)
>>> turtle.end_poly()
>>> p = turtle.get_poly()
>>> register_shape("myFavouriteShape", p)
```

turtle.clone()
Create and return a clone of the turtle with same position, heading and turtle properties.

```
>>> mick = Turtle()
>>> joe = mick.clone()
```

turtle.getturtle()
turtle.getpen()
Return the Turtle object itself. Only reasonable use: as a function to return the "anonymous turtle":

```
>>> pet = getturtle()
>>> pet.fd(50)
>>> pet
<turtle.Turtle object at 0x...>
```

turtle.getscreen()
Return the *TurtleScreen* object the turtle is drawing on. TurtleScreen methods can then be called for that object.

```
>>> ts = turtle.getscreen()
>>> ts
<turtle._Screen object at 0x...>
>>> ts.bgcolor("pink")
```

turtle.setundobuffer(*size*)

Parameters **size** – an integer or None

Set or disable undobuffer. If *size* is an integer an empty undobuffer of given size is installed. *size* gives the maximum number of turtle actions that can be undone by the *undo()* method/function. If *size* is `None`, the undobuffer is disabled.

```
>>> turtle.setundobuffer(42)
```

`turtle.undobufferentries()`

Return number of entries in the undobuffer.

```
>>> while undobufferentries():
...     undo()
```

Compound shapes

To use compound turtle shapes, which consist of several polygons of different color, you must use the helper class *Shape* explicitly as described below:

1. Create an empty Shape object of type "compound".
2. Add as many components to this object as desired, using the `addcomponent()` method.

   For example:

```
>>> s = Shape("compound")
>>> poly1 = ((0,0),(10,-5),(0,10),(-10,-5))
>>> s.addcomponent(poly1, "red", "blue")
>>> poly2 = ((0,0),(10,-5),(-10,-5))
>>> s.addcomponent(poly2, "blue", "red")
```

3. Now add the Shape to the Screen's shapelist and use it:

```
>>> register_shape("myshape", s)
>>> shape("myshape")
```

Note: The *Shape* class is used internally by the *register_shape()* method in different ways. The application programmer has to deal with the Shape class *only* when using compound shapes like shown above!

25.1.4 Methods of TurtleScreen/Screen and corresponding functions

Most of the examples in this section refer to a TurtleScreen instance called `screen`.

Window control

`turtle.bgcolor(*args)`

Parameters `args` – a color string or three numbers in the range 0..colormode or a 3-tuple of such numbers

Set or return background color of the TurtleScreen.

```
>>> screen.bgcolor("orange")
>>> screen.bgcolor()
'orange'
```

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```
>>> screen.bgcolor("#800080")
>>> screen.bgcolor()
(128.0, 0.0, 128.0)
```

turtle.bgpic(*picname=None*)

Parameters **picname** – a string, name of a gif-file or "nopic", or None

Set background image or return name of current backgroundimage. If *picname* is a filename, set the corresponding image as background. If *picname* is "nopic", delete background image, if present. If *picname* is None, return the filename of the current backgroundimage.

```
>>> screen.bgpic()
'nopic'
>>> screen.bgpic("landscape.gif")
>>> screen.bgpic()
"landscape.gif"
```

turtle.clear()
turtle.clearscreen()

Delete all drawings and all turtles from the TurtleScreen. Reset the now empty TurtleScreen to its initial state: white background, no background image, no event bindings and tracing on.

Note: This TurtleScreen method is available as a global function only under the name clearscreen. The global function clear is a different one derived from the Turtle method clear.

---

turtle.reset()
turtle.resetscreen()

Reset all Turtles on the Screen to their initial state.

Note: This TurtleScreen method is available as a global function only under the name resetscreen. The global function reset is another one derived from the Turtle method reset.

---

turtle.screensize(*canvwidth=None*, *canvheight=None*, *bg=None*)

Parameters

- **canvwidth** – positive integer, new width of canvas in pixels
- **canvheight** – positive integer, new height of canvas in pixels
- **bg** – colorstring or color-tuple, new background color

If no arguments are given, return current (canvaswidth, canvasheight). Else resize the canvas the turtles are drawing on. Do not alter the drawing window. To observe hidden parts of the canvas, use the scrollbars. With this method, one can make visible those parts of a drawing which were outside the canvas before.

```
>>> screen.screensize()
(400, 300)
>>> screen.screensize(2000,1500)
>>> screen.screensize()
(2000, 1500)
```

e.g. to search for an erroneously escaped turtle ;-)

turtle.setworldcoordinates(*llx*, *lly*, *urx*, *ury*)

Parameters

- **llx** – a number, x-coordinate of lower left corner of canvas
- **lly** – a number, y-coordinate of lower left corner of canvas
- **urx** – a number, x-coordinate of upper right corner of canvas
- **ury** – a number, y-coordinate of upper right corner of canvas

Set up user-defined coordinate system and switch to mode "world" if necessary. This performs a `screen.reset()`. If mode "world" is already active, all drawings are redrawn according to the new coordinates.

ATTENTION: in user-defined coordinate systems angles may appear distorted.

```
>>> screen.reset()
>>> screen.setworldcoordinates(-50,-7.5,50,7.5)
>>> for _ in range(72):
...     left(10)
...
>>> for _ in range(8):
...     left(45); fd(2)   # a regular octagon
```

Animation control

`turtle.delay(`*delay=None*`)`

Parameters **delay** – positive integer

Set or return the drawing *delay* in milliseconds. (This is approximately the time interval between two consecutive canvas updates.) The longer the drawing delay, the slower the animation.

Optional argument:

```
>>> screen.delay()
10
>>> screen.delay(5)
>>> screen.delay()
5
```

`turtle.tracer(`*n=None*, *delay=None*`)`

Parameters

- **n** – nonnegative integer
- **delay** – nonnegative integer

Turn turtle animation on/off and set delay for update drawings. If *n* is given, only each n-th regular screen update is really performed. (Can be used to accelerate the drawing of complex graphics.) When called without arguments, returns the currently stored value of n. Second argument sets delay value (see *delay()*).

```
>>> screen.tracer(8, 25)
>>> dist = 2
>>> for i in range(200):
...     fd(dist)
...     rt(90)
...     dist += 2
```

`turtle.update()`

Perform a TurtleScreen update. To be used when tracer is turned off.

See also the RawTurtle/Turtle method *speed()*.

Using screen events

turtle.listen(*xdummy=None*, *ydummy=None*)
Set focus on TurtleScreen (in order to collect key-events). Dummy arguments are provided in order to be able to pass *listen()* to the onclick method.

turtle.onkey(*fun*, *key*)
turtle.onkeyrelease(*fun*, *key*)

Parameters

- **fun** – a function with no arguments or `None`
- **key** – a string: key (e.g. "a") or key-symbol (e.g. "space")

Bind *fun* to key-release event of key. If *fun* is `None`, event bindings are removed. Remark: in order to be able to register key-events, TurtleScreen must have the focus. (See method *listen()*.)

```
>>> def f():
...     fd(50)
...     lt(60)
...
>>> screen.onkey(f, "Up")
>>> screen.listen()
```

turtle.onkeypress(*fun*, *key=None*)

Parameters

- **fun** – a function with no arguments or `None`
- **key** – a string: key (e.g. "a") or key-symbol (e.g. "space")

Bind *fun* to key-press event of key if key is given, or to any key-press-event if no key is given. Remark: in order to be able to register key-events, TurtleScreen must have focus. (See method *listen()*.)

```
>>> def f():
...     fd(50)
...
>>> screen.onkey(f, "Up")
>>> screen.listen()
```

turtle.onclick(*fun*, *btn=1*, *add=None*)
turtle.onscreenclick(*fun*, *btn=1*, *add=None*)

Parameters

- **fun** – a function with two arguments which will be called with the coordinates of the clicked point on the canvas
- **num** – number of the mouse-button, defaults to 1 (left mouse button)
- **add** – `True` or `False` – if `True`, a new binding will be added, otherwise it will replace a former binding

Bind *fun* to mouse-click events on this screen. If *fun* is `None`, existing bindings are removed.

Example for a TurtleScreen instance named `screen` and a Turtle instance named turtle:

```
>>> screen.onclick(turtle.goto) # Subsequently clicking into the TurtleScreen will
>>>                             # make the turtle move to the clicked point.
>>> screen.onclick(None)        # remove event binding again
```

Note: This TurtleScreen method is available as a global function only under the name `onscreenclick`. The global function `onclick` is another one derived from the Turtle method `onclick`.

`turtle.ontimer`(*fun*, *t=0*)

Parameters

- **fun** – a function with no arguments
- **t** – a number >= 0

Install a timer that calls *fun* after *t* milliseconds.

```
>>> running = True
>>> def f():
...     if running:
...         fd(50)
...         lt(60)
...         screen.ontimer(f, 250)
>>> f()   ### makes the turtle march around
>>> running = False
```

`turtle.mainloop`()
`turtle.done`()

Starts event loop - calling Tkinter's mainloop function. Must be the last statement in a turtle graphics program. Must *not* be used if a script is run from within IDLE in -n mode (No subprocess) - for interactive use of turtle graphics.

```
>>> screen.mainloop()
```

Input methods

`turtle.textinput`(*title*, *prompt*)

Parameters

- **title** – string
- **prompt** – string

Pop up a dialog window for input of a string. Parameter title is the title of the dialog window, prompt is a text mostly describing what information to input. Return the string input. If the dialog is canceled, return `None`.

```
>>> screen.textinput("NIM", "Name of first player:")
```

`turtle.numinput`(*title*, *prompt*, *default=None*, *minval=None*, *maxval=None*)

Parameters

- **title** – string
- **prompt** – string
- **default** – number (optional)
- **minval** – number (optional)
- **maxval** – number (optional)

Pop up a dialog window for input of a number. title is the title of the dialog window, prompt is a text mostly describing what numerical information to input. default: default value, minval: minimum value for input, maxval: maximum value for input The number input must be in the range minval .. maxval if these are given. If not, a hint is issued and the dialog remains open for correction. Return the number input. If the dialog is canceled, return `None`.

```
>>> screen.numinput("Poker", "Your stakes:", 1000, minval=10, maxval=10000)
```

Settings and special methods

`turtle.mode`(*mode=None*)

Parameters `mode` – one of the strings "standard", "logo" or "world"

Set turtle mode ("standard", "logo" or "world") and perform reset. If mode is not given, current mode is returned.

Mode "standard" is compatible with old *turtle*. Mode "logo" is compatible with most Logo turtle graphics. Mode "world" uses user-defined "world coordinates". **Attention**: in this mode angles appear distorted if `x/y` unit-ratio doesn't equal 1.

Mode	Initial turtle heading	positive angles
"standard"	to the right (east)	counterclockwise
"logo"	upward (north)	clockwise

```
>>> mode("logo")   # resets turtle heading to north
>>> mode()
'logo'
```

`turtle.colormode`(*cmode=None*)

Parameters `cmode` – one of the values 1.0 or 255

Return the colormode or set it to 1.0 or 255. Subsequently *r*, *g*, *b* values of color triples have to be in the range 0..*cmode*.

```
>>> screen.colormode(1)
>>> turtle.pencolor(240, 160, 80)
Traceback (most recent call last):
     ...
TurtleGraphicsError: bad color sequence: (240, 160, 80)
>>> screen.colormode()
1.0
>>> screen.colormode(255)
>>> screen.colormode()
255
>>> turtle.pencolor(240,160,80)
```

`turtle.getcanvas`()

Return the Canvas of this TurtleScreen. Useful for insiders who know what to do with a Tkinter Canvas.

```
>>> cv = screen.getcanvas()
>>> cv
<turtle.ScrolledCanvas object ...>
```

`turtle.getshapes`()

Return a list of names of all currently available turtle shapes.

```
>>> screen.getshapes()
['arrow', 'blank', 'circle', ..., 'turtle']
```

turtle.register_shape(*name*, *shape=None*)
turtle.addshape(*name*, *shape=None*)

There are three different ways to call this function:

1. *name* is the name of a gif-file and *shape* is `None`: Install the corresponding image shape.

```
>>> screen.register_shape("turtle.gif")
```

> **Note:** Image shapes *do not* rotate when turning the turtle, so they do not display the heading of the turtle!

2. *name* is an arbitrary string and *shape* is a tuple of pairs of coordinates: Install the corresponding polygon shape.

```
>>> screen.register_shape("triangle", ((5,-3), (0,5), (-5,-3)))
```

3. *name* is an arbitrary string and shape is a (compound) *Shape* object: Install the corresponding compound shape.

Add a turtle shape to TurtleScreen's shapelist. Only thusly registered shapes can be used by issuing the command `shape(shapename)`.

turtle.turtles()

Return the list of turtles on the screen.

```
>>> for turtle in screen.turtles():
...     turtle.color("red")
```

turtle.window_height()

Return the height of the turtle window.

```
>>> screen.window_height()
480
```

turtle.window_width()

Return the width of the turtle window.

```
>>> screen.window_width()
640
```

Methods specific to Screen, not inherited from TurtleScreen

turtle.bye()

Shut the turtlegraphics window.

turtle.exitonclick()

Bind bye() method to mouse clicks on the Screen.

If the value "using_IDLE" in the configuration dictionary is `False` (default value), also enter mainloop. Remark: If IDLE with the `-n` switch (no subprocess) is used, this value should be set to `True` in `turtle.cfg`. In this case IDLE's own mainloop is active also for the client script.

turtle.setup(*width=_CFG["width"], height=_CFG["height"], startx=_CFG["leftright"], starty=_CFG["topbottom"]*)

Set the size and position of the main window. Default values of arguments are stored in the configuration dictionary and can be changed via a `turtle.cfg` file.

Parameters

- **width** – if an integer, a size in pixels, if a float, a fraction of the screen; default is 50% of screen
- **height** – if an integer, the height in pixels, if a float, a fraction of the screen; default is 75% of screen
- **startx** – if positive, starting position in pixels from the left edge of the screen, if negative from the right edge, if `None`, center window horizontally
- **starty** – if positive, starting position in pixels from the top edge of the screen, if negative from the bottom edge, if `None`, center window vertically

```
>>> screen.setup (width=200, height=200, startx=0, starty=0)
>>>              # sets window to 200x200 pixels, in upper left of screen
>>> screen.setup(width=.75, height=0.5, startx=None, starty=None)
>>>              # sets window to 75% of screen by 50% of screen and centers
```

turtle.title(*titlestring*)

Parameters **titlestring** – a string that is shown in the titlebar of the turtle graphics window

Set title of turtle window to *titlestring*.

```
>>> screen.title("Welcome to the turtle zoo!")
```

25.1.5 Public classes

class turtle.RawTurtle(*canvas*)
class turtle.RawPen(*canvas*)

Parameters **canvas** – a `tkinter.Canvas`, a *ScrolledCanvas* or a *TurtleScreen*

Create a turtle. The turtle has all methods described above as "methods of Turtle/RawTurtle".

class turtle.Turtle

Subclass of RawTurtle, has the same interface but draws on a default *Screen* object created automatically when needed for the first time.

class turtle.TurtleScreen(*cv*)

Parameters **cv** – a `tkinter.Canvas`

Provides screen oriented methods like `setbg()` etc. that are described above.

class turtle.Screen

Subclass of TurtleScreen, with *four methods added*.

class turtle.ScrolledCanvas(*master*)

Parameters **master** – some Tkinter widget to contain the ScrolledCanvas, i.e. a Tkinter-canvas with scrollbars added

Used by class Screen, which thus automatically provides a ScrolledCanvas as playground for the turtles.

class turtle.Shape(*type_*, *data*)

Parameters **type_** – one of the strings "polygon", "image", "compound"

Data structure modeling shapes. The pair `(type_, data)` must follow this specification:

*type_*	*data*
"polygon"	a polygon-tuple, i.e. a tuple of pairs of coordinates
"image"	an image (in this form only used internally!)
"compound"	`None` (a compound shape has to be constructed using the *addcomponent()* method)

addcomponent(*poly*, *fill*, *outline=None*)

Parameters

- **poly** – a polygon, i.e. a tuple of pairs of numbers
- **fill** – a color the *poly* will be filled with
- **outline** – a color for the poly's outline (if given)

Example:

```
>>> poly = ((0,0),(10,-5),(0,10),(-10,-5))
>>> s = Shape("compound")
>>> s.addcomponent(poly, "red", "blue")
>>> # ... add more components and then use register_shape()
```

See *Compound shapes*.

class turtle.Vec2D(*x*, *y*)

A two-dimensional vector class, used as a helper class for implementing turtle graphics. May be useful for turtle graphics programs too. Derived from tuple, so a vector is a tuple!

Provides (for *a*, *b* vectors, *k* number):

- `a + b` vector addition
- `a - b` vector subtraction
- `a * b` inner product
- `k * a` and `a * k` multiplication with scalar
- `abs(a)` absolute value of a
- `a.rotate(angle)` rotation

25.1.6 Help and configuration

How to use help

The public methods of the Screen and Turtle classes are documented extensively via docstrings. So these can be used as online-help via the Python help facilities:

- When using IDLE, tooltips show the signatures and first lines of the docstrings of typed in function-/method calls.
- Calling *help()* on methods or functions displays the docstrings:

```
>>> help(Screen.bgcolor)
Help on method bgcolor in module turtle:

bgcolor(self, *args) unbound turtle.Screen method
    Set or return backgroundcolor of the TurtleScreen.
```

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```
    Arguments (if given): a color string or three numbers
    in the range 0..colormode or a 3-tuple of such numbers.


      >>> screen.bgcolor("orange")
      >>> screen.bgcolor()
      "orange"
      >>> screen.bgcolor(0.5,0,0.5)
      >>> screen.bgcolor()
      "#800080"

>>> help(Turtle.penup)
Help on method penup in module turtle:

penup(self) unbound turtle.Turtle method
    Pull the pen up -- no drawing when moving.

    Aliases: penup | pu | up

    No argument

    >>> turtle.penup()
```

- The docstrings of the functions which are derived from methods have a modified form:

```
>>> help(bgcolor)
Help on function bgcolor in module turtle:

bgcolor(*args)
    Set or return backgroundcolor of the TurtleScreen.

    Arguments (if given): a color string or three numbers
    in the range 0..colormode or a 3-tuple of such numbers.

    Example::

      >>> bgcolor("orange")
      >>> bgcolor()
      "orange"
      >>> bgcolor(0.5,0,0.5)
      >>> bgcolor()
      "#800080"

>>> help(penup)
Help on function penup in module turtle:

penup()
    Pull the pen up -- no drawing when moving.

    Aliases: penup | pu | up

    No argument

    Example:
    >>> penup()
```

These modified docstrings are created automatically together with the function definitions that are derived from the methods at import time.

Translation of docstrings into different languages

There is a utility to create a dictionary the keys of which are the method names and the values of which are the docstrings of the public methods of the classes Screen and Turtle.

`turtle.write_docstringdict`(*filename="turtle_docstringdict"*)

Parameters `filename` – a string, used as filename

Create and write docstring-dictionary to a Python script with the given filename. This function has to be called explicitly (it is not used by the turtle graphics classes). The docstring dictionary will be written to the Python script *filename*`.py`. It is intended to serve as a template for translation of the docstrings into different languages.

If you (or your students) want to use *turtle* with online help in your native language, you have to translate the docstrings and save the resulting file as e.g. `turtle_docstringdict_german.py`.

If you have an appropriate entry in your `turtle.cfg` file this dictionary will be read in at import time and will replace the original English docstrings.

At the time of this writing there are docstring dictionaries in German and in Italian. (Requests please to glingl@aon.at.)

How to configure Screen and Turtles

The built-in default configuration mimics the appearance and behaviour of the old turtle module in order to retain best possible compatibility with it.

If you want to use a different configuration which better reflects the features of this module or which better fits to your needs, e.g. for use in a classroom, you can prepare a configuration file `turtle.cfg` which will be read at import time and modify the configuration according to its settings.

The built in configuration would correspond to the following turtle.cfg:

```
width = 0.5
height = 0.75
leftright = None
topbottom = None
canvwidth = 400
canvheight = 300
mode = standard
colormode = 1.0
delay = 10
undobuffersize = 1000
shape = classic
pencolor = black
fillcolor = black
resizemode = noresize
visible = True
language = english
exampleturtle = turtle
examplescreen = screen
title = Python Turtle Graphics
using_IDLE = False
```

Short explanation of selected entries:

- The first four lines correspond to the arguments of the `Screen.setup()` method.
- Line 5 and 6 correspond to the arguments of the method `Screen.screensize()`.
- *shape* can be any of the built-in shapes, e.g: arrow, turtle, etc. For more info try `help(shape)`.
- If you want to use no fillcolor (i.e. make the turtle transparent), you have to write `fillcolor = ""` (but all nonempty strings must not have quotes in the cfg-file).
- If you want to reflect the turtle its state, you have to use `resizemode = auto`.
- If you set e.g. `language = italian` the docstringdict `turtle_docstringdict_italian.py` will be loaded at import time (if present on the import path, e.g. in the same directory as *turtle*.
- The entries *exampleturtle* and *examplescreen* define the names of these objects as they occur in the docstrings. The transformation of method-docstrings to function-docstrings will delete these names from the docstrings.
- *using_IDLE*: Set this to `True` if you regularly work with IDLE and its -n switch ("no subprocess"). This will prevent *exitonclick()* to enter the mainloop.

There can be a `turtle.cfg` file in the directory where *turtle* is stored and an additional one in the current working directory. The latter will override the settings of the first one.

The `Lib/turtledemo` directory contains a `turtle.cfg` file. You can study it as an example and see its effects when running the demos (preferably not from within the demo-viewer).

25.1.7 `turtledemo` — Demo scripts

The *turtledemo* package includes a set of demo scripts. These scripts can be run and viewed using the supplied demo viewer as follows:

```
python -m turtledemo
```

Alternatively, you can run the demo scripts individually. For example,

```
python -m turtledemo.bytedesign
```

The *turtledemo* package directory contains:

- A demo viewer `__main__.py` which can be used to view the sourcecode of the scripts and run them at the same time.
- Multiple scripts demonstrating different features of the *turtle* module. Examples can be accessed via the Examples menu. They can also be run standalone.
- A `turtle.cfg` file which serves as an example of how to write and use such files.

The demo scripts are:

Name	Description	Features
bytedesign	complex classical turtle graphics pattern	`tracer()`, delay, `update()`
chaos	graphs Verhulst dynamics, shows that computer's computations can generate results sometimes against the common sense expectations	world coordinates
clock	analog clock showing time of your computer	turtles as clock's hands, ontimer
colormixer	experiment with r, g, b	`ondrag()`
forest	3 breadth-first trees	randomization
fractalcurves	Hilbert & Koch curves	recursion
lindenmayer	ethnomathematics (indian kolams)	L-System
minimal_hanoi	Towers of Hanoi	Rectangular Turtles as Hanoi discs (shape, shapesize)
nim	play the classical nim game with three heaps of sticks against the computer.	turtles as nimsticks, event driven (mouse, keyboard)
paint	super minimalistic drawing program	`onclick()`
peace	elementary	turtle: appearance and animation
penrose	aperiodic tiling with kites and darts	`stamp()`
planet_and_moon	simulation of gravitational system	compound shapes, `Vec2D`
round_dance	dancing turtles rotating pairwise in opposite direction	compound shapes, clone shapesize, tilt, get_shapepoly, update
sorting_animate	visual demonstration of different sorting methods	simple alignment, randomization
tree	a (graphical) breadth first tree (using generators)	`clone()`
two_canvases	simple design	turtles on two canvases
wikipedia	a pattern from the wikipedia article on turtle graphics	`clone()`, `undo()`
yinyang	another elementary example	`circle()`

Have fun!

25.1.8 Changes since Python 2.6

- The methods `Turtle.tracer()`, `Turtle.window_width()` and `Turtle.window_height()` have been eliminated. Methods with these names and functionality are now available only as methods of `Screen`. The functions derived from these remain available. (In fact already in Python 2.6 these methods were merely duplications of the corresponding `TurtleScreen`/`Screen`-methods.)
- The method `Turtle.fill()` has been eliminated. The behaviour of `begin_fill()` and `end_fill()` have changed slightly: now every filling-process must be completed with an `end_fill()` call.
- A method `Turtle.filling()` has been added. It returns a boolean value: `True` if a filling process is under way, `False` otherwise. This behaviour corresponds to a `fill()` call without arguments in Python 2.6.

25.1.9 Changes since Python 3.0

- The methods `Turtle.shearfactor()`, `Turtle.shapetransform()` and `Turtle.get_shapepoly()` have been added. Thus the full range of regular linear transforms is now available for transforming turtle shapes. `Turtle.tiltangle()` has been enhanced in functionality: it now can be used to get or set the tiltangle. `Turtle.settiltangle()` has been deprecated.
- The method `Screen.onkeypress()` has been added as a complement to `Screen.onkey()` which in fact binds actions to the keyrelease event. Accordingly the latter has got an alias: `Screen.onkeyrelease()`.
- The method `Screen.mainloop()` has been added. So when working only with Screen and Turtle objects one must not additionally import `mainloop()` anymore.
- Two input methods has been added `Screen.textinput()` and `Screen.numinput()`. These popup input dialogs and return strings and numbers respectively.
- Two example scripts `tdemo_nim.py` and `tdemo_round_dance.py` have been added to the `Lib/turtledemo` directory.

25.2 cmd — Support for line-oriented command interpreters

Source code: Lib/cmd.py

The *Cmd* class provides a simple framework for writing line-oriented command interpreters. These are often useful for test harnesses, administrative tools, and prototypes that will later be wrapped in a more sophisticated interface.

class cmd.**Cmd**(*completekey='tab'*, *stdin=None*, *stdout=None*)

A *Cmd* instance or subclass instance is a line-oriented interpreter framework. There is no good reason to instantiate *Cmd* itself; rather, it's useful as a superclass of an interpreter class you define yourself in order to inherit *Cmd*'s methods and encapsulate action methods.

The optional argument *completekey* is the *readline* name of a completion key; it defaults to `Tab`. If *completekey* is not *None* and *readline* is available, command completion is done automatically.

The optional arguments *stdin* and *stdout* specify the input and output file objects that the Cmd instance or subclass instance will use for input and output. If not specified, they will default to *sys.stdin* and *sys.stdout*.

If you want a given *stdin* to be used, make sure to set the instance's *use_rawinput* attribute to `False`, otherwise *stdin* will be ignored.

25.2.1 Cmd Objects

A *Cmd* instance has the following methods:

Cmd.**cmdloop**(*intro=None*)

Repeatedly issue a prompt, accept input, parse an initial prefix off the received input, and dispatch to action methods, passing them the remainder of the line as argument.

The optional argument is a banner or intro string to be issued before the first prompt (this overrides the *intro* class attribute).

If the *readline* module is loaded, input will automatically inherit **bash**-like history-list editing (e.g. `Control-P` scrolls back to the last command, `Control-N` forward to the next one, `Control-F` moves the cursor to the right non-destructively, `Control-B` moves the cursor to the left non-destructively, etc.).

An end-of-file on input is passed back as the string `'EOF'`.

An interpreter instance will recognize a command name `foo` if and only if it has a method `do_foo()`. As a special case, a line beginning with the character `'?'` is dispatched to the method `do_help()`. As another special case, a line beginning with the character `'!'` is dispatched to the method `do_shell()` (if such a method is defined).

This method will return when the *postcmd()* method returns a true value. The *stop* argument to *postcmd()* is the return value from the command's corresponding `do_*()` method.

If completion is enabled, completing commands will be done automatically, and completing of commands args is done by calling `complete_foo()` with arguments *text*, *line*, *begidx*, and *endidx*. *text* is the string prefix we are attempting to match: all returned matches must begin with it. *line* is the current input line with leading whitespace removed, *begidx* and *endidx* are the beginning and ending indexes of the prefix text, which could be used to provide different completion depending upon which position the argument is in.

All subclasses of *Cmd* inherit a predefined `do_help()`. This method, called with an argument `'bar'`, invokes the corresponding method `help_bar()`, and if that is not present, prints the docstring of `do_bar()`, if available. With no argument, `do_help()` lists all available help topics (that is, all commands with corresponding `help_*()` methods or commands that have docstrings), and also lists any undocumented commands.

`Cmd.onecmd(`*str*`)`
Interpret the argument as though it had been typed in response to the prompt. This may be overridden, but should not normally need to be; see the *precmd()* and *postcmd()* methods for useful execution hooks. The return value is a flag indicating whether interpretation of commands by the interpreter should stop. If there is a `do_*()` method for the command *str*, the return value of that method is returned, otherwise the return value from the *default()* method is returned.

`Cmd.emptyline()`
Method called when an empty line is entered in response to the prompt. If this method is not overridden, it repeats the last nonempty command entered.

`Cmd.default(`*line*`)`
Method called on an input line when the command prefix is not recognized. If this method is not overridden, it prints an error message and returns.

`Cmd.completedefault(`*text*, *line*, *begidx*, *endidx*`)`
Method called to complete an input line when no command-specific `complete_*()` method is available. By default, it returns an empty list.

`Cmd.precmd(`*line*`)`
Hook method executed just before the command line *line* is interpreted, but after the input prompt is generated and issued. This method is a stub in *Cmd*; it exists to be overridden by subclasses. The return value is used as the command which will be executed by the *onecmd()* method; the *precmd()* implementation may re-write the command or simply return *line* unchanged.

`Cmd.postcmd(`*stop*, *line*`)`
Hook method executed just after a command dispatch is finished. This method is a stub in *Cmd*; it exists to be overridden by subclasses. *line* is the command line which was executed, and *stop* is a flag which indicates whether execution will be terminated after the call to *postcmd()*; this will be the return value of the *onecmd()* method. The return value of this method will be used as the new value for the internal flag which corresponds to *stop*; returning false will cause interpretation to continue.

`Cmd.preloop()`
Hook method executed once when *cmdloop()* is called. This method is a stub in *Cmd*; it exists to be overridden by subclasses.

`Cmd.postloop()`
Hook method executed once when *cmdloop()* is about to return. This method is a stub in *Cmd*; it

exists to be overridden by subclasses.

Instances of *Cmd* subclasses have some public instance variables:

Cmd.prompt
The prompt issued to solicit input.

Cmd.identchars
The string of characters accepted for the command prefix.

Cmd.lastcmd
The last nonempty command prefix seen.

Cmd.cmdqueue
A list of queued input lines. The cmdqueue list is checked in *cmdloop()* when new input is needed; if it is nonempty, its elements will be processed in order, as if entered at the prompt.

Cmd.intro
A string to issue as an intro or banner. May be overridden by giving the *cmdloop()* method an argument.

Cmd.doc_header
The header to issue if the help output has a section for documented commands.

Cmd.misc_header
The header to issue if the help output has a section for miscellaneous help topics (that is, there are `help_*()` methods without corresponding `do_*()` methods).

Cmd.undoc_header
The header to issue if the help output has a section for undocumented commands (that is, there are `do_*()` methods without corresponding `help_*()` methods).

Cmd.ruler
The character used to draw separator lines under the help-message headers. If empty, no ruler line is drawn. It defaults to `'='`.

Cmd.use_rawinput
A flag, defaulting to true. If true, *cmdloop()* uses *input()* to display a prompt and read the next command; if false, `sys.stdout.write()` and `sys.stdin.readline()` are used. (This means that by importing *readline*, on systems that support it, the interpreter will automatically support **Emacs**-like line editing and command-history keystrokes.)

25.2.2 Cmd Example

The *cmd* module is mainly useful for building custom shells that let a user work with a program interactively.

This section presents a simple example of how to build a shell around a few of the commands in the *turtle* module.

Basic turtle commands such as *forward()* are added to a *Cmd* subclass with method named `do_forward()`. The argument is converted to a number and dispatched to the turtle module. The docstring is used in the help utility provided by the shell.

The example also includes a basic record and playback facility implemented with the *precmd()* method which is responsible for converting the input to lowercase and writing the commands to a file. The `do_playback()` method reads the file and adds the recorded commands to the `cmdqueue` for immediate playback:

```
import cmd, sys
from turtle import *

class TurtleShell(cmd.Cmd):
```

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```
    intro = 'Welcome to the turtle shell.   Type help or ? to list commands.\n'
    prompt = '(turtle) '
    file = None

    # ----- basic turtle commands -----
    def do_forward(self, arg):
        'Move the turtle forward by the specified distance:  FORWARD 10'
        forward(*parse(arg))
    def do_right(self, arg):
        'Turn turtle right by given number of degrees:  RIGHT 20'
        right(*parse(arg))
    def do_left(self, arg):
        'Turn turtle left by given number of degrees:  LEFT 90'
        left(*parse(arg))
    def do_goto(self, arg):
        'Move turtle to an absolute position with changing orientation.  GOTO 100 200'
        goto(*parse(arg))
    def do_home(self, arg):
        'Return turtle to the home position:  HOME'
        home()
    def do_circle(self, arg):
        'Draw circle with given radius an options extent and steps:  CIRCLE 50'
        circle(*parse(arg))
    def do_position(self, arg):
        'Print the current turtle position:  POSITION'
        print('Current position is %d %d\n' % position())
    def do_heading(self, arg):
        'Print the current turtle heading in degrees:  HEADING'
        print('Current heading is %d\n' % (heading(),))
    def do_color(self, arg):
        'Set the color:  COLOR BLUE'
        color(arg.lower())
    def do_undo(self, arg):
        'Undo (repeatedly) the last turtle action(s):  UNDO'
    def do_reset(self, arg):
        'Clear the screen and return turtle to center:  RESET'
        reset()
    def do_bye(self, arg):
        'Stop recording, close the turtle window, and exit:  BYE'
        print('Thank you for using Turtle')
        self.close()
        bye()
        return True

    # ----- record and playback -----
    def do_record(self, arg):
        'Save future commands to filename:  RECORD rose.cmd'
        self.file = open(arg, 'w')
    def do_playback(self, arg):
        'Playback commands from a file:  PLAYBACK rose.cmd'
        self.close()
        with open(arg) as f:
            self.cmdqueue.extend(f.read().splitlines())
    def precmd(self, line):
        line = line.lower()
        if self.file and 'playback' not in line:
```

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```
            print(line, file=self.file)
        return line
    def close(self):
        if self.file:
            self.file.close()
            self.file = None

def parse(arg):
    'Convert a series of zero or more numbers to an argument tuple'
    return tuple(map(int, arg.split()))

if __name__ == '__main__':
    TurtleShell().cmdloop()
```

Here is a sample session with the turtle shell showing the help functions, using blank lines to repeat commands, and the simple record and playback facility:

```
Welcome to the turtle shell.   Type help or ? to list commands.

(turtle) ?

Documented commands (type help <topic>):
========================================
bye     color    goto     home  playback  record  right
circle  forward  heading  left  position  reset   undo

(turtle) help forward
Move the turtle forward by the specified distance:  FORWARD 10
(turtle) record spiral.cmd
(turtle) position
Current position is 0 0

(turtle) heading
Current heading is 0

(turtle) reset
(turtle) circle 20
(turtle) right 30
(turtle) circle 40
(turtle) right 30
(turtle) circle 60
(turtle) right 30
(turtle) circle 80
(turtle) right 30
(turtle) circle 100
(turtle) right 30
(turtle) circle 120
(turtle) right 30
(turtle) circle 120
(turtle) heading
Current heading is 180

(turtle) forward 100
(turtle)
(turtle) right 90
(turtle) forward 100
```

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```
(turtle)
(turtle) right 90
(turtle) forward 400
(turtle) right 90
(turtle) forward 500
(turtle) right 90
(turtle) forward 400
(turtle) right 90
(turtle) forward 300
(turtle) playback spiral.cmd
Current position is 0 0

Current heading is 0

Current heading is 180

(turtle) bye
Thank you for using Turtle
```

25.3 shlex — Simple lexical analysis

Source code: Lib/shlex.py

The *shlex* class makes it easy to write lexical analyzers for simple syntaxes resembling that of the Unix shell. This will often be useful for writing minilanguages, (for example, in run control files for Python applications) or for parsing quoted strings.

The *shlex* module defines the following functions:

shlex.split(*s*, *comments=False*, *posix=True*)

Split the string *s* using shell-like syntax. If *comments* is *False* (the default), the parsing of comments in the given string will be disabled (setting the *commenters* attribute of the *shlex* instance to the empty string). This function operates in POSIX mode by default, but uses non-POSIX mode if the *posix* argument is false.

Note: Since the *split()* function instantiates a *shlex* instance, passing `None` for *s* will read the string to split from standard input.

---

shlex.quote(*s*)

Return a shell-escaped version of the string *s*. The returned value is a string that can safely be used as one token in a shell command line, for cases where you cannot use a list.

This idiom would be unsafe:

```
>>> filename = 'somefile; rm -rf ~'
>>> command = 'ls -l {}'.format(filename)
>>> print(command)  # executed by a shell: boom!
ls -l somefile; rm -rf ~
```

quote() lets you plug the security hole:

```
>>> from shlex import quote
>>> command = 'ls -l {}'.format(quote(filename))
>>> print(command)
ls -l 'somefile; rm -rf ~'
>>> remote_command = 'ssh home {}'.format(quote(command))
>>> print(remote_command)
ssh home 'ls -l '"'"'somefile; rm -rf ~'"'"''
```

The quoting is compatible with UNIX shells and with *split()*:

```
>>> from shlex import split
>>> remote_command = split(remote_command)
>>> remote_command
['ssh', 'home', "ls -l 'somefile; rm -rf ~'"]
>>> command = split(remote_command[-1])
>>> command
['ls', '-l', 'somefile; rm -rf ~']
```

New in version 3.3.

The *shlex* module defines the following class:

class shlex.shlex(*instream=None*, *infile=None*, *posix=False*, *punctuation_chars=False*)

A *shlex* instance or subclass instance is a lexical analyzer object. The initialization argument, if present, specifies where to read characters from. It must be a file-/stream-like object with *read()* and *readline()* methods, or a string. If no argument is given, input will be taken from `sys.stdin`. The second optional argument is a filename string, which sets the initial value of the *infile* attribute. If the *instream* argument is omitted or equal to `sys.stdin`, this second argument defaults to "stdin". The *posix* argument defines the operational mode: when *posix* is not true (default), the *shlex* instance will operate in compatibility mode. When operating in POSIX mode, *shlex* will try to be as close as possible to the POSIX shell parsing rules. The *punctuation_chars* argument provides a way to make the behaviour even closer to how real shells parse. This can take a number of values: the default value, `False`, preserves the behaviour seen under Python 3.5 and earlier. If set to `True`, then parsing of the characters `();<>|&` is changed: any run of these characters (considered punctuation characters) is returned as a single token. If set to a non-empty string of characters, those characters will be used as the punctuation characters. Any characters in the *wordchars* attribute that appear in *punctuation_chars* will be removed from *wordchars*. See *Improved Compatibility with Shells* for more information.

Changed in version 3.6: The *punctuation_chars* parameter was added.

See also:

Module *configparser* Parser for configuration files similar to the Windows `.ini` files.

25.3.1 shlex Objects

A *shlex* instance has the following methods:

shlex.get_token()

Return a token. If tokens have been stacked using *push_token()*, pop a token off the stack. Otherwise, read one from the input stream. If reading encounters an immediate end-of-file, *eof* is returned (the empty string (`''`) in non-POSIX mode, and `None` in POSIX mode).

shlex.push_token(*str*)

Push the argument onto the token stack.

shlex.read_token()

Read a raw token. Ignore the pushback stack, and do not interpret source requests. (This is not ordinarily a useful entry point, and is documented here only for the sake of completeness.)

shlex.**sourcehook**(*filename*)
When *shlex* detects a source request (see *source* below) this method is given the following token as argument, and expected to return a tuple consisting of a filename and an open file-like object.

Normally, this method first strips any quotes off the argument. If the result is an absolute pathname, or there was no previous source request in effect, or the previous source was a stream (such as `sys.stdin`), the result is left alone. Otherwise, if the result is a relative pathname, the directory part of the name of the file immediately before it on the source inclusion stack is prepended (this behavior is like the way the C preprocessor handles `#include "file.h"`).

The result of the manipulations is treated as a filename, and returned as the first component of the tuple, with *open()* called on it to yield the second component. (Note: this is the reverse of the order of arguments in instance initialization!)

This hook is exposed so that you can use it to implement directory search paths, addition of file extensions, and other namespace hacks. There is no corresponding 'close' hook, but a shlex instance will call the *close()* method of the sourced input stream when it returns EOF.

For more explicit control of source stacking, use the *push_source()* and *pop_source()* methods.

shlex.**push_source**(*newstream*, *newfile=None*)
Push an input source stream onto the input stack. If the filename argument is specified it will later be available for use in error messages. This is the same method used internally by the *sourcehook()* method.

shlex.**pop_source**()
Pop the last-pushed input source from the input stack. This is the same method used internally when the lexer reaches EOF on a stacked input stream.

shlex.**error_leader**(*infile=None*, *lineno=None*)
This method generates an error message leader in the format of a Unix C compiler error label; the format is `'"%s", line %d: '`, where the `%s` is replaced with the name of the current source file and the `%d` with the current input line number (the optional arguments can be used to override these).

This convenience is provided to encourage *shlex* users to generate error messages in the standard, parseable format understood by Emacs and other Unix tools.

Instances of *shlex* subclasses have some public instance variables which either control lexical analysis or can be used for debugging:

shlex.**commenters**
The string of characters that are recognized as comment beginners. All characters from the comment beginner to end of line are ignored. Includes just `'#'` by default.

shlex.**wordchars**
The string of characters that will accumulate into multi-character tokens. By default, includes all ASCII alphanumerics and underscore. In POSIX mode, the accented characters in the Latin-1 set are also included. If *punctuation_chars* is not empty, the characters `~-./*?=`, which can appear in filename specifications and command line parameters, will also be included in this attribute, and any characters which appear in `punctuation_chars` will be removed from `wordchars` if they are present there.

shlex.**whitespace**
Characters that will be considered whitespace and skipped. Whitespace bounds tokens. By default, includes space, tab, linefeed and carriage-return.

shlex.**escape**
Characters that will be considered as escape. This will be only used in POSIX mode, and includes just `'\'` by default.

shlex.**quotes**
Characters that will be considered string quotes. The token accumulates until the same quote is

encountered again (thus, different quote types protect each other as in the shell.) By default, includes ASCII single and double quotes.

shlex.escapedquotes
Characters in *quotes* that will interpret escape characters defined in *escape*. This is only used in POSIX mode, and includes just `'"'` by default.

shlex.whitespace_split
If `True`, tokens will only be split in whitespaces. This is useful, for example, for parsing command lines with *shlex*, getting tokens in a similar way to shell arguments. If this attribute is `True`, *punctuation_chars* will have no effect, and splitting will happen only on whitespaces. When using *punctuation_chars*, which is intended to provide parsing closer to that implemented by shells, it is advisable to leave `whitespace_split` as `False` (the default value).

shlex.infile
The name of the current input file, as initially set at class instantiation time or stacked by later source requests. It may be useful to examine this when constructing error messages.

shlex.instream
The input stream from which this *shlex* instance is reading characters.

shlex.source
This attribute is `None` by default. If you assign a string to it, that string will be recognized as a lexical-level inclusion request similar to the `source` keyword in various shells. That is, the immediately following token will be opened as a filename and input will be taken from that stream until EOF, at which point the *close()* method of that stream will be called and the input source will again become the original input stream. Source requests may be stacked any number of levels deep.

shlex.debug
If this attribute is numeric and `1` or more, a *shlex* instance will print verbose progress output on its behavior. If you need to use this, you can read the module source code to learn the details.

shlex.lineno
Source line number (count of newlines seen so far plus one).

shlex.token
The token buffer. It may be useful to examine this when catching exceptions.

shlex.eof
Token used to determine end of file. This will be set to the empty string (`''`), in non-POSIX mode, and to `None` in POSIX mode.

shlex.punctuation_chars
Characters that will be considered punctuation. Runs of punctuation characters will be returned as a single token. However, note that no semantic validity checking will be performed: for example, '>>>' could be returned as a token, even though it may not be recognised as such by shells.

New in version 3.6.

25.3.2 Parsing Rules

When operating in non-POSIX mode, *shlex* will try to obey to the following rules.

- Quote characters are not recognized within words (`Do"Not"Separate` is parsed as the single word `Do"Not"Separate`);
- Escape characters are not recognized;
- Enclosing characters in quotes preserve the literal value of all characters within the quotes;
- Closing quotes separate words (`"Do"Separate` is parsed as `"Do"` and `Separate`);

- If *whitespace_split* is `False`, any character not declared to be a word character, whitespace, or a quote will be returned as a single-character token. If it is `True`, *shlex* will only split words in whitespaces;
- EOF is signaled with an empty string (`''`);
- It's not possible to parse empty strings, even if quoted.

When operating in POSIX mode, *shlex* will try to obey to the following parsing rules.

- Quotes are stripped out, and do not separate words (`"Do"Not"Separate"` is parsed as the single word `DoNotSeparate`);
- Non-quoted escape characters (e.g. `'\'`) preserve the literal value of the next character that follows;
- Enclosing characters in quotes which are not part of *escapedquotes* (e.g. `"'"`) preserve the literal value of all characters within the quotes;
- Enclosing characters in quotes which are part of *escapedquotes* (e.g. `'"'`) preserves the literal value of all characters within the quotes, with the exception of the characters mentioned in *escape*. The escape characters retain its special meaning only when followed by the quote in use, or the escape character itself. Otherwise the escape character will be considered a normal character.
- EOF is signaled with a *None* value;
- Quoted empty strings (`''`) are allowed.

25.3.3 Improved Compatibility with Shells

New in version 3.6.

The *shlex* class provides compatibility with the parsing performed by common Unix shells like `bash`, `dash`, and `sh`. To take advantage of this compatibility, specify the `punctuation_chars` argument in the constructor. This defaults to `False`, which preserves pre-3.6 behaviour. However, if it is set to `True`, then parsing of the characters `();<>|&` is changed: any run of these characters is returned as a single token. While this is short of a full parser for shells (which would be out of scope for the standard library, given the multiplicity of shells out there), it does allow you to perform processing of command lines more easily than you could otherwise. To illustrate, you can see the difference in the following snippet:

```
>>> import shlex
>>> text = "a && b; c && d || e; f >'abc'; (def \"ghi\")"
>>> list(shlex.shlex(text))
['a', '&', '&', 'b', ';', 'c', '&', '&', 'd', '|', '|', 'e', ';', 'f', '>',
"'abc'", ';', '(', 'def', '"ghi"', ')']
>>> list(shlex.shlex(text, punctuation_chars=True))
['a', '&&', 'b', ';', 'c', '&&', 'd', '||', 'e', ';', 'f', '>', "'abc'",
';', '(', 'def', '"ghi"', ')']
```

Of course, tokens will be returned which are not valid for shells, and you'll need to implement your own error checks on the returned tokens.

Instead of passing `True` as the value for the punctuation_chars parameter, you can pass a string with specific characters, which will be used to determine which characters constitute punctuation. For example:

```
>>> import shlex
>>> s = shlex.shlex("a && b || c", punctuation_chars="|")
>>> list(s)
['a', '&', '&', 'b', '||', 'c']
```

Note: When `punctuation_chars` is specified, the *wordchars* attribute is augmented with the characters `~-./*?=`. That is because these characters can appear in file names (including wildcards) and command-line arguments (e.g. `--color=auto`). Hence:

```
>>> import shlex
>>> s = shlex.shlex('~/a && b-c --color=auto || d *.py?',
...                 punctuation_chars=True)
>>> list(s)
['~/a', '&&', 'b-c', '--color=auto', '||', 'd', '*.py?']
```

For best effect, `punctuation_chars` should be set in conjunction with `posix=True`. (Note that `posix=False` is the default for *shlex*.)

CHAPTER

TWENTYSIX

GRAPHICAL USER INTERFACES WITH TK

Tk/Tcl has long been an integral part of Python. It provides a robust and platform independent windowing toolkit, that is available to Python programmers using the *tkinter* package, and its extension, the *tkinter.tix* and the *tkinter.ttk* modules.

The *tkinter* package is a thin object-oriented layer on top of Tcl/Tk. To use *tkinter*, you don't need to write Tcl code, but you will need to consult the Tk documentation, and occasionally the Tcl documentation. *tkinter* is a set of wrappers that implement the Tk widgets as Python classes. In addition, the internal module `_tkinter` provides a threadsafe mechanism which allows Python and Tcl to interact.

tkinter's chief virtues are that it is fast, and that it usually comes bundled with Python. Although its standard documentation is weak, good material is available, which includes: references, tutorials, a book and others. *tkinter* is also famous for having an outdated look and feel, which has been vastly improved in Tk 8.5. Nevertheless, there are many other GUI libraries that you could be interested in. For more information about alternatives, see the *Other Graphical User Interface Packages* section.

26.1 `tkinter` — Python interface to Tcl/Tk

Source code: Lib/tkinter/__init__.py

The *tkinter* package ("Tk interface") is the standard Python interface to the Tk GUI toolkit. Both Tk and *tkinter* are available on most Unix platforms, as well as on Windows systems. (Tk itself is not part of Python; it is maintained at ActiveState.)

Running `python -m tkinter` from the command line should open a window demonstrating a simple Tk interface, letting you know that *tkinter* is properly installed on your system, and also showing what version of Tcl/Tk is installed, so you can read the Tcl/Tk documentation specific to that version.

See also:

Tkinter documentation:

Python Tkinter Resources The Python Tkinter Topic Guide provides a great deal of information on using Tk from Python and links to other sources of information on Tk.

TKDocs Extensive tutorial plus friendlier widget pages for some of the widgets.

Tkinter reference: a GUI for Python On-line reference material.

Tkinter docs from effbot Online reference for tkinter supported by effbot.org.

Programming Python Book by Mark Lutz, has excellent coverage of Tkinter.

Modern Tkinter for Busy Python Developers Book by Mark Rozerman about building attractive and modern graphical user interfaces with Python and Tkinter.

Python and Tkinter Programming Book by John Grayson (ISBN 1-884777-81-3).

Tcl/Tk documentation:

Tk commands Most commands are available as *tkinter* or *tkinter.ttk* classes. Change '8.6' to match the version of your Tcl/Tk installation.

Tcl/Tk recent man pages Recent Tcl/Tk manuals on www.tcl.tk.

ActiveState Tcl Home Page The Tk/Tcl development is largely taking place at ActiveState.

Tcl and the Tk Toolkit Book by John Ousterhout, the inventor of Tcl.

Practical Programming in Tcl and Tk Brent Welch's encyclopedic book.

26.1.1 Tkinter Modules

Most of the time, *tkinter* is all you really need, but a number of additional modules are available as well. The Tk interface is located in a binary module named `_tkinter`. This module contains the low-level interface to Tk, and should never be used directly by application programmers. It is usually a shared library (or DLL), but might in some cases be statically linked with the Python interpreter.

In addition to the Tk interface module, *tkinter* includes a number of Python modules, `tkinter.constants` being one of the most important. Importing *tkinter* will automatically import `tkinter.constants`, so, usually, to use Tkinter all you need is a simple import statement:

```
import tkinter
```

Or, more often:

```
from tkinter import *
```

class tkinter.Tk(*screenName=None*, *baseName=None*, *className='Tk'*, *useTk=1*)
The *Tk* class is instantiated without arguments. This creates a toplevel widget of Tk which usually is the main window of an application. Each instance has its own associated Tcl interpreter.

tkinter.Tcl(*screenName=None*, *baseName=None*, *className='Tk'*, *useTk=0*)
The *Tcl()* function is a factory function which creates an object much like that created by the *Tk* class, except that it does not initialize the Tk subsystem. This is most often useful when driving the Tcl interpreter in an environment where one doesn't want to create extraneous toplevel windows, or where one cannot (such as Unix/Linux systems without an X server). An object created by the *Tcl()* object can have a Toplevel window created (and the Tk subsystem initialized) by calling its `loadtk()` method.

Other modules that provide Tk support include:

tkinter.scrolledtext Text widget with a vertical scroll bar built in.

tkinter.colorchooser Dialog to let the user choose a color.

tkinter.commondialog Base class for the dialogs defined in the other modules listed here.

tkinter.filedialog Common dialogs to allow the user to specify a file to open or save.

tkinter.font Utilities to help work with fonts.

tkinter.messagebox Access to standard Tk dialog boxes.

tkinter.simpledialog Basic dialogs and convenience functions.

tkinter.dnd Drag-and-drop support for *tkinter*. This is experimental and should become deprecated when it is replaced with the Tk DND.

turtle Turtle graphics in a Tk window.

26.1.2 Tkinter Life Preserver

This section is not designed to be an exhaustive tutorial on either Tk or Tkinter. Rather, it is intended as a stop gap, providing some introductory orientation on the system.

Credits:

- Tk was written by John Ousterhout while at Berkeley.
- Tkinter was written by Steen Lumholt and Guido van Rossum.
- This Life Preserver was written by Matt Conway at the University of Virginia.
- The HTML rendering, and some liberal editing, was produced from a FrameMaker version by Ken Manheimer.
- Fredrik Lundh elaborated and revised the class interface descriptions, to get them current with Tk 4.2.
- Mike Clarkson converted the documentation to LaTeX, and compiled the User Interface chapter of the reference manual.

How To Use This Section

This section is designed in two parts: the first half (roughly) covers background material, while the second half can be taken to the keyboard as a handy reference.

When trying to answer questions of the form "how do I do blah", it is often best to find out how to do "blah" in straight Tk, and then convert this back into the corresponding *tkinter* call. Python programmers can often guess at the correct Python command by looking at the Tk documentation. This means that in order to use Tkinter, you will have to know a little bit about Tk. This document can't fulfill that role, so the best we can do is point you to the best documentation that exists. Here are some hints:

- The authors strongly suggest getting a copy of the Tk man pages. Specifically, the man pages in the `manN` directory are most useful. The `man3` man pages describe the C interface to the Tk library and thus are not especially helpful for script writers.
- Addison-Wesley publishes a book called Tcl and the Tk Toolkit by John Ousterhout (ISBN 0-201-63337-X) which is a good introduction to Tcl and Tk for the novice. The book is not exhaustive, and for many details it defers to the man pages.
- `tkinter/__init__.py` is a last resort for most, but can be a good place to go when nothing else makes sense.

A Simple Hello World Program

```
import tkinter as tk

class Application(tk.Frame):
    def __init__(self, master=None):
        super().__init__(master)
        self.pack()
        self.create_widgets()

    def create_widgets(self):
        self.hi_there = tk.Button(self)
        self.hi_there["text"] = "Hello World\n(click me)"
        self.hi_there["command"] = self.say_hi
        self.hi_there.pack(side="top")
```

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```
        self.quit = tk.Button(self, text="QUIT", fg="red",
                              command=root.destroy)
        self.quit.pack(side="bottom")

    def say_hi(self):
        print("hi there, everyone!")

root = tk.Tk()
app = Application(master=root)
app.mainloop()
```

26.1.3 A (Very) Quick Look at Tcl/Tk

The class hierarchy looks complicated, but in actual practice, application programmers almost always refer to the classes at the very bottom of the hierarchy.

Notes:

- These classes are provided for the purposes of organizing certain functions under one namespace. They aren't meant to be instantiated independently.
- The *Tk* class is meant to be instantiated only once in an application. Application programmers need not instantiate one explicitly, the system creates one whenever any of the other classes are instantiated.
- The `Widget` class is not meant to be instantiated, it is meant only for subclassing to make "real" widgets (in C++, this is called an 'abstract class').

To make use of this reference material, there will be times when you will need to know how to read short passages of Tk and how to identify the various parts of a Tk command. (See section *Mapping Basic Tk into Tkinter* for the *tkinter* equivalents of what's below.)

Tk scripts are Tcl programs. Like all Tcl programs, Tk scripts are just lists of tokens separated by spaces. A Tk widget is just its *class*, the *options* that help configure it, and the *actions* that make it do useful things.

To make a widget in Tk, the command is always of the form:

```
classCommand newPathname options
```

classCommand denotes which kind of widget to make (a button, a label, a menu…)

newPathname is the new name for this widget. All names in Tk must be unique. To help enforce this, widgets in Tk are named with *pathnames*, just like files in a file system. The top level widget, the *root*, is called `.` (period) and children are delimited by more periods. For example, `.myApp.controlPanel.okButton` might be the name of a widget.

options configure the widget's appearance and in some cases, its behavior. The options come in the form of a list of flags and values. Flags are preceded by a '-', like Unix shell command flags, and values are put in quotes if they are more than one word.

For example:

```
button   .fred   -fg red -text "hi there"
   ^       ^     \_____________________/
   |       |                |
 class    new            options
command  widget  (-opt val -opt val ...)
```

Once created, the pathname to the widget becomes a new command. This new *widget command* is the programmer's handle for getting the new widget to perform some *action*. In C, you'd express this as

someAction(fred, someOptions), in C++, you would express this as fred.someAction(someOptions), and in Tk, you say:

```
.fred someAction someOptions
```

Note that the object name, `.fred`, starts with a dot.

As you'd expect, the legal values for *someAction* will depend on the widget's class: `.fred disable` works if fred is a button (fred gets greyed out), but does not work if fred is a label (disabling of labels is not supported in Tk).

The legal values of *someOptions* is action dependent. Some actions, like `disable`, require no arguments, others, like a text-entry box's `delete` command, would need arguments to specify what range of text to delete.

26.1.4 Mapping Basic Tk into Tkinter

Class commands in Tk correspond to class constructors in Tkinter.

```
button .fred                =====>  fred = Button()
```

The master of an object is implicit in the new name given to it at creation time. In Tkinter, masters are specified explicitly.

```
button .panel.fred          =====>  fred = Button(panel)
```

The configuration options in Tk are given in lists of hyphened tags followed by values. In Tkinter, options are specified as keyword-arguments in the instance constructor, and keyword-args for configure calls or as instance indices, in dictionary style, for established instances. See section *Setting Options* on setting options.

```
button .fred -fg red        =====>  fred = Button(panel, fg="red")
.fred configure -fg red     =====>  fred["fg"] = red
                            OR ==>  fred.config(fg="red")
```

In Tk, to perform an action on a widget, use the widget name as a command, and follow it with an action name, possibly with arguments (options). In Tkinter, you call methods on the class instance to invoke actions on the widget. The actions (methods) that a given widget can perform are listed in `tkinter/__init__.py`.

```
.fred invoke                =====>  fred.invoke()
```

To give a widget to the packer (geometry manager), you call pack with optional arguments. In Tkinter, the Pack class holds all this functionality, and the various forms of the pack command are implemented as methods. All widgets in *tkinter* are subclassed from the Packer, and so inherit all the packing methods. See the *tkinter.tix* module documentation for additional information on the Form geometry manager.

```
pack .fred -side left       =====>  fred.pack(side="left")
```

26.1.5 How Tk and Tkinter are Related

From the top down:

Your App Here (Python) A Python application makes a *tkinter* call.

tkinter (Python Package) This call (say, for example, creating a button widget), is implemented in the *tkinter* package, which is written in Python. This Python function will parse the commands and the arguments and convert them into a form that makes them look as if they had come from a Tk script instead of a Python script.

_tkinter (C) These commands and their arguments will be passed to a C function in the `_tkinter` - note the underscore - extension module.

Tk Widgets (C and Tcl) This C function is able to make calls into other C modules, including the C functions that make up the Tk library. Tk is implemented in C and some Tcl. The Tcl part of the Tk widgets is used to bind certain default behaviors to widgets, and is executed once at the point where the Python *tkinter* package is imported. (The user never sees this stage).

Tk (C) The Tk part of the Tk Widgets implement the final mapping to ...

Xlib (C) the Xlib library to draw graphics on the screen.

26.1.6 Handy Reference

Setting Options

Options control things like the color and border width of a widget. Options can be set in three ways:

At object creation time, using keyword arguments

```
fred = Button(self, fg="red", bg="blue")
```

After object creation, treating the option name like a dictionary index

```
fred["fg"] = "red"
fred["bg"] = "blue"
```

Use the config() method to update multiple attrs subsequent to object creation

```
fred.config(fg="red", bg="blue")
```

For a complete explanation of a given option and its behavior, see the Tk man pages for the widget in question.

Note that the man pages list "STANDARD OPTIONS" and "WIDGET SPECIFIC OPTIONS" for each widget. The former is a list of options that are common to many widgets, the latter are the options that are idiosyncratic to that particular widget. The Standard Options are documented on the *options(3)* man page.

No distinction between standard and widget-specific options is made in this document. Some options don't apply to some kinds of widgets. Whether a given widget responds to a particular option depends on the class of the widget; buttons have a `command` option, labels do not.

The options supported by a given widget are listed in that widget's man page, or can be queried at runtime by calling the `config()` method without arguments, or by calling the `keys()` method on that widget. The return value of these calls is a dictionary whose key is the name of the option as a string (for example, `'relief'`) and whose values are 5-tuples.

Some options, like `bg` are synonyms for common options with long names (`bg` is shorthand for "background"). Passing the `config()` method the name of a shorthand option will return a 2-tuple, not 5-tuple. The 2-tuple passed back will contain the name of the synonym and the "real" option (such as `('bg', 'background')`).

Index	Meaning	Example
0	option name	`'relief'`
1	option name for database lookup	`'relief'`
2	option class for database lookup	`'Relief'`
3	default value	`'raised'`
4	current value	`'groove'`

Example:

```
>>> print(fred.config())
{'relief': ('relief', 'relief', 'Relief', 'raised', 'groove')}
```

Of course, the dictionary printed will include all the options available and their values. This is meant only as an example.

The Packer

The packer is one of Tk's geometry-management mechanisms. Geometry managers are used to specify the relative positioning of the positioning of widgets within their container - their mutual *master*. In contrast to the more cumbersome *placer* (which is used less commonly, and we do not cover here), the packer takes qualitative relationship specification - *above*, *to the left of*, *filling*, etc - and works everything out to determine the exact placement coordinates for you.

The size of any *master* widget is determined by the size of the "slave widgets" inside. The packer is used to control where slave widgets appear inside the master into which they are packed. You can pack widgets into frames, and frames into other frames, in order to achieve the kind of layout you desire. Additionally, the arrangement is dynamically adjusted to accommodate incremental changes to the configuration, once it is packed.

Note that widgets do not appear until they have had their geometry specified with a geometry manager. It's a common early mistake to leave out the geometry specification, and then be surprised when the widget is created but nothing appears. A widget will appear only after it has had, for example, the packer's `pack()` method applied to it.

The pack() method can be called with keyword-option/value pairs that control where the widget is to appear within its container, and how it is to behave when the main application window is resized. Here are some examples:

```
fred.pack()                     # defaults to side = "top"
fred.pack(side="left")
fred.pack(expand=1)
```

Packer Options

For more extensive information on the packer and the options that it can take, see the man pages and page 183 of John Ousterhout's book.

anchor Anchor type. Denotes where the packer is to place each slave in its parcel.

expand Boolean, `0` or `1`.

fill Legal values: `'x'`, `'y'`, `'both'`, `'none'`.

ipadx and ipady A distance - designating internal padding on each side of the slave widget.

padx and pady A distance - designating external padding on each side of the slave widget.

side Legal values are: `'left'`, `'right'`, `'top'`, `'bottom'`.

Coupling Widget Variables

The current-value setting of some widgets (like text entry widgets) can be connected directly to application variables by using special options. These options are `variable`, `textvariable`, `onvalue`, `offvalue`, and `value`. This connection works both ways: if the variable changes for any reason, the widget it's connected to will be updated to reflect the new value.

Unfortunately, in the current implementation of *tkinter* it is not possible to hand over an arbitrary Python variable to a widget through a `variable` or `textvariable` option. The only kinds of variables for which this works are variables that are subclassed from a class called Variable, defined in *tkinter*.

There are many useful subclasses of Variable already defined: `StringVar`, `IntVar`, `DoubleVar`, and `BooleanVar`. To read the current value of such a variable, call the `get()` method on it, and to change its value you call the `set()` method. If you follow this protocol, the widget will always track the value of the variable, with no further intervention on your part.

For example:

```
class App(Frame):
    def __init__(self, master=None):
        super().__init__(master)
        self.pack()

        self.entrythingy = Entry()
        self.entrythingy.pack()

        # here is the application variable
        self.contents = StringVar()
        # set it to some value
        self.contents.set("this is a variable")
        # tell the entry widget to watch this variable
        self.entrythingy["textvariable"] = self.contents

        # and here we get a callback when the user hits return.
        # we will have the program print out the value of the
        # application variable when the user hits return
        self.entrythingy.bind('<Key-Return>',
                              self.print_contents)

    def print_contents(self, event):
        print("hi. contents of entry is now ---->",
              self.contents.get())
```

The Window Manager

In Tk, there is a utility command, `wm`, for interacting with the window manager. Options to the `wm` command allow you to control things like titles, placement, icon bitmaps, and the like. In *tkinter*, these commands have been implemented as methods on the `Wm` class. Toplevel widgets are subclassed from the `Wm` class, and so can call the `Wm` methods directly.

To get at the toplevel window that contains a given widget, you can often just refer to the widget's master. Of course if the widget has been packed inside of a frame, the master won't represent a toplevel window. To get at the toplevel window that contains an arbitrary widget, you can call the `_root()` method. This method begins with an underscore to denote the fact that this function is part of the implementation, and not an interface to Tk functionality.

Here are some examples of typical usage:

```
import tkinter as tk

class App(tk.Frame):
    def __init__(self, master=None):
        super().__init__(master)
        self.pack()
```

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```
# create the application
myapp = App()

#
# here are method calls to the window manager class
#
myapp.master.title("My Do-Nothing Application")
myapp.master.maxsize(1000, 400)

# start the program
myapp.mainloop()
```

Tk Option Data Types

anchor Legal values are points of the compass: `"n"`, `"ne"`, `"e"`, `"se"`, `"s"`, `"sw"`, `"w"`, `"nw"`, and also `"center"`.

bitmap There are eight built-in, named bitmaps: `'error'`, `'gray25'`, `'gray50'`, `'hourglass'`, `'info'`, `'questhead'`, `'question'`, `'warning'`. To specify an X bitmap filename, give the full path to the file, preceded with an `@`, as in `"@/usr/contrib/bitmap/gumby.bit"`.

boolean You can pass integers 0 or 1 or the strings `"yes"` or `"no"`.

callback This is any Python function that takes no arguments. For example:

```
def print_it():
    print("hi there")
fred["command"] = print_it
```

color Colors can be given as the names of X colors in the rgb.txt file, or as strings representing RGB values in 4 bit: `"#RGB"`, 8 bit: `"#RRGGBB"`, 12 bit" `"#RRRGGGBBB"`, or 16 bit `"#RRRRGGGGBBBB"` ranges, where R,G,B here represent any legal hex digit. See page 160 of Ousterhout's book for details.

cursor The standard X cursor names from `cursorfont.h` can be used, without the `XC_` prefix. For example to get a hand cursor (`XC_hand2`), use the string `"hand2"`. You can also specify a bitmap and mask file of your own. See page 179 of Ousterhout's book.

distance Screen distances can be specified in either pixels or absolute distances. Pixels are given as numbers and absolute distances as strings, with the trailing character denoting units: `c` for centimetres, `i` for inches, `m` for millimetres, `p` for printer's points. For example, 3.5 inches is expressed as `"3.5i"`.

font Tk uses a list font name format, such as `{courier 10 bold}`. Font sizes with positive numbers are measured in points; sizes with negative numbers are measured in pixels.

geometry This is a string of the form `widthxheight`, where width and height are measured in pixels for most widgets (in characters for widgets displaying text). For example: `fred["geometry"] = "200x100"`.

justify Legal values are the strings: `"left"`, `"center"`, `"right"`, and `"fill"`.

region This is a string with four space-delimited elements, each of which is a legal distance (see above). For example: `"2 3 4 5"` and `"3i 2i 4.5i 2i"` and `"3c 2c 4c 10.43c"` are all legal regions.

relief Determines what the border style of a widget will be. Legal values are: `"raised"`, `"sunken"`, `"flat"`, `"groove"`, and `"ridge"`.

scrollcommand This is almost always the `set()` method of some scrollbar widget, but can be any widget method that takes a single argument.

wrap: Must be one of: `"none"`, `"char"`, or `"word"`.

Bindings and Events

The bind method from the widget command allows you to watch for certain events and to have a callback function trigger when that event type occurs. The form of the bind method is:

```
def bind(self, sequence, func, add=''):
```

where:

sequence is a string that denotes the target kind of event. (See the bind man page and page 201 of John Ousterhout's book for details).

func is a Python function, taking one argument, to be invoked when the event occurs. An Event instance will be passed as the argument. (Functions deployed this way are commonly known as *callbacks*.)

add is optional, either `''` or `'+'`. Passing an empty string denotes that this binding is to replace any other bindings that this event is associated with. Passing a `'+'` means that this function is to be added to the list of functions bound to this event type.

For example:

```
def turn_red(self, event):
    event.widget["activeforeground"] = "red"

self.button.bind("<Enter>", self.turn_red)
```

Notice how the widget field of the event is being accessed in the `turn_red()` callback. This field contains the widget that caught the X event. The following table lists the other event fields you can access, and how they are denoted in Tk, which can be useful when referring to the Tk man pages.

Tk	Tkinter Event Field	Tk	Tkinter Event Field
%f	focus	%A	char
%h	height	%E	send_event
%k	keycode	%K	keysym
%s	state	%N	keysym_num
%t	time	%T	type
%w	width	%W	widget
%x	x	%X	x_root
%y	y	%Y	y_root

The index Parameter

A number of widgets require "index" parameters to be passed. These are used to point at a specific place in a Text widget, or to particular characters in an Entry widget, or to particular menu items in a Menu widget.

Entry widget indexes (index, view index, etc.) Entry widgets have options that refer to character positions in the text being displayed. You can use these *tkinter* functions to access these special points in text widgets:

Text widget indexes The index notation for Text widgets is very rich and is best described in the Tk man pages.

Menu indexes (menu.invoke(), menu.entryconfig(), etc.) Some options and methods for menus manipulate specific menu entries. Anytime a menu index is needed for an option or a parameter, you may pass in:

- an integer which refers to the numeric position of the entry in the widget, counted from the top, starting with 0;

- the string `"active"`, which refers to the menu position that is currently under the cursor;
- the string `"last"` which refers to the last menu item;
- An integer preceded by `@`, as in `@6`, where the integer is interpreted as a y pixel coordinate in the menu's coordinate system;
- the string `"none"`, which indicates no menu entry at all, most often used with menu.activate() to deactivate all entries, and finally,
- a text string that is pattern matched against the label of the menu entry, as scanned from the top of the menu to the bottom. Note that this index type is considered after all the others, which means that matches for menu items labelled `last`, `active`, or `none` may be interpreted as the above literals, instead.

Images

Images of different formats can be created through the corresponding subclass of `tkinter.Image`:

- `BitmapImage` for images in XBM format.
- `PhotoImage` for images in PGM, PPM, GIF and PNG formats. The latter is supported starting with Tk 8.6.

Either type of image is created through either the `file` or the `data` option (other options are available as well).

The image object can then be used wherever an `image` option is supported by some widget (e.g. labels, buttons, menus). In these cases, Tk will not keep a reference to the image. When the last Python reference to the image object is deleted, the image data is deleted as well, and Tk will display an empty box wherever the image was used.

See also:

The Pillow package adds support for formats such as BMP, JPEG, TIFF, and WebP, among others.

26.1.7 File Handlers

Tk allows you to register and unregister a callback function which will be called from the Tk mainloop when I/O is possible on a file descriptor. Only one handler may be registered per file descriptor. Example code:

```
import tkinter
widget = tkinter.Tk()
mask = tkinter.READABLE | tkinter.WRITABLE
widget.tk.createfilehandler(file, mask, callback)
...
widget.tk.deletefilehandler(file)
```

This feature is not available on Windows.

Since you don't know how many bytes are available for reading, you may not want to use the *BufferedIOBase* or *TextIOBase* *read()* or *readline()* methods, since these will insist on reading a predefined number of bytes. For sockets, the *recv()* or *recvfrom()* methods will work fine; for other files, use raw reads or `os.read(file.fileno(), maxbytecount)`.

`Widget.tk.createfilehandler`(*file*, *mask*, *func*)

Registers the file handler callback function *func*. The *file* argument may either be an object with a *fileno()* method (such as a file or socket object), or an integer file descriptor. The *mask* argument is an ORed combination of any of the three constants below. The callback is called as follows:

```
callback(file, mask)
```

Widget.tk.**deletefilehandler**(*file*)
Unregisters a file handler.

tkinter.**READABLE**
tkinter.**WRITABLE**
tkinter.**EXCEPTION**
Constants used in the *mask* arguments.

26.2 tkinter.ttk — Tk themed widgets

Source code: Lib/tkinter/ttk.py

The *tkinter.ttk* module provides access to the Tk themed widget set, introduced in Tk 8.5. If Python has not been compiled against Tk 8.5, this module can still be accessed if *Tile* has been installed. The former method using Tk 8.5 provides additional benefits including anti-aliased font rendering under X11 and window transparency (requiring a composition window manager on X11).

The basic idea for *tkinter.ttk* is to separate, to the extent possible, the code implementing a widget's behavior from the code implementing its appearance.

See also:

Tk Widget Styling Support A document introducing theming support for Tk

26.2.1 Using Ttk

To start using Ttk, import its module:

```
from tkinter import ttk
```

To override the basic Tk widgets, the import should follow the Tk import:

```
from tkinter import *
from tkinter.ttk import *
```

That code causes several *tkinter.ttk* widgets (`Button`, `Checkbutton`, `Entry`, `Frame`, `Label`, `LabelFrame`, `Menubutton`, `PanedWindow`, `Radiobutton`, `Scale` and `Scrollbar`) to automatically replace the Tk widgets.

This has the direct benefit of using the new widgets which gives a better look and feel across platforms; however, the replacement widgets are not completely compatible. The main difference is that widget options such as "fg", "bg" and others related to widget styling are no longer present in Ttk widgets. Instead, use the `ttk.Style` class for improved styling effects.

See also:

Converting existing applications to use Tile widgets A monograph (using Tcl terminology) about differences typically encountered when moving applications to use the new widgets.

26.2.2 Ttk Widgets

Ttk comes with 18 widgets, twelve of which already existed in tkinter: `Button`, `Checkbutton`, `Entry`, `Frame`, `Label`, `LabelFrame`, `Menubutton`, `PanedWindow`, `Radiobutton`, `Scale`, `Scrollbar`, and *Spinbox*. The other

six are new: *Combobox*, *Notebook*, *Progressbar*, `Separator`, `Sizegrip` and *Treeview*. And all them are subclasses of *Widget*.

Using the Ttk widgets gives the application an improved look and feel. As discussed above, there are differences in how the styling is coded.

Tk code:

```
l1 = tkinter.Label(text="Test", fg="black", bg="white")
l2 = tkinter.Label(text="Test", fg="black", bg="white")
```

Ttk code:

```
style = ttk.Style()
style.configure("BW.TLabel", foreground="black", background="white")

l1 = ttk.Label(text="Test", style="BW.TLabel")
l2 = ttk.Label(text="Test", style="BW.TLabel")
```

For more information about *TtkStyling*, see the *Style* class documentation.

26.2.3 Widget

`ttk.Widget` defines standard options and methods supported by Tk themed widgets and is not supposed to be directly instantiated.

Standard Options

All the `ttk` Widgets accepts the following options:

Option	Description
class	Specifies the window class. The class is used when querying the option database for the window's other options, to determine the default bindtags for the window, and to select the widget's default layout and style. This option is read-only, and may only be specified when the window is created.
cursor	Specifies the mouse cursor to be used for the widget. If set to the empty string (the default), the cursor is inherited for the parent widget.
takefocus	Determines whether the window accepts the focus during keyboard traversal. 0, 1 or an empty string is returned. If 0 is returned, it means that the window should be skipped entirely during keyboard traversal. If 1, it means that the window should receive the input focus as long as it is viewable. And an empty string means that the traversal scripts make the decision about whether or not to focus on the window.
style	May be used to specify a custom widget style.

Scrollable Widget Options

The following options are supported by widgets that are controlled by a scrollbar.

Option	Description
xscrollcommand	Used to communicate with horizontal scrollbars. When the view in the widget's window change, the widget will generate a Tcl command based on the scrollcommand. Usually this option consists of the method `Scrollbar.set()` of some scrollbar. This will cause the scrollbar to be updated whenever the view in the window changes.
yscrollcommand	Used to communicate with vertical scrollbars. For some more information, see above.

Label Options

The following options are supported by labels, buttons and other button-like widgets.

Option	Description
text	Specifies a text string to be displayed inside the widget.
textvariable	Specifies a name whose value will be used in place of the text option resource.
underline	If set, specifies the index (0-based) of a character to underline in the text string. The underline character is used for mnemonic activation.
image	Specifies an image to display. This is a list of 1 or more elements. The first element is the default image name. The rest of the list if a sequence of statespec/value pairs as defined by *`Style.map()`*, specifying different images to use when the widget is in a particular state or a combination of states. All images in the list should have the same size.
compound	Specifies how to display the image relative to the text, in the case both text and images options are present. Valid values are: • text: display text only • image: display image only • top, bottom, left, right: display image above, below, left of, or right of the text, respectively. • none: the default. display the image if present, otherwise the text.
width	If greater than zero, specifies how much space, in character widths, to allocate for the text label, if less than zero, specifies a minimum width. If zero or unspecified, the natural width of the text label is used.

Compatibility Options

Option	Description
state	May be set to "normal" or "disabled" to control the "disabled" state bit. This is a write-only option: setting it changes the widget state, but the *`Widget.state()`* method does not affect this option.

Widget States

The widget state is a bitmap of independent state flags.

Flag	Description
active	The mouse cursor is over the widget and pressing a mouse button will cause some action to occur
disabled	Widget is disabled under program control
focus	Widget has keyboard focus
pressed	Widget is being pressed
selected	"On", "true", or "current" for things like Checkbuttons and radiobuttons
background	Windows and Mac have a notion of an "active" or foreground window. The *background* state is set for widgets in a background window, and cleared for those in the foreground window
readonly	Widget should not allow user modification
alternate	A widget-specific alternate display format
invalid	The widget's value is invalid

A state specification is a sequence of state names, optionally prefixed with an exclamation point indicating that the bit is off.

ttk.Widget

Besides the methods described below, the `ttk.Widget` supports the methods `tkinter.Widget.cget()` and `tkinter.Widget.configure()`.

class `tkinter.ttk.Widget`

identify(*x*, *y*)
Returns the name of the element at position *x* *y*, or the empty string if the point does not lie within any element.

x and *y* are pixel coordinates relative to the widget.

instate(*statespec*, *callback=None*, **args*, ***kw*)
Test the widget's state. If a callback is not specified, returns `True` if the widget state matches *statespec* and `False` otherwise. If callback is specified then it is called with args if widget state matches *statespec*.

state(*statespec=None*)
Modify or inquire widget state. If *statespec* is specified, sets the widget state according to it and return a new *statespec* indicating which flags were changed. If *statespec* is not specified, returns the currently-enabled state flags.

statespec will usually be a list or a tuple.

26.2.4 Combobox

The `ttk.Combobox` widget combines a text field with a pop-down list of values. This widget is a subclass of `Entry`.

Besides the methods inherited from *Widget*: `Widget.cget()`, `Widget.configure()`, *Widget.identify()*, *Widget.instate()* and *Widget.state()*, and the following inherited from `Entry`: `Entry.bbox()`, `Entry.delete()`, `Entry.icursor()`, `Entry.index()`, `Entry.insert()`, `Entry.selection()`, `Entry.xview()`, it has some other methods, described at `ttk.Combobox`.

Options

This widget accepts the following specific options:

Option	Description
exportselection	Boolean value. If set, the widget selection is linked to the Window Manager selection (which can be returned by invoking Misc.selection_get, for example).
justify	Specifies how the text is aligned within the widget. One of "left", "center", or "right".
height	Specifies the height of the pop-down listbox, in rows.
postcommand	A script (possibly registered with Misc.register) that is called immediately before displaying the values. It may specify which values to display.
state	One of "normal", "readonly", or "disabled". In the "readonly" state, the value may not be edited directly, and the user can only selection of the values from the dropdown list. In the "normal" state, the text field is directly editable. In the "disabled" state, no interaction is possible.
textvariable	Specifies a name whose value is linked to the widget value. Whenever the value associated with that name changes, the widget value is updated, and vice versa. See `tkinter.StringVar`.
values	Specifies the list of values to display in the drop-down listbox.
width	Specifies an integer value indicating the desired width of the entry window, in average-size characters of the widget's font.

Virtual events

The combobox widgets generates a **<<ComboboxSelected>>** virtual event when the user selects an element from the list of values.

ttk.Combobox

`class tkinter.ttk.Combobox`

`current(`*newindex=None*`)`
: If *newindex* is specified, sets the combobox value to the element position *newindex*. Otherwise, returns the index of the current value or -1 if the current value is not in the values list.

`get()`
: Returns the current value of the combobox.

`set(`*value*`)`
: Sets the value of the combobox to *value*.

26.2.5 Spinbox

The `ttk.Spinbox` widget is a `ttk.Entry` enhanced with increment and decrement arrows. It can be used for numbers or lists of string values. This widget is a subclass of `Entry`.

Besides the methods inherited from *`Widget`*: `Widget.cget()`, `Widget.configure()`, *`Widget.identify()`*, *`Widget.instate()`* and *`Widget.state()`*, and the following inherited from `Entry`: `Entry.bbox()`, `Entry.delete()`, `Entry.icursor()`, `Entry.index()`, `Entry.insert()`, `Entry.xview()`, it has some other methods, described at `ttk.Spinbox`.

Options

This widget accepts the following specific options:

Option	Description
from	Float value. If set, this is the minimum value to which the decrement button will decrement. Must be spelled as `from_` when used as an argument, since `from` is a Python keyword.
to	Float value. If set, this is the maximum value to which the increment button will increment.
increment	Float value. Specifies the amount which the increment/decrement buttons change the value. Defaults to 1.0.
values	Sequence of string or float values. If specified, the increment/decrement buttons will cycle through the items in this sequence rather than incrementing or decrementing numbers.
wrap	Boolean value. If `True`, increment and decrement buttons will cycle from the `to` value to the `from` value or the `from` value to the `to` value, respectively.
format	String value. This specifies the format of numbers set by the increment/decrement buttons. It must be in the form "%W.Pf", where W is the padded width of the value, P is the precision, and '%' and 'f' are literal.
command	Python callable. Will be called with no arguments whenever either of the increment or decrement buttons are pressed.

Virtual events

The spinbox widget generates an **<<Increment>>** virtual event when the user presses <Up>, and a **<<Decrement>>** virtual event when the user presses <Down>.

ttk.Spinbox

`class tkinter.ttk.Spinbox`

`get()`
Returns the current value of the spinbox.

`set(`*value*`)`
Sets the value of the spinbox to *value*.

26.2.6 Notebook

Ttk Notebook widget manages a collection of windows and displays a single one at a time. Each child window is associated with a tab, which the user may select to change the currently-displayed window.

Options

This widget accepts the following specific options:

Option	Description
height	If present and greater than zero, specifies the desired height of the pane area (not including internal padding or tabs). Otherwise, the maximum height of all panes is used.
padding	Specifies the amount of extra space to add around the outside of the notebook. The padding is a list up to four length specifications left top right bottom. If fewer than four elements are specified, bottom defaults to top, right defaults to left, and top defaults to left.
width	If present and greater than zero, specified the desired width of the pane area (not including internal padding). Otherwise, the maximum width of all panes is used.

Tab Options

There are also specific options for tabs:

Option	Description
state	Either "normal", "disabled" or "hidden". If "disabled", then the tab is not selectable. If "hidden", then the tab is not shown.
sticky	Specifies how the child window is positioned within the pane area. Value is a string containing zero or more of the characters "n", "s", "e" or "w". Each letter refers to a side (north, south, east or west) that the child window will stick to, as per the `grid()` geometry manager.
padding	Specifies the amount of extra space to add between the notebook and this pane. Syntax is the same as for the option padding used by this widget.
text	Specifies a text to be displayed in the tab.
image	Specifies an image to display in the tab. See the option image described in *Widget*.
compound	Specifies how to display the image relative to the text, in the case both options text and image are present. See *Label Options* for legal values.
underline	Specifies the index (0-based) of a character to underline in the text string. The underlined character is used for mnemonic activation if *Notebook.enable_traversal()* is called.

Tab Identifiers

The tab_id present in several methods of `ttk.Notebook` may take any of the following forms:

- An integer between zero and the number of tabs
- The name of a child window
- A positional specification of the form "@x,y", which identifies the tab
- The literal string "current", which identifies the currently-selected tab
- The literal string "end", which returns the number of tabs (only valid for *Notebook.index()*)

Virtual Events

This widget generates a **<<NotebookTabChanged>>** virtual event after a new tab is selected.

ttk.Notebook

class tkinter.ttk.Notebook

add(*child*, ***kw*)
Adds a new tab to the notebook.

If window is currently managed by the notebook but hidden, it is restored to its previous position.

See *Tab Options* for the list of available options.

forget(*tab_id*)
Removes the tab specified by *tab_id*, unmaps and unmanages the associated window.

hide(*tab_id*)
Hides the tab specified by *tab_id*.

The tab will not be displayed, but the associated window remains managed by the notebook and its configuration remembered. Hidden tabs may be restored with the *add()* command.

identify(*x*, *y*)
Returns the name of the tab element at position *x*, *y*, or the empty string if none.

index(*tab_id*)
Returns the numeric index of the tab specified by *tab_id*, or the total number of tabs if *tab_id* is the string "end".

insert(*pos*, *child*, ***kw*)
Inserts a pane at the specified position.

pos is either the string "end", an integer index, or the name of a managed child. If *child* is already managed by the notebook, moves it to the specified position.

See *Tab Options* for the list of available options.

select(*tab_id=None*)
Selects the specified *tab_id*.

The associated child window will be displayed, and the previously-selected window (if different) is unmapped. If *tab_id* is omitted, returns the widget name of the currently selected pane.

tab(*tab_id*, *option=None*, ***kw*)
Query or modify the options of the specific *tab_id*.

If *kw* is not given, returns a dictionary of the tab option values. If *option* is specified, returns the value of that *option*. Otherwise, sets the options to the corresponding values.

tabs()
Returns a list of windows managed by the notebook.

enable_traversal()
Enable keyboard traversal for a toplevel window containing this notebook.

This will extend the bindings for the toplevel window containing the notebook as follows:

- `Control-Tab`: selects the tab following the currently selected one.
- `Shift-Control-Tab`: selects the tab preceding the currently selected one.
- `Alt-K`: where *K* is the mnemonic (underlined) character of any tab, will select that tab.

Multiple notebooks in a single toplevel may be enabled for traversal, including nested notebooks. However, notebook traversal only works properly if all panes have the notebook they are in as master.

26.2.7 Progressbar

The `ttk.Progressbar` widget shows the status of a long-running operation. It can operate in two modes: 1) the determinate mode which shows the amount completed relative to the total amount of work to be done and 2) the indeterminate mode which provides an animated display to let the user know that work is progressing.

Options

This widget accepts the following specific options:

Option	Description
orient	One of "horizontal" or "vertical". Specifies the orientation of the progress bar.
length	Specifies the length of the long axis of the progress bar (width if horizontal, height if vertical).
mode	One of "determinate" or "indeterminate".
maximum	A number specifying the maximum value. Defaults to 100.
value	The current value of the progress bar. In "determinate" mode, this represents the amount of work completed. In "indeterminate" mode, it is interpreted as modulo *maximum*; that is, the progress bar completes one "cycle" when its value increases by *maximum*.
variable	A name which is linked to the option value. If specified, the value of the progress bar is automatically set to the value of this name whenever the latter is modified.
phase	Read-only option. The widget periodically increments the value of this option whenever its value is greater than 0 and, in determinate mode, less than maximum. This option may be used by the current theme to provide additional animation effects.

ttk.Progressbar

class tkinter.ttk.Progressbar

start(*interval=None*)
Begin autoincrement mode: schedules a recurring timer event that calls *Progressbar.step()* every *interval* milliseconds. If omitted, *interval* defaults to 50 milliseconds.

step(*amount=None*)
Increments the progress bar's value by *amount*.

amount defaults to 1.0 if omitted.

stop()
Stop autoincrement mode: cancels any recurring timer event initiated by *Progressbar.start()* for this progress bar.

26.2.8 Separator

The `ttk.Separator` widget displays a horizontal or vertical separator bar.

It has no other methods besides the ones inherited from `ttk.Widget`.

Options

This widget accepts the following specific option:

Option	Description
orient	One of “horizontal” or “vertical”. Specifies the orientation of the separator.

26.2.9 Sizegrip

The `ttk.Sizegrip` widget (also known as a grow box) allows the user to resize the containing toplevel window by pressing and dragging the grip.

This widget has neither specific options nor specific methods, besides the ones inherited from `ttk.Widget`.

Platform-specific notes

- On MacOS X, toplevel windows automatically include a built-in size grip by default. Adding a `Sizegrip` is harmless, since the built-in grip will just mask the widget.

Bugs

- If the containing toplevel’s position was specified relative to the right or bottom of the screen (e.g. ….), the `Sizegrip` widget will not resize the window.
- This widget supports only “southeast” resizing.

26.2.10 Treeview

The `ttk.Treeview` widget displays a hierarchical collection of items. Each item has a textual label, an optional image, and an optional list of data values. The data values are displayed in successive columns after the tree label.

The order in which data values are displayed may be controlled by setting the widget option `displaycolumns`. The tree widget can also display column headings. Columns may be accessed by number or symbolic names listed in the widget option columns. See *Column Identifiers*.

Each item is identified by a unique name. The widget will generate item IDs if they are not supplied by the caller. There is a distinguished root item, named `{}`. The root item itself is not displayed; its children appear at the top level of the hierarchy.

Each item also has a list of tags, which can be used to associate event bindings with individual items and control the appearance of the item.

The Treeview widget supports horizontal and vertical scrolling, according to the options described in *Scrollable Widget Options* and the methods *`Treeview.xview()`* and *`Treeview.yview()`*.

Options

This widget accepts the following specific options:

Option	Description
columns	A list of column identifiers, specifying the number of columns and their names.
displaycolumns	A list of column identifiers (either symbolic or integer indices) specifying which data columns are displayed and the order in which they appear, or the string "#all".
height	Specifies the number of rows which should be visible. Note: the requested width is determined from the sum of the column widths.
padding	Specifies the internal padding for the widget. The padding is a list of up to four length specifications.
selectmode	Controls how the built-in class bindings manage the selection. One of "extended", "browse" or "none". If set to "extended" (the default), multiple items may be selected. If "browse", only a single item will be selected at a time. If "none", the selection will not be changed. Note that the application code and tag bindings can set the selection however they wish, regardless of the value of this option.
show	A list containing zero or more of the following values, specifying which elements of the tree to display. • tree: display tree labels in column #0. • headings: display the heading row. The default is "tree headings", i.e., show all elements. **Note**: Column #0 always refers to the tree column, even if show="tree" is not specified.

Item Options

The following item options may be specified for items in the insert and item widget commands.

Option	Description
text	The textual label to display for the item.
image	A Tk Image, displayed to the left of the label.
values	The list of values associated with the item. Each item should have the same number of values as the widget option columns. If there are fewer values than columns, the remaining values are assumed empty. If there are more values than columns, the extra values are ignored.
open	True/False value indicating whether the item's children should be displayed or hidden.
tags	A list of tags associated with this item.

Tag Options

The following options may be specified on tags:

Option	Description
foreground	Specifies the text foreground color.
background	Specifies the cell or item background color.
font	Specifies the font to use when drawing text.
image	Specifies the item image, in case the item's image option is empty.

Column Identifiers

Column identifiers take any of the following forms:

- A symbolic name from the list of columns option.
- An integer n, specifying the nth data column.
- A string of the form #n, where n is an integer, specifying the nth display column.

Notes:

- Item's option values may be displayed in a different order than the order in which they are stored.
- Column #0 always refers to the tree column, even if show="tree" is not specified.

A data column number is an index into an item's option values list; a display column number is the column number in the tree where the values are displayed. Tree labels are displayed in column #0. If option displaycolumns is not set, then data column n is displayed in column #n+1. Again, **column #0 always refers to the tree column**.

Virtual Events

The Treeview widget generates the following virtual events.

Event	Description
<<TreeviewSelect>>	Generated whenever the selection changes.
<<TreeviewOpen>>	Generated just before settings the focus item to open=True.
<<TreeviewClose>>	Generated just after setting the focus item to open=False.

The *Treeview.focus()* and *Treeview.selection()* methods can be used to determine the affected item or items.

ttk.Treeview

class tkinter.ttk.Treeview

bbox(*item*, *column=None*)
Returns the bounding box (relative to the treeview widget's window) of the specified *item* in the form (x, y, width, height).

If *column* is specified, returns the bounding box of that cell. If the *item* is not visible (i.e., if it is a descendant of a closed item or is scrolled offscreen), returns an empty string.

get_children(*item=None*)
Returns the list of children belonging to *item*.

If *item* is not specified, returns root children.

set_children(*item*, **newchildren*)
Replaces *item*'s child with *newchildren*.

Children present in *item* that are not present in *newchildren* are detached from the tree. No items in *newchildren* may be an ancestor of *item*. Note that not specifying *newchildren* results in detaching *item*'s children.

column(*column*, *option=None*, ***kw*)
Query or modify the options for the specified *column*.

If *kw* is not given, returns a dict of the column option values. If *option* is specified then the value for that *option* is returned. Otherwise, sets the options to the corresponding values.

The valid options/values are:

- **id** Returns the column name. This is a read-only option.
- **anchor: One of the standard Tk anchor values.** Specifies how the text in this column should be aligned with respect to the cell.
- **minwidth: width** The minimum width of the column in pixels. The treeview widget will not make the column any smaller than specified by this option when the widget is resized or the user drags a column.
- **stretch: True/False** Specifies whether the column's width should be adjusted when the widget is resized.
- **width: width** The width of the column in pixels.

To configure the tree column, call this with column = "#0"

`delete`(**items*)
Delete all specified *items* and all their descendants.

The root item may not be deleted.

`detach`(**items*)
Unlinks all of the specified *items* from the tree.

The items and all of their descendants are still present, and may be reinserted at another point in the tree, but will not be displayed.

The root item may not be detached.

`exists`(*item*)
Returns `True` if the specified *item* is present in the tree.

`focus`(*item=None*)
If *item* is specified, sets the focus item to *item*. Otherwise, returns the current focus item, or '' if there is none.

`heading`(*column*, *option=None*, ***kw*)
Query or modify the heading options for the specified *column*.

If *kw* is not given, returns a dict of the heading option values. If *option* is specified then the value for that *option* is returned. Otherwise, sets the options to the corresponding values.

The valid options/values are:

- **text: text** The text to display in the column heading.
- **image: imageName** Specifies an image to display to the right of the column heading.
- **anchor: anchor** Specifies how the heading text should be aligned. One of the standard Tk anchor values.
- **command: callback** A callback to be invoked when the heading label is pressed.

To configure the tree column heading, call this with column = "#0".

`identify`(*component*, *x*, *y*)
Returns a description of the specified *component* under the point given by *x* and *y*, or the empty string if no such *component* is present at that position.

`identify_row`(*y*)
Returns the item ID of the item at position *y*.

identify_column(*x*)
Returns the data column identifier of the cell at position *x*.

The tree column has ID #0.

identify_region(*x*, *y*)
Returns one of:

region	meaning
heading	Tree heading area.
separator	Space between two columns headings.
tree	The tree area.
cell	A data cell.

Availability: Tk 8.6.

identify_element(*x*, *y*)
Returns the element at position *x*, *y*.

Availability: Tk 8.6.

index(*item*)
Returns the integer index of *item* within its parent's list of children.

insert(*parent*, *index*, *iid=None*, ***kw*)
Creates a new item and returns the item identifier of the newly created item.

parent is the item ID of the parent item, or the empty string to create a new top-level item. *index* is an integer, or the value "end", specifying where in the list of parent's children to insert the new item. If *index* is less than or equal to zero, the new node is inserted at the beginning; if *index* is greater than or equal to the current number of children, it is inserted at the end. If *iid* is specified, it is used as the item identifier; *iid* must not already exist in the tree. Otherwise, a new unique identifier is generated.

See *Item Options* for the list of available points.

item(*item*, *option=None*, ***kw*)
Query or modify the options for the specified *item*.

If no options are given, a dict with options/values for the item is returned. If *option* is specified then the value for that option is returned. Otherwise, sets the options to the corresponding values as given by *kw*.

move(*item*, *parent*, *index*)
Moves *item* to position *index* in *parent*'s list of children.

It is illegal to move an item under one of its descendants. If *index* is less than or equal to zero, *item* is moved to the beginning; if greater than or equal to the number of children, it is moved to the end. If *item* was detached it is reattached.

next(*item*)
Returns the identifier of *item*'s next sibling, or '' if *item* is the last child of its parent.

parent(*item*)
Returns the ID of the parent of *item*, or '' if *item* is at the top level of the hierarchy.

prev(*item*)
Returns the identifier of *item*'s previous sibling, or '' if *item* is the first child of its parent.

reattach(*item*, *parent*, *index*)
An alias for *Treeview.move()*.

see(*item*)
Ensure that *item* is visible.

Sets all of *item*'s ancestors open option to `True`, and scrolls the widget if necessary so that *item* is within the visible portion of the tree.

selection(*selop=None*, *items=None*)
If *selop* is not specified, returns selected items. Otherwise, it will act according to the following selection methods.

Deprecated since version 3.6, will be removed in version 3.8: Using `selection()` for changing the selection state is deprecated. Use the following selection methods instead.

selection_set(**items*)
items becomes the new selection.

Changed in version 3.6: *items* can be passed as separate arguments, not just as a single tuple.

selection_add(**items*)
Add *items* to the selection.

Changed in version 3.6: *items* can be passed as separate arguments, not just as a single tuple.

selection_remove(**items*)
Remove *items* from the selection.

Changed in version 3.6: *items* can be passed as separate arguments, not just as a single tuple.

selection_toggle(**items*)
Toggle the selection state of each item in *items*.

Changed in version 3.6: *items* can be passed as separate arguments, not just as a single tuple.

set(*item*, *column=None*, *value=None*)
With one argument, returns a dictionary of column/value pairs for the specified *item*. With two arguments, returns the current value of the specified *column*. With three arguments, sets the value of given *column* in given *item* to the specified *value*.

tag_bind(*tagname*, *sequence=None*, *callback=None*)
Bind a callback for the given event *sequence* to the tag *tagname*. When an event is delivered to an item, the callbacks for each of the item's tags option are called.

tag_configure(*tagname*, *option=None*, ***kw*)
Query or modify the options for the specified *tagname*.

If *kw* is not given, returns a dict of the option settings for *tagname*. If *option* is specified, returns the value for that *option* for the specified *tagname*. Otherwise, sets the options to the corresponding values for the given *tagname*.

tag_has(*tagname*, *item=None*)
If *item* is specified, returns 1 or 0 depending on whether the specified *item* has the given *tagname*. Otherwise, returns a list of all items that have the specified tag.

Availability: Tk 8.6

xview(**args*)
Query or modify horizontal position of the treeview.

yview(**args*)
Query or modify vertical position of the treeview.

26.2.11 Ttk Styling

Each widget in `ttk` is assigned a style, which specifies the set of elements making up the widget and how they are arranged, along with dynamic and default settings for element options. By default the style name is the same as the widget's class name, but it may be overridden by the widget's style option. If you don't know the class name of a widget, use the method `Misc.winfo_class()` (somewidget.winfo_class()).

See also:

Tcl'2004 conference presentation This document explains how the theme engine works

class tkinter.ttk.Style

This class is used to manipulate the style database.

configure(*style*, *query_opt=None*, ***kw*)

Query or set the default value of the specified option(s) in *style*.

Each key in *kw* is an option and each value is a string identifying the value for that option.

For example, to change every default button to be a flat button with some padding and a different background color:

```
from tkinter import ttk
import tkinter

root = tkinter.Tk()

ttk.Style().configure("TButton", padding=6, relief="flat",
   background="#ccc")

btn = ttk.Button(text="Sample")
btn.pack()

root.mainloop()
```

map(*style*, *query_opt=None*, ***kw*)

Query or sets dynamic values of the specified option(s) in *style*.

Each key in *kw* is an option and each value should be a list or a tuple (usually) containing statespecs grouped in tuples, lists, or some other preference. A statespec is a compound of one or more states and then a value.

An example may make it more understandable:

```
import tkinter
from tkinter import ttk

root = tkinter.Tk()

style = ttk.Style()
style.map("C.TButton",
    foreground=[('pressed', 'red'), ('active', 'blue')],
    background=[('pressed', '!disabled', 'black'), ('active', 'white')]
    )

colored_btn = ttk.Button(text="Test", style="C.TButton").pack()

root.mainloop()
```

Note that the order of the (states, value) sequences for an option does matter, if the order is changed to `[('active', 'blue'), ('pressed', 'red')]` in the foreground option, for example,

the result would be a blue foreground when the widget were in active or pressed states.

lookup(*style*, *option*, *state=None*, *default=None*)
Returns the value specified for *option* in *style*.

If *state* is specified, it is expected to be a sequence of one or more states. If the *default* argument is set, it is used as a fallback value in case no specification for option is found.

To check what font a Button uses by default:

```
from tkinter import ttk

print(ttk.Style().lookup("TButton", "font"))
```

layout(*style*, *layoutspec=None*)
Define the widget layout for given *style*. If *layoutspec* is omitted, return the layout specification for given style.

layoutspec, if specified, is expected to be a list or some other sequence type (excluding strings), where each item should be a tuple and the first item is the layout name and the second item should have the format described in *Layouts*.

To understand the format, see the following example (it is not intended to do anything useful):

```
from tkinter import ttk
import tkinter

root = tkinter.Tk()

style = ttk.Style()
style.layout("TMenubutton", [
   ("Menubutton.background", None),
   ("Menubutton.button", {"children":
       [("Menubutton.focus", {"children":
           [("Menubutton.padding", {"children":
               [("Menubutton.label", {"side": "left", "expand": 1})]
           })]
       })]
   }),
])

mbtn = ttk.Menubutton(text='Text')
mbtn.pack()
root.mainloop()
```

element_create(*elementname*, *etype*, **args*, ***kw*)
Create a new element in the current theme, of the given *etype* which is expected to be either "image", "from" or "vsapi". The latter is only available in Tk 8.6a for Windows XP and Vista and is not described here.

If "image" is used, *args* should contain the default image name followed by statespec/value pairs (this is the imagespec), and *kw* may have the following options:

- **border=padding** padding is a list of up to four integers, specifying the left, top, right, and bottom borders, respectively.
- **height=height** Specifies a minimum height for the element. If less than zero, the base image's height is used as a default.
- **padding=padding** Specifies the element's interior padding. Defaults to border's value if not specified.

- **sticky=spec** Specifies how the image is placed within the final parcel. spec contains zero or more characters “n”, “s”, “w”, or “e”.
- **width=width** Specifies a minimum width for the element. If less than zero, the base image’s width is used as a default.

If “from” is used as the value of *etype*, *element_create()* will clone an existing element. *args* is expected to contain a themename, from which the element will be cloned, and optionally an element to clone from. If this element to clone from is not specified, an empty element will be used. *kw* is discarded.

element_names()
Returns the list of elements defined in the current theme.

element_options(*elementname*)
Returns the list of *elementname*’s options.

theme_create(*themename*, *parent=None*, *settings=None*)
Create a new theme.

It is an error if *themename* already exists. If *parent* is specified, the new theme will inherit styles, elements and layouts from the parent theme. If *settings* are present they are expected to have the same syntax used for *theme_settings()*.

theme_settings(*themename*, *settings*)
Temporarily sets the current theme to *themename*, apply specified *settings* and then restore the previous theme.

Each key in *settings* is a style and each value may contain the keys ‘configure’, ‘map’, ‘layout’ and ‘element create’ and they are expected to have the same format as specified by the methods *Style.configure()*, *Style.map()*, *Style.layout()* and *Style.element_create()* respectively.

As an example, let’s change the Combobox for the default theme a bit:

```
from tkinter import ttk
import tkinter

root = tkinter.Tk()

style = ttk.Style()
style.theme_settings("default", {
   "TCombobox": {
       "configure": {"padding": 5},
       "map": {
           "background": [("active", "green2"),
                          ("!disabled", "green4")],
           "fieldbackground": [("!disabled", "green3")],
           "foreground": [("focus", "OliveDrab1"),
                          ("!disabled", "OliveDrab2")]
       }
   }
})

combo = ttk.Combobox().pack()

root.mainloop()
```

theme_names()
Returns a list of all known themes.

theme_use(*themename=None*)
If *themename* is not given, returns the theme in use. Otherwise, sets the current theme to

themename, refreshes all widgets and emits a <<ThemeChanged>> event.

Layouts

A layout can be just `None`, if it takes no options, or a dict of options specifying how to arrange the element. The layout mechanism uses a simplified version of the pack geometry manager: given an initial cavity, each element is allocated a parcel. Valid options/values are:

- **side: whichside** Specifies which side of the cavity to place the element; one of top, right, bottom or left. If omitted, the element occupies the entire cavity.
- **sticky: nswe** Specifies where the element is placed inside its allocated parcel.
- **unit: 0 or 1** If set to 1, causes the element and all of its descendants to be treated as a single element for the purposes of *Widget.identify()* et al. It's used for things like scrollbar thumbs with grips.
- **children: [sublayout...]** Specifies a list of elements to place inside the element. Each element is a tuple (or other sequence type) where the first item is the layout name, and the other is a *Layout*.

26.3 `tkinter.tix` — Extension widgets for Tk

Source code: Lib/tkinter/tix.py

Deprecated since version 3.6: This Tk extension is unmaintained and should not be used in new code. Use *tkinter.ttk* instead.

The *tkinter.tix* (Tk Interface Extension) module provides an additional rich set of widgets. Although the standard Tk library has many useful widgets, they are far from complete. The *tkinter.tix* library provides most of the commonly needed widgets that are missing from standard Tk: *HList*, *ComboBox*, *Control* (a.k.a. SpinBox) and an assortment of scrollable widgets. *tkinter.tix* also includes many more widgets that are generally useful in a wide range of applications: *NoteBook*, *FileEntry*, *PanedWindow*, etc; there are more than 40 of them.

With all these new widgets, you can introduce new interaction techniques into applications, creating more useful and more intuitive user interfaces. You can design your application by choosing the most appropriate widgets to match the special needs of your application and users.

See also:

Tix Homepage The home page for `Tix`. This includes links to additional documentation and downloads.

Tix Man Pages On-line version of the man pages and reference material.

Tix Programming Guide On-line version of the programmer's reference material.

Tix Development Applications Tix applications for development of Tix and Tkinter programs. Tide applications work under Tk or Tkinter, and include `TixInspect`, an inspector to remotely modify and debug Tix/Tk/Tkinter applications.

26.3.1 Using Tix

`class tkinter.tix.Tk(`*screenName=None*, *baseName=None*, *className='Tix'*`)`
Toplevel widget of Tix which represents mostly the main window of an application. It has an associated Tcl interpreter.

Classes in the *tkinter.tix* module subclasses the classes in the *tkinter*. The former imports the latter, so to use *tkinter.tix* with Tkinter, all you need to do is to import one module. In general, you can just import *tkinter.tix*, and replace the toplevel call to *tkinter.Tk* with `tix.Tk`:

```
from tkinter import tix
from tkinter.constants import *
root = tix.Tk()
```

To use *tkinter.tix*, you must have the Tix widgets installed, usually alongside your installation of the Tk widgets. To test your installation, try the following:

```
from tkinter import tix
root = tix.Tk()
root.tk.eval('package require Tix')
```

If this fails, you have a Tk installation problem which must be resolved before proceeding. Use the environment variable `TIX_LIBRARY` to point to the installed Tix library directory, and make sure you have the dynamic object library (`tix8183.dll` or `libtix8183.so`) in the same directory that contains your Tk dynamic object library (`tk8183.dll` or `libtk8183.so`). The directory with the dynamic object library should also have a file called `pkgIndex.tcl` (case sensitive), which contains the line:

```
package ifneeded Tix 8.1 [list load "[file join $dir tix8183.dll]" Tix]
```

26.3.2 Tix Widgets

Tix introduces over 40 widget classes to the *tkinter* repertoire.

Basic Widgets

class tkinter.tix.Balloon
A Balloon that pops up over a widget to provide help. When the user moves the cursor inside a widget to which a Balloon widget has been bound, a small pop-up window with a descriptive message will be shown on the screen.

class tkinter.tix.ButtonBox
The ButtonBox widget creates a box of buttons, such as is commonly used for `Ok Cancel`.

class tkinter.tix.ComboBox
The ComboBox widget is similar to the combo box control in MS Windows. The user can select a choice by either typing in the entry subwidget or selecting from the listbox subwidget.

class tkinter.tix.Control
The Control widget is also known as the `SpinBox` widget. The user can adjust the value by pressing the two arrow buttons or by entering the value directly into the entry. The new value will be checked against the user-defined upper and lower limits.

class tkinter.tix.LabelEntry
The LabelEntry widget packages an entry widget and a label into one mega widget. It can be used to simplify the creation of "entry-form" type of interface.

class tkinter.tix.LabelFrame
The LabelFrame widget packages a frame widget and a label into one mega widget. To create widgets inside a LabelFrame widget, one creates the new widgets relative to the `frame` subwidget and manage them inside the `frame` subwidget.

class tkinter.tix.Meter
The Meter widget can be used to show the progress of a background job which may take a long time to execute.

class tkinter.tix.OptionMenu
The OptionMenu creates a menu button of options.

class tkinter.tix.PopupMenu
The PopupMenu widget can be used as a replacement of the `tk_popup` command. The advantage of the `Tix` *PopupMenu* widget is it requires less application code to manipulate.

class tkinter.tix.Select
The Select widget is a container of button subwidgets. It can be used to provide radio-box or check-box style of selection options for the user.

class tkinter.tix.StdButtonBox
The StdButtonBox widget is a group of standard buttons for Motif-like dialog boxes.

File Selectors

class tkinter.tix.DirList
The DirList widget displays a list view of a directory, its previous directories and its sub-directories. The user can choose one of the directories displayed in the list or change to another directory.

class tkinter.tix.DirTree
The DirTree widget displays a tree view of a directory, its previous directories and its sub-directories. The user can choose one of the directories displayed in the list or change to another directory.

class tkinter.tix.DirSelectDialog
The DirSelectDialog widget presents the directories in the file system in a dialog window. The user can use this dialog window to navigate through the file system to select the desired directory.

class tkinter.tix.DirSelectBox
The *DirSelectBox* is similar to the standard Motif(TM) directory-selection box. It is generally used for the user to choose a directory. DirSelectBox stores the directories mostly recently selected into a ComboBox widget so that they can be quickly selected again.

class tkinter.tix.ExFileSelectBox
The ExFileSelectBox widget is usually embedded in a tixExFileSelectDialog widget. It provides a convenient method for the user to select files. The style of the *ExFileSelectBox* widget is very similar to the standard file dialog on MS Windows 3.1.

class tkinter.tix.FileSelectBox
The FileSelectBox is similar to the standard Motif(TM) file-selection box. It is generally used for the user to choose a file. FileSelectBox stores the files mostly recently selected into a *ComboBox* widget so that they can be quickly selected again.

class tkinter.tix.FileEntry
The FileEntry widget can be used to input a filename. The user can type in the filename manually. Alternatively, the user can press the button widget that sits next to the entry, which will bring up a file selection dialog.

Hierarchical ListBox

class tkinter.tix.HList
The HList widget can be used to display any data that have a hierarchical structure, for example, file system directory trees. The list entries are indented and connected by branch lines according to their places in the hierarchy.

class tkinter.tix.CheckList
The CheckList widget displays a list of items to be selected by the user. CheckList acts similarly to the Tk checkbutton or radiobutton widgets, except it is capable of handling many more items than checkbuttons or radiobuttons.

class tkinter.tix.Tree
The Tree widget can be used to display hierarchical data in a tree form. The user can adjust the view of the tree by opening or closing parts of the tree.

Tabular ListBox

class tkinter.tix.TList
The TList widget can be used to display data in a tabular format. The list entries of a *TList* widget are similar to the entries in the Tk listbox widget. The main differences are (1) the *TList* widget can display the list entries in a two dimensional format and (2) you can use graphical images as well as multiple colors and fonts for the list entries.

Manager Widgets

class tkinter.tix.PanedWindow
The PanedWindow widget allows the user to interactively manipulate the sizes of several panes. The panes can be arranged either vertically or horizontally. The user changes the sizes of the panes by dragging the resize handle between two panes.

class tkinter.tix.ListNoteBook
The ListNoteBook widget is very similar to the `TixNoteBook` widget: it can be used to display many windows in a limited space using a notebook metaphor. The notebook is divided into a stack of pages (windows). At one time only one of these pages can be shown. The user can navigate through these pages by choosing the name of the desired page in the `hlist` subwidget.

class tkinter.tix.NoteBook
The NoteBook widget can be used to display many windows in a limited space using a notebook metaphor. The notebook is divided into a stack of pages. At one time only one of these pages can be shown. The user can navigate through these pages by choosing the visual "tabs" at the top of the NoteBook widget.

Image Types

The *tkinter.tix* module adds:

- pixmap capabilities to all *tkinter.tix* and *tkinter* widgets to create color images from XPM files.
- Compound image types can be used to create images that consists of multiple horizontal lines; each line is composed of a series of items (texts, bitmaps, images or spaces) arranged from left to right. For example, a compound image can be used to display a bitmap and a text string simultaneously in a Tk `Button` widget.

Miscellaneous Widgets

class tkinter.tix.InputOnly
The InputOnly widgets are to accept inputs from the user, which can be done with the `bind` command (Unix only).

Form Geometry Manager

In addition, *tkinter.tix* augments *tkinter* by providing:

class tkinter.tix.Form
The Form geometry manager based on attachment rules for all Tk widgets.

26.3.3 Tix Commands

class tkinter.tix.tixCommand

The tix commands provide access to miscellaneous elements of `Tix`'s internal state and the `Tix` application context. Most of the information manipulated by these methods pertains to the application as a whole, or to a screen or display, rather than to a particular window.

To view the current settings, the common usage is:

```
from tkinter import tix
root = tix.Tk()
print(root.tix_configure())
```

tixCommand.tix_configure(*cnf=None*, ***kw*)

Query or modify the configuration options of the Tix application context. If no option is specified, returns a dictionary all of the available options. If option is specified with no value, then the method returns a list describing the one named option (this list will be identical to the corresponding sublist of the value returned if no option is specified). If one or more option-value pairs are specified, then the method modifies the given option(s) to have the given value(s); in this case the method returns an empty string. Option may be any of the configuration options.

tixCommand.tix_cget(*option*)

Returns the current value of the configuration option given by *option*. Option may be any of the configuration options.

tixCommand.tix_getbitmap(*name*)

Locates a bitmap file of the name `name.xpm` or `name` in one of the bitmap directories (see the *tix_addbitmapdir()* method). By using *tix_getbitmap()*, you can avoid hard coding the pathnames of the bitmap files in your application. When successful, it returns the complete pathname of the bitmap file, prefixed with the character `@`. The returned value can be used to configure the `bitmap` option of the Tk and Tix widgets.

tixCommand.tix_addbitmapdir(*directory*)

Tix maintains a list of directories under which the *tix_getimage()* and *tix_getbitmap()* methods will search for image files. The standard bitmap directory is `$TIX_LIBRARY/bitmaps`. The *tix_addbitmapdir()* method adds *directory* into this list. By using this method, the image files of an applications can also be located using the *tix_getimage()* or *tix_getbitmap()* method.

tixCommand.tix_filedialog([*dlgclass*])

Returns the file selection dialog that may be shared among different calls from this application. This method will create a file selection dialog widget when it is called the first time. This dialog will be returned by all subsequent calls to *tix_filedialog()*. An optional dlgclass parameter can be passed as a string to specified what type of file selection dialog widget is desired. Possible options are `tix`, `FileSelectDialog` or `tixExFileSelectDialog`.

tixCommand.tix_getimage(*self*, *name*)

Locates an image file of the name `name.xpm`, `name.xbm` or `name.ppm` in one of the bitmap directories (see the *tix_addbitmapdir()* method above). If more than one file with the same name (but different extensions) exist, then the image type is chosen according to the depth of the X display: xbm images are chosen on monochrome displays and color images are chosen on color displays. By using *tix_getimage()*, you can avoid hard coding the pathnames of the image files in your application. When successful, this method returns the name of the newly created image, which can be used to configure the `image` option of the Tk and Tix widgets.

tixCommand.tix_option_get(*name*)

Gets the options maintained by the Tix scheme mechanism.

tixCommand.tix_resetoptions(*newScheme*, *newFontSet*[, *newScmPrio*])

Resets the scheme and fontset of the Tix application to *newScheme* and *newFontSet*, respectively. This

affects only those widgets created after this call. Therefore, it is best to call the resetoptions method before the creation of any widgets in a Tix application.

The optional parameter *newScmPrio* can be given to reset the priority level of the Tk options set by the Tix schemes.

Because of the way Tk handles the X option database, after Tix has been has imported and inited, it is not possible to reset the color schemes and font sets using the `tix_config()` method. Instead, the *`tix_resetoptions()`* method must be used.

26.4 `tkinter.scrolledtext` — Scrolled Text Widget

Source code: Lib/tkinter/scrolledtext.py

The *`tkinter.scrolledtext`* module provides a class of the same name which implements a basic text widget which has a vertical scroll bar configured to do the "right thing." Using the `ScrolledText` class is a lot easier than setting up a text widget and scroll bar directly. The constructor is the same as that of the `tkinter.Text` class.

The text widget and scrollbar are packed together in a `Frame`, and the methods of the `Grid` and `Pack` geometry managers are acquired from the `Frame` object. This allows the `ScrolledText` widget to be used directly to achieve most normal geometry management behavior.

Should more specific control be necessary, the following attributes are available:

`ScrolledText.frame`
: The frame which surrounds the text and scroll bar widgets.

`ScrolledText.vbar`
: The scroll bar widget.

26.5 IDLE

Source code: Lib/idlelib/

IDLE is Python's Integrated Development and Learning Environment.

IDLE has the following features:

- coded in 100% pure Python, using the *`tkinter`* GUI toolkit
- cross-platform: works mostly the same on Windows, Unix, and Mac OS X
- Python shell window (interactive interpreter) with colorizing of code input, output, and error messages
- multi-window text editor with multiple undo, Python colorizing, smart indent, call tips, auto completion, and other features
- search within any window, replace within editor windows, and search through multiple files (grep)
- debugger with persistent breakpoints, stepping, and viewing of global and local namespaces
- configuration, browsers, and other dialogs

26.5.1 Menus

IDLE has two main window types, the Shell window and the Editor window. It is possible to have multiple editor windows simultaneously. Output windows, such as used for Edit / Find in Files, are a subtype of edit window. They currently have the same top menu as Editor windows but a different default title and context menu.

IDLE's menus dynamically change based on which window is currently selected. Each menu documented below indicates which window type it is associated with.

File menu (Shell and Editor)

New File Create a new file editing window.

Open... Open an existing file with an Open dialog.

Recent Files Open a list of recent files. Click one to open it.

Open Module... Open an existing module (searches sys.path).

Class Browser Show functions, classes, and methods in the current Editor file in a tree structure. In the shell, open a module first.

Path Browser Show sys.path directories, modules, functions, classes and methods in a tree structure.

Save Save the current window to the associated file, if there is one. Windows that have been changed since being opened or last saved have a * before and after the window title. If there is no associated file, do Save As instead.

Save As... Save the current window with a Save As dialog. The file saved becomes the new associated file for the window.

Save Copy As... Save the current window to different file without changing the associated file.

Print Window Print the current window to the default printer.

Close Close the current window (ask to save if unsaved).

Exit Close all windows and quit IDLE (ask to save unsaved windows).

Edit menu (Shell and Editor)

Undo Undo the last change to the current window. A maximum of 1000 changes may be undone.

Redo Redo the last undone change to the current window.

Cut Copy selection into the system-wide clipboard; then delete the selection.

Copy Copy selection into the system-wide clipboard.

Paste Insert contents of the system-wide clipboard into the current window.

The clipboard functions are also available in context menus.

Select All Select the entire contents of the current window.

Find... Open a search dialog with many options

Find Again Repeat the last search, if there is one.

Find Selection Search for the currently selected string, if there is one.

Find in Files... Open a file search dialog. Put results in a new output window.

Replace... Open a search-and-replace dialog.

Go to Line Move cursor to the line number requested and make that line visible.

Show Completions Open a scrollable list allowing selection of keywords and attributes. See Completions in the Tips sections below.

Expand Word Expand a prefix you have typed to match a full word in the same window; repeat to get a different expansion.

Show call tip After an unclosed parenthesis for a function, open a small window with function parameter hints.

Show surrounding parens Highlight the surrounding parenthesis.

Format menu (Editor window only)

Indent Region Shift selected lines right by the indent width (default 4 spaces).

Dedent Region Shift selected lines left by the indent width (default 4 spaces).

Comment Out Region Insert ## in front of selected lines.

Uncomment Region Remove leading # or ## from selected lines.

Tabify Region Turn *leading* stretches of spaces into tabs. (Note: We recommend using 4 space blocks to indent Python code.)

Untabify Region Turn *all* tabs into the correct number of spaces.

Toggle Tabs Open a dialog to switch between indenting with spaces and tabs.

New Indent Width Open a dialog to change indent width. The accepted default by the Python community is 4 spaces.

Format Paragraph Reformat the current blank-line-delimited paragraph in comment block or multiline string or selected line in a string. All lines in the paragraph will be formatted to less than N columns, where N defaults to 72.

Strip trailing whitespace Remove trailing space and other whitespace characters after the last non-whitespace character of a line by applying str.rstrip to each line, including lines within multiline strings.

Run menu (Editor window only)

Python Shell Open or wake up the Python Shell window.

Check Module Check the syntax of the module currently open in the Editor window. If the module has not been saved IDLE will either prompt the user to save or autosave, as selected in the General tab of the Idle Settings dialog. If there is a syntax error, the approximate location is indicated in the Editor window.

Run Module Do Check Module (above). If no error, restart the shell to clean the environment, then execute the module. Output is displayed in the Shell window. Note that output requires use of `print` or `write`. When execution is complete, the Shell retains focus and displays a prompt. At this point, one may interactively explore the result of execution. This is similar to executing a file with `python -i file` at a command line.

Shell menu (Shell window only)

View Last Restart Scroll the shell window to the last Shell restart.

Restart Shell Restart the shell to clean the environment.

Interrupt Execution Stop a running program.

Debug menu (Shell window only)

Go to File/Line Look on the current line. with the cursor, and the line above for a filename and line number. If found, open the file if not already open, and show the line. Use this to view source lines referenced in an exception traceback and lines found by Find in Files. Also available in the context menu of the Shell window and Output windows.

Debugger (toggle) When activated, code entered in the Shell or run from an Editor will run under the debugger. In the Editor, breakpoints can be set with the context menu. This feature is still incomplete and somewhat experimental.

Stack Viewer Show the stack traceback of the last exception in a tree widget, with access to locals and globals.

Auto-open Stack Viewer Toggle automatically opening the stack viewer on an unhandled exception.

Options menu (Shell and Editor)

Configure IDLE Open a configuration dialog and change preferences for the following: fonts, indentation, keybindings, text color themes, startup windows and size, additional help sources, and extensions (see below). On OS X, open the configuration dialog by selecting Preferences in the application menu. To use a new built-in color theme (IDLE Dark) with older IDLEs, save it as a new custom theme.

Non-default user settings are saved in a .idlerc directory in the user's home directory. Problems caused by bad user configuration files are solved by editing or deleting one or more of the files in .idlerc.

Code Context (toggle)(Editor Window only) Open a pane at the top of the edit window which shows the block context of the code which has scrolled above the top of the window. Clicking a line in this pane exposes that line at the top of the editor.

Window menu (Shell and Editor)

Zoom Height Toggles the window between normal size and maximum height. The initial size defaults to 40 lines by 80 chars unless changed on the General tab of the Configure IDLE dialog.

The rest of this menu lists the names of all open windows; select one to bring it to the foreground (deiconifying it if necessary).

Help menu (Shell and Editor)

About IDLE Display version, copyright, license, credits, and more.

IDLE Help Display a help file for IDLE detailing the menu options, basic editing and navigation, and other tips.

Python Docs Access local Python documentation, if installed, or start a web browser and open docs.python.org showing the latest Python documentation.

Turtle Demo Run the turtledemo module with example python code and turtle drawings.

Additional help sources may be added here with the Configure IDLE dialog under the General tab.

Context Menus

Open a context menu by right-clicking in a window (Control-click on OS X). Context menus have the standard clipboard functions also on the Edit menu.

Cut Copy selection into the system-wide clipboard; then delete the selection.

Copy Copy selection into the system-wide clipboard.

Paste Insert contents of the system-wide clipboard into the current window.

Editor windows also have breakpoint functions. Lines with a breakpoint set are specially marked. Breakpoints only have an effect when running under the debugger. Breakpoints for a file are saved in the user's .idlerc directory.

Set Breakpoint Set a breakpoint on the current line.

Clear Breakpoint Clear the breakpoint on that line.

Shell and Output windows have the following.

Go to file/line Same as in Debug menu.

26.5.2 Editing and navigation

In this section, 'C' refers to the `Control` key on Windows and Unix and the `Command` key on Mac OSX.

- `Backspace` deletes to the left; `Del` deletes to the right
- `C-Backspace` delete word left; `C-Del` delete word to the right
- Arrow keys and `Page Up`/`Page Down` to move around
- `C-LeftArrow` and `C-RightArrow` moves by words
- `Home`/`End` go to begin/end of line
- `C-Home`/`C-End` go to begin/end of file
- Some useful Emacs bindings are inherited from Tcl/Tk:
  - `C-a` beginning of line
  - `C-e` end of line
  - `C-k` kill line (but doesn't put it in clipboard)
  - `C-l` center window around the insertion point
  - `C-b` go backward one character without deleting (usually you can also use the cursor key for this)
  - `C-f` go forward one character without deleting (usually you can also use the cursor key for this)
  - `C-p` go up one line (usually you can also use the cursor key for this)
  - `C-d` delete next character

Standard keybindings (like `C-c` to copy and `C-v` to paste) may work. Keybindings are selected in the Configure IDLE dialog.

Automatic indentation

After a block-opening statement, the next line is indented by 4 spaces (in the Python Shell window by one tab). After certain keywords (break, return etc.) the next line is dedented. In leading indentation, `Backspace` deletes up to 4 spaces if they are there. `Tab` inserts spaces (in the Python Shell window one tab), number depends on Indent width. Currently, tabs are restricted to four spaces due to Tcl/Tk limitations.

See also the indent/dedent region commands in the edit menu.

Completions

Completions are supplied for functions, classes, and attributes of classes, both built-in and user-defined. Completions are also provided for filenames.

The AutoCompleteWindow (ACW) will open after a predefined delay (default is two seconds) after a '.' or (in a string) an os.sep is typed. If after one of those characters (plus zero or more other characters) a tab is typed the ACW will open immediately if a possible continuation is found.

If there is only one possible completion for the characters entered, a `Tab` will supply that completion without opening the ACW.

'Show Completions' will force open a completions window, by default the `C-space` will open a completions window. In an empty string, this will contain the files in the current directory. On a blank line, it will contain the built-in and user-defined functions and classes in the current namespaces, plus any modules imported. If some characters have been entered, the ACW will attempt to be more specific.

If a string of characters is typed, the ACW selection will jump to the entry most closely matching those characters. Entering a `tab` will cause the longest non-ambiguous match to be entered in the Editor window or Shell. Two `tab` in a row will supply the current ACW selection, as will return or a double click. Cursor keys, Page Up/Down, mouse selection, and the scroll wheel all operate on the ACW.

"Hidden" attributes can be accessed by typing the beginning of hidden name after a '.', e.g. '_'. This allows access to modules with `__all__` set, or to class-private attributes.

Completions and the 'Expand Word' facility can save a lot of typing!

Completions are currently limited to those in the namespaces. Names in an Editor window which are not via `__main__` and *sys.modules* will not be found. Run the module once with your imports to correct this situation. Note that IDLE itself places quite a few modules in sys.modules, so much can be found by default, e.g. the re module.

If you don't like the ACW popping up unbidden, simply make the delay longer or disable the extension.

Calltips

A calltip is shown when one types `(` after the name of an *accessible* function. A name expression may include dots and subscripts. A calltip remains until it is clicked, the cursor is moved out of the argument area, or `)` is typed. When the cursor is in the argument part of a definition, the menu or shortcut display a calltip.

A calltip consists of the function signature and the first line of the docstring. For builtins without an accessible signature, the calltip consists of all lines up the fifth line or the first blank line. These details may change.

The set of *accessible* functions depends on what modules have been imported into the user process, including those imported by Idle itself, and what definitions have been run, all since the last restart.

For example, restart the Shell and enter `itertools.count(`. A calltip appears because Idle imports itertools into the user process for its own use. (This could change.) Enter `turtle.write(` and nothing appears. Idle does not import turtle. The menu or shortcut do nothing either. Enter `import turtle` and then `turtle.write(` will work.

In an editor, import statements have no effect until one runs the file. One might want to run a file after writing the import statements at the top, or immediately run an existing file before editing.

Python Shell window

- `C-c` interrupts executing command
- `C-d` sends end-of-file; closes window if typed at a `>>>` prompt

- `Alt-/` (Expand word) is also useful to reduce typing

  Command history

  - `Alt-p` retrieves previous command matching what you have typed. On OS X use `C-p`.
  - `Alt-n` retrieves next. On OS X use `C-n`.
  - `Return` while on any previous command retrieves that command

Text colors

Idle defaults to black on white text, but colors text with special meanings. For the shell, these are shell output, shell error, user output, and user error. For Python code, at the shell prompt or in an editor, these are keywords, builtin class and function names, names following `class` and `def`, strings, and comments. For any text window, these are the cursor (when present), found text (when possible), and selected text.

Text coloring is done in the background, so uncolorized text is occasionally visible. To change the color scheme, use the Configure IDLE dialog Highlighting tab. The marking of debugger breakpoint lines in the editor and text in popups and dialogs is not user-configurable.

26.5.3 Startup and code execution

Upon startup with the `-s` option, IDLE will execute the file referenced by the environment variables `IDLESTARTUP` or `PYTHONSTARTUP`. IDLE first checks for `IDLESTARTUP`; if `IDLESTARTUP` is present the file referenced is run. If `IDLESTARTUP` is not present, IDLE checks for `PYTHONSTARTUP`. Files referenced by these environment variables are convenient places to store functions that are used frequently from the IDLE shell, or for executing import statements to import common modules.

In addition, `Tk` also loads a startup file if it is present. Note that the Tk file is loaded unconditionally. This additional file is `.Idle.py` and is looked for in the user's home directory. Statements in this file will be executed in the Tk namespace, so this file is not useful for importing functions to be used from IDLE's Python shell.

Command line usage

```
idle.py [-c command] [-d] [-e] [-h] [-i] [-r file] [-s] [-t title] [-] [arg] ...

-c command  run command in the shell window
-d          enable debugger and open shell window
-e          open editor window
-h          print help message with legal combinations and exit
-i          open shell window
-r file     run file in shell window
-s          run $IDLESTARTUP or $PYTHONSTARTUP first, in shell window
-t title    set title of shell window
-           run stdin in shell (- must be last option before args)
```

If there are arguments:

- If `-`, `-c`, or `r` is used, all arguments are placed in `sys.argv[1:...]` and `sys.argv[0]` is set to `''`, `'-c'`, or `'-r'`. No editor window is opened, even if that is the default set in the Options dialog.
- Otherwise, arguments are files opened for editing and `sys.argv` reflects the arguments passed to IDLE itself.

Startup failure

IDLE uses a socket to communicate between the IDLE GUI process and the user code execution process. A connection must be established whenever the Shell starts or restarts. (The latter is indicated by a divider line that says 'RESTART'). If the user process fails to connect to the GUI process, it displays a `Tk` error box with a 'cannot connect' message that directs the user here. It then exits.

A common cause of failure is a user-written file with the same name as a standard library module, such as *random.py* and *tkinter.py*. When such a file is located in the same directory as a file that is about to be run, IDLE cannot import the stdlib file. The current fix is to rename the user file.

Though less common than in the past, an antivirus or firewall program may stop the connection. If the program cannot be taught to allow the connection, then it must be turned off for IDLE to work. It is safe to allow this internal connection because no data is visible on external ports. A similar problem is a network mis-configuration that blocks connections.

Python installation issues occasionally stop IDLE: multiple versions can clash, or a single installation might need admin access. If one undo the clash, or cannot or does not want to run as admin, it might be easiest to completely remove Python and start over.

A zombie pythonw.exe process could be a problem. On Windows, use Task Manager to detect and stop one. Sometimes a restart initiated by a program crash or Keyboard Interrupt (control-C) may fail to connect. Dismissing the error box or Restart Shell on the Shell menu may fix a temporary problem.

When IDLE first starts, it attempts to read user configuration files in ~/.idlerc/ (~ is one's home directory). If there is a problem, an error message should be displayed. Leaving aside random disk glitches, this can be prevented by never editing the files by hand, using the configuration dialog, under Options, instead Options. Once it happens, the solution may be to delete one or more of the configuration files.

If IDLE quits with no message, and it was not started from a console, try starting from a console (`python -m idlelib`) and see if a message appears.

IDLE-console differences

With rare exceptions, the result of executing Python code with IDLE is intended to be the same as executing the same code in a console window. However, the different interface and operation occasionally affect visible results. For instance, `sys.modules` starts with more entries.

IDLE also replaces `sys.stdin`, `sys.stdout`, and `sys.stderr` with objects that get input from and send output to the Shell window. When Shell has the focus, it controls the keyboard and screen. This is normally transparent, but functions that directly access the keyboard and screen will not work. If `sys` is reset with `importlib.reload(sys)`, IDLE's changes are lost and things like `input`, `raw_input`, and `print` will not work correctly.

With IDLE's Shell, one enters, edits, and recalls complete statements. Some consoles only work with a single physical line at a time. IDLE uses `exec` to run each statement. As a result, `'__builtins__'` is always defined for each statement.

Developing tkinter applications

IDLE is intentionally different from standard Python in order to facilitate development of tkinter programs. Enter `import tkinter as tk; root = tk.Tk()` in standard Python and nothing appears. Enter the same in IDLE and a tk window appears. In standard Python, one must also enter `root.update()` to see the window. IDLE does the equivalent in the background, about 20 times a second, which is about every 50 milleseconds. Next enter `b = tk.Button(root, text='button'); b.pack()`. Again, nothing visibly changes in standard Python until one enters `root.update()`.

Most tkinter programs run `root.mainloop()`, which usually does not return until the tk app is destroyed. If the program is run with `python -i` or from an IDLE editor, a `>>>` shell prompt does not appear until `mainloop()` returns, at which time there is nothing left to interact with.

When running a tkinter program from an IDLE editor, one can comment out the mainloop call. One then gets a shell prompt immediately and can interact with the live application. One just has to remember to re-enable the mainloop call when running in standard Python.

Running without a subprocess

By default, IDLE executes user code in a separate subprocess via a socket, which uses the internal loopback interface. This connection is not externally visible and no data is sent to or received from the Internet. If firewall software complains anyway, you can ignore it.

If the attempt to make the socket connection fails, Idle will notify you. Such failures are sometimes transient, but if persistent, the problem may be either a firewall blocking the connection or misconfiguration of a particular system. Until the problem is fixed, one can run Idle with the -n command line switch.

If IDLE is started with the -n command line switch it will run in a single process and will not create the subprocess which runs the RPC Python execution server. This can be useful if Python cannot create the subprocess or the RPC socket interface on your platform. However, in this mode user code is not isolated from IDLE itself. Also, the environment is not restarted when Run/Run Module (F5) is selected. If your code has been modified, you must reload() the affected modules and re-import any specific items (e.g. from foo import baz) if the changes are to take effect. For these reasons, it is preferable to run IDLE with the default subprocess if at all possible.

Deprecated since version 3.4.

26.5.4 Help and preferences

Additional help sources

IDLE includes a help menu entry called “Python Docs” that will open the extensive sources of help, including tutorials, available at docs.python.org. Selected URLs can be added or removed from the help menu at any time using the Configure IDLE dialog. See the IDLE help option in the help menu of IDLE for more information.

Setting preferences

The font preferences, highlighting, keys, and general preferences can be changed via Configure IDLE on the Option menu. Keys can be user defined; IDLE ships with four built-in key sets. In addition, a user can create a custom key set in the Configure IDLE dialog under the keys tab.

Extensions

IDLE contains an extension facility. Preferences for extensions can be changed with the Extensions tab of the preferences dialog. See the beginning of config-extensions.def in the idlelib directory for further information. The only current default extension is zzdummy, an example also used for testing.

26.6 Other Graphical User Interface Packages

Major cross-platform (Windows, Mac OS X, Unix-like) GUI toolkits are available for Python:

See also:

PyGObject PyGObject provides introspection bindings for C libraries using GObject. One of these libraries is the GTK+ 3 widget set. GTK+ comes with many more widgets than Tkinter provides. An online Python GTK+ 3 Tutorial is available.

PyGTK PyGTK provides bindings for an older version of the library, GTK+ 2. It provides an object oriented interface that is slightly higher level than the C one. There are also bindings to GNOME. An online tutorial is available.

PyQt PyQt is a `sip`-wrapped binding to the Qt toolkit. Qt is an extensive C++ GUI application development framework that is available for Unix, Windows and Mac OS X. `sip` is a tool for generating bindings for C++ libraries as Python classes, and is specifically designed for Python.

PySide PySide is a newer binding to the Qt toolkit, provided by Nokia. Compared to PyQt, its licensing scheme is friendlier to non-open source applications.

wxPython wxPython is a cross-platform GUI toolkit for Python that is built around the popular wxWidgets (formerly wxWindows) C++ toolkit. It provides a native look and feel for applications on Windows, Mac OS X, and Unix systems by using each platform's native widgets where ever possible, (GTK+ on Unix-like systems). In addition to an extensive set of widgets, wxPython provides classes for online documentation and context sensitive help, printing, HTML viewing, low-level device context drawing, drag and drop, system clipboard access, an XML-based resource format and more, including an ever growing library of user-contributed modules.

PyGTK, PyQt, and wxPython, all have a modern look and feel and more widgets than Tkinter. In addition, there are many other GUI toolkits for Python, both cross-platform, and platform-specific. See the GUI Programming page in the Python Wiki for a much more complete list, and also for links to documents where the different GUI toolkits are compared.

CHAPTER

TWENTYSEVEN

DEVELOPMENT TOOLS

The modules described in this chapter help you write software. For example, the *pydoc* module takes a module and generates documentation based on the module's contents. The *doctest* and *unittest* modules contains frameworks for writing unit tests that automatically exercise code and verify that the expected output is produced. `2to3` can translate Python 2.x source code into valid Python 3.x code.

The list of modules described in this chapter is:

27.1 `typing` — Support for type hints

New in version 3.5.

Source code: Lib/typing.py

Note: The typing module has been included in the standard library on a *provisional basis*. New features might be added and API may change even between minor releases if deemed necessary by the core developers.

This module supports type hints as specified by **PEP 484** and **PEP 526**. The most fundamental support consists of the types *Any*, *Union*, *Tuple*, *Callable*, *TypeVar*, and *Generic*. For full specification please see **PEP 484**. For a simplified introduction to type hints see **PEP 483**.

The function below takes and returns a string and is annotated as follows:

```
def greeting(name: str) -> str:
    return 'Hello ' + name
```

In the function `greeting`, the argument `name` is expected to be of type *str* and the return type *str*. Subtypes are accepted as arguments.

27.1.1 Type aliases

A type alias is defined by assigning the type to the alias. In this example, `Vector` and `List[float]` will be treated as interchangeable synonyms:

```
from typing import List
Vector = List[float]

def scale(scalar: float, vector: Vector) -> Vector:
    return [scalar * num for num in vector]
```

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```
# typechecks; a list of floats qualifies as a Vector.
new_vector = scale(2.0, [1.0, -4.2, 5.4])
```

Type aliases are useful for simplifying complex type signatures. For example:

```
from typing import Dict, Tuple, List

ConnectionOptions = Dict[str, str]
Address = Tuple[str, int]
Server = Tuple[Address, ConnectionOptions]

def broadcast_message(message: str, servers: List[Server]) -> None:
    ...

# The static type checker will treat the previous type signature as
# being exactly equivalent to this one.
def broadcast_message(
        message: str,
        servers: List[Tuple[Tuple[str, int], Dict[str, str]]]) -> None:
    ...
```

Note that `None` as a type hint is a special case and is replaced by `type(None)`.

27.1.2 NewType

Use the *NewType()* helper function to create distinct types:

```
from typing import NewType

UserId = NewType('UserId', int)
some_id = UserId(524313)
```

The static type checker will treat the new type as if it were a subclass of the original type. This is useful in helping catch logical errors:

```
def get_user_name(user_id: UserId) -> str:
    ...

# typechecks
user_a = get_user_name(UserId(42351))

# does not typecheck; an int is not a UserId
user_b = get_user_name(-1)
```

You may still perform all `int` operations on a variable of type `UserId`, but the result will always be of type `int`. This lets you pass in a `UserId` wherever an `int` might be expected, but will prevent you from accidentally creating a `UserId` in an invalid way:

```
# 'output' is of type 'int', not 'UserId'
output = UserId(23413) + UserId(54341)
```

Note that these checks are enforced only by the static type checker. At runtime the statement `Derived = NewType('Derived', Base)` will make `Derived` a function that immediately returns whatever parameter you pass it. That means the expression `Derived(some_value)` does not create a new class or introduce any overhead beyond that of a regular function call.

More precisely, the expression `some_value is Derived(some_value)` is always true at runtime.

This also means that it is not possible to create a subtype of `Derived` since it is an identity function at runtime, not an actual type:

```
from typing import NewType

UserId = NewType('UserId', int)

# Fails at runtime and does not typecheck
class AdminUserId(UserId): pass
```

However, it is possible to create a *NewType()* based on a 'derived' `NewType`:

```
from typing import NewType

UserId = NewType('UserId', int)

ProUserId = NewType('ProUserId', UserId)
```

and typechecking for `ProUserId` will work as expected.

See **PEP 484** for more details.

Note: Recall that the use of a type alias declares two types to be *equivalent* to one another. Doing `Alias = Original` will make the static type checker treat `Alias` as being *exactly equivalent* to `Original` in all cases. This is useful when you want to simplify complex type signatures.

In contrast, `NewType` declares one type to be a *subtype* of another. Doing `Derived = NewType('Derived', Original)` will make the static type checker treat `Derived` as a *subclass* of `Original`, which means a value of type `Original` cannot be used in places where a value of type `Derived` is expected. This is useful when you want to prevent logic errors with minimal runtime cost.

New in version 3.5.2.

27.1.3 Callable

Frameworks expecting callback functions of specific signatures might be type hinted using `Callable[[Arg1Type, Arg2Type], ReturnType]`.

For example:

```
from typing import Callable

def feeder(get_next_item: Callable[[], str]) -> None:
    # Body

def async_query(on_success: Callable[[int], None],
                on_error: Callable[[int, Exception], None]) -> None:
    # Body
```

It is possible to declare the return type of a callable without specifying the call signature by substituting a literal ellipsis for the list of arguments in the type hint: `Callable[..., ReturnType]`.

27.1.4 Generics

Since type information about objects kept in containers cannot be statically inferred in a generic way, abstract base classes have been extended to support subscription to denote expected types for container elements.

```
from typing import Mapping, Sequence

def notify_by_email(employees: Sequence[Employee],
                    overrides: Mapping[str, str]) -> None: ...
```

Generics can be parametrized by using a new factory available in typing called *TypeVar*.

```
from typing import Sequence, TypeVar

T = TypeVar('T')      # Declare type variable

def first(l: Sequence[T]) -> T:   # Generic function
    return l[0]
```

27.1.5 User-defined generic types

A user-defined class can be defined as a generic class.

```
from typing import TypeVar, Generic
from logging import Logger

T = TypeVar('T')

class LoggedVar(Generic[T]):
    def __init__(self, value: T, name: str, logger: Logger) -> None:
        self.name = name
        self.logger = logger
        self.value = value

    def set(self, new: T) -> None:
        self.log('Set ' + repr(self.value))
        self.value = new

    def get(self) -> T:
        self.log('Get ' + repr(self.value))
        return self.value

    def log(self, message: str) -> None:
        self.logger.info('%s: %s', self.name, message)
```

`Generic[T]` as a base class defines that the class `LoggedVar` takes a single type parameter `T` . This also makes `T` valid as a type within the class body.

The *Generic* base class uses a metaclass that defines `__getitem__()` so that `LoggedVar[t]` is valid as a type:

```
from typing import Iterable

def zero_all_vars(vars: Iterable[LoggedVar[int]]) -> None:
    for var in vars:
        var.set(0)
```

A generic type can have any number of type variables, and type variables may be constrained:

```
from typing import TypeVar, Generic
...

T = TypeVar('T')
S = TypeVar('S', int, str)

class StrangePair(Generic[T, S]):
    ...
```

Each type variable argument to *Generic* must be distinct. This is thus invalid:

```
from typing import TypeVar, Generic
...

T = TypeVar('T')

class Pair(Generic[T, T]):   # INVALID
    ...
```

You can use multiple inheritance with *Generic*:

```
from typing import TypeVar, Generic, Sized

T = TypeVar('T')

class LinkedList(Sized, Generic[T]):
    ...
```

When inheriting from generic classes, some type variables could be fixed:

```
from typing import TypeVar, Mapping

T = TypeVar('T')

class MyDict(Mapping[str, T]):
    ...
```

In this case `MyDict` has a single parameter, `T`.

Using a generic class without specifying type parameters assumes *Any* for each position. In the following example, `MyIterable` is not generic but implicitly inherits from `Iterable[Any]`:

```
from typing import Iterable

class MyIterable(Iterable): # Same as Iterable[Any]
```

User defined generic type aliases are also supported. Examples:

```
from typing import TypeVar, Iterable, Tuple, Union
S = TypeVar('S')
Response = Union[Iterable[S], int]

# Return type here is same as Union[Iterable[str], int]
def response(query: str) -> Response[str]:
    ...

T = TypeVar('T', int, float, complex)
Vec = Iterable[Tuple[T, T]]
```

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```
def inproduct(v: Vec[T]) -> T: # Same as Iterable[Tuple[T, T]]
    return sum(x*y for x, y in v)
```

The metaclass used by *Generic* is a subclass of *abc.ABCMeta*. A generic class can be an ABC by including abstract methods or properties, and generic classes can also have ABCs as base classes without a metaclass conflict. Generic metaclasses are not supported. The outcome of parameterizing generics is cached, and most types in the typing module are hashable and comparable for equality.

27.1.6 The Any type

A special kind of type is *Any*. A static type checker will treat every type as being compatible with *Any* and *Any* as being compatible with every type.

This means that it is possible to perform any operation or method call on a value of type on *Any* and assign it to any variable:

```
from typing import Any

a = None    # type: Any
a = []      # OK
a = 2       # OK

s = ''      # type: str
s = a       # OK

def foo(item: Any) -> int:
    # Typechecks; 'item' could be any type,
    # and that type might have a 'bar' method
    item.bar()
    ...
```

Notice that no typechecking is performed when assigning a value of type *Any* to a more precise type. For example, the static type checker did not report an error when assigning `a` to `s` even though `s` was declared to be of type *str* and receives an *int* value at runtime!

Furthermore, all functions without a return type or parameter types will implicitly default to using *Any*:

```
def legacy_parser(text):
    ...
    return data

# A static type checker will treat the above
# as having the same signature as:
def legacy_parser(text: Any) -> Any:
    ...
    return data
```

This behavior allows *Any* to be used as an *escape hatch* when you need to mix dynamically and statically typed code.

Contrast the behavior of *Any* with the behavior of *object*. Similar to *Any*, every type is a subtype of *object*. However, unlike *Any*, the reverse is not true: *object* is *not* a subtype of every other type.

That means when the type of a value is *object*, a type checker will reject almost all operations on it, and assigning it to a variable (or using it as a return value) of a more specialized type is a type error. For example:

```
def hash_a(item: object) -> int:
    # Fails; an object does not have a 'magic' method.
    item.magic()
    ...

def hash_b(item: Any) -> int:
    # Typechecks
    item.magic()
    ...

# Typechecks, since ints and strs are subclasses of object
hash_a(42)
hash_a("foo")

# Typechecks, since Any is compatible with all types
hash_b(42)
hash_b("foo")
```

Use *object* to indicate that a value could be any type in a typesafe manner. Use *Any* to indicate that a value is dynamically typed.

27.1.7 Classes, functions, and decorators

The module defines the following classes, functions and decorators:

class typing.TypeVar

Type variable.

Usage:

```
T = TypeVar('T')  # Can be anything
A = TypeVar('A', str, bytes)  # Must be str or bytes
```

Type variables exist primarily for the benefit of static type checkers. They serve as the parameters for generic types as well as for generic function definitions. See class Generic for more information on generic types. Generic functions work as follows:

```
def repeat(x: T, n: int) -> Sequence[T]:
    """Return a list containing n references to x."""
    return [x]*n

def longest(x: A, y: A) -> A:
    """Return the longest of two strings."""
    return x if len(x) >= len(y) else y
```

The latter example's signature is essentially the overloading of `(str, str) -> str` and `(bytes, bytes) -> bytes`. Also note that if the arguments are instances of some subclass of *str*, the return type is still plain *str*.

At runtime, `isinstance(x, T)` will raise *TypeError*. In general, *isinstance()* and *issubclass()* should not be used with types.

Type variables may be marked covariant or contravariant by passing `covariant=True` or `contravariant=True`. See **PEP 484** for more details. By default type variables are invariant. Alternatively, a type variable may specify an upper bound using `bound=<type>`. This means that an actual type substituted (explicitly or implicitly) for the type variable must be a subclass of the boundary type, see **PEP 484**.

class typing.Generic
Abstract base class for generic types.

A generic type is typically declared by inheriting from an instantiation of this class with one or more type variables. For example, a generic mapping type might be defined as:

```
class Mapping(Generic[KT, VT]):
    def __getitem__(self, key: KT) -> VT:
        ...
        # Etc.
```

This class can then be used as follows:

```
X = TypeVar('X')
Y = TypeVar('Y')

def lookup_name(mapping: Mapping[X, Y], key: X, default: Y) -> Y:
    try:
        return mapping[key]
    except KeyError:
        return default
```

class typing.Type(*Generic[CT_co]*)
A variable annotated with C may accept a value of type C. In contrast, a variable annotated with Type[C] may accept values that are classes themselves – specifically, it will accept the *class object* of C. For example:

```
a = 3         # Has type 'int'
b = int       # Has type 'Type[int]'
c = type(a)   # Also has type 'Type[int]'
```

Note that Type[C] is covariant:

```
class User: ...
class BasicUser(User): ...
class ProUser(User): ...
class TeamUser(User): ...

# Accepts User, BasicUser, ProUser, TeamUser, ...
def make_new_user(user_class: Type[User]) -> User:
    # ...
    return user_class()
```

The fact that Type[C] is covariant implies that all subclasses of C should implement the same constructor signature and class method signatures as C. The type checker should flag violations of this, but should also allow constructor calls in subclasses that match the constructor calls in the indicated base class. How the type checker is required to handle this particular case may change in future revisions of **PEP 484**.

The only legal parameters for *Type* are classes, unions of classes, and *Any*. For example:

```
def new_non_team_user(user_class: Type[Union[BaseUser, ProUser]]): ...
```

Type[Any] is equivalent to Type which in turn is equivalent to type, which is the root of Python's metaclass hierarchy.

New in version 3.5.2.

class typing.Iterable(*Generic[T_co]*)
A generic version of *collections.abc.Iterable*.

class typing.**Iterator**(*Iterable[T_co]*)
A generic version of *collections.abc.Iterator*.

class typing.**Reversible**(*Iterable[T_co]*)
A generic version of *collections.abc.Reversible*.

class typing.**SupportsInt**
An ABC with one abstract method `__int__`.

class typing.**SupportsFloat**
An ABC with one abstract method `__float__`.

class typing.**SupportsComplex**
An ABC with one abstract method `__complex__`.

class typing.**SupportsBytes**
An ABC with one abstract method `__bytes__`.

class typing.**SupportsAbs**
An ABC with one abstract method `__abs__` that is covariant in its return type.

class typing.**SupportsRound**
An ABC with one abstract method `__round__` that is covariant in its return type.

class typing.**Container**(*Generic[T_co]*)
A generic version of *collections.abc.Container*.

class typing.**Hashable**
An alias to *collections.abc.Hashable*

class typing.**Sized**
An alias to *collections.abc.Sized*

class typing.**Collection**(*Sized, Iterable[T_co], Container[T_co]*)
A generic version of *collections.abc.Collection*

New in version 3.6.

class typing.**AbstractSet**(*Sized, Collection[T_co]*)
A generic version of *collections.abc.Set*.

class typing.**MutableSet**(*AbstractSet[T]*)
A generic version of *collections.abc.MutableSet*.

class typing.**Mapping**(*Sized, Collection[KT], Generic[VT_co]*)
A generic version of *collections.abc.Mapping*.

class typing.**MutableMapping**(*Mapping[KT, VT]*)
A generic version of *collections.abc.MutableMapping*.

class typing.**Sequence**(*Reversible[T_co], Collection[T_co]*)
A generic version of *collections.abc.Sequence*.

class typing.**MutableSequence**(*Sequence[T]*)
A generic version of *collections.abc.MutableSequence*.

class typing.**ByteString**(*Sequence[int]*)
A generic version of *collections.abc.ByteString*.

This type represents the types *bytes*, *bytearray*, and *memoryview*.

As a shorthand for this type, *bytes* can be used to annotate arguments of any of the types mentioned above.

class typing.**Deque**(*deque, MutableSequence[T]*)
A generic version of *collections.deque*.

New in version 3.6.1.

class typing.**List**(*list, MutableSequence[T]*)
Generic version of *list*. Useful for annotating return types. To annotate arguments it is preferred to use abstract collection types such as *Mapping*, *Sequence*, or *AbstractSet*.

This type may be used as follows:

```
T = TypeVar('T', int, float)

def vec2(x: T, y: T) -> List[T]:
    return [x, y]

def keep_positives(vector: Sequence[T]) -> List[T]:
    return [item for item in vector if item > 0]
```

class typing.**Set**(*set, MutableSet[T]*)
A generic version of *builtins.set*.

class typing.**FrozenSet**(*frozenset, AbstractSet[T_co]*)
A generic version of *builtins.frozenset*.

class typing.**MappingView**(*Sized, Iterable[T_co]*)
A generic version of *collections.abc.MappingView*.

class typing.**KeysView**(*MappingView[KT_co], AbstractSet[KT_co]*)
A generic version of *collections.abc.KeysView*.

class typing.**ItemsView**(*MappingView, Generic[KT_co, VT_co]*)
A generic version of *collections.abc.ItemsView*.

class typing.**ValuesView**(*MappingView[VT_co]*)
A generic version of *collections.abc.ValuesView*.

class typing.**Awaitable**(*Generic[T_co]*)
A generic version of *collections.abc.Awaitable*.

class typing.**Coroutine**(*Awaitable[V_co], Generic[T_co T_contra, V_co]*)
A generic version of *collections.abc.Coroutine*. The variance and order of type variables correspond to those of *Generator*, for example:

```
from typing import List, Coroutine
c = None # type: Coroutine[List[str], str, int]
...
x = c.send('hi') # type: List[str]
async def bar() -> None:
    x = await c # type: int
```

class typing.**AsyncIterable**(*Generic[T_co]*)
A generic version of *collections.abc.AsyncIterable*.

class typing.**AsyncIterator**(*AsyncIterable[T_co]*)
A generic version of *collections.abc.AsyncIterator*.

class typing.**ContextManager**(*Generic[T_co]*)
A generic version of *contextlib.AbstractContextManager*.

New in version 3.6.

class typing.**AsyncContextManager**(*Generic[T_co]*)
A generic version of *contextlib.AbstractAsyncContextManager*.

New in version 3.6.

class typing.Dict(*dict, MutableMapping[KT, VT]*)
A generic version of *dict*. The usage of this type is as follows:

```
def get_position_in_index(word_list: Dict[str, int], word: str) -> int:
    return word_list[word]
```

class typing.DefaultDict(*collections.defaultdict, MutableMapping[KT, VT]*)
A generic version of *collections.defaultdict*.

New in version 3.5.2.

class typing.Counter(*collections.Counter, Dict[T, int]*)
A generic version of *collections.Counter*.

New in version 3.6.1.

class typing.ChainMap(*collections.ChainMap, MutableMapping[KT, VT]*)
A generic version of *collections.ChainMap*.

New in version 3.6.1.

class typing.Generator(*Iterator[T_co], Generic[T_co, T_contra, V_co]*)
A generator can be annotated by the generic type `Generator[YieldType, SendType, ReturnType]`. For example:

```
def echo_round() -> Generator[int, float, str]:
    sent = yield 0
    while sent >= 0:
        sent = yield round(sent)
    return 'Done'
```

Note that unlike many other generics in the typing module, the `SendType` of *Generator* behaves contravariantly, not covariantly or invariantly.

If your generator will only yield values, set the `SendType` and `ReturnType` to `None`:

```
def infinite_stream(start: int) -> Generator[int, None, None]:
    while True:
        yield start
        start += 1
```

Alternatively, annotate your generator as having a return type of either `Iterable[YieldType]` or `Iterator[YieldType]`:

```
def infinite_stream(start: int) -> Iterator[int]:
    while True:
        yield start
        start += 1
```

class typing.AsyncGenerator(*AsyncIterator[T_co], Generic[T_co, T_contra]*)
An async generator can be annotated by the generic type `AsyncGenerator[YieldType, SendType]`. For example:

```
async def echo_round() -> AsyncGenerator[int, float]:
    sent = yield 0
    while sent >= 0.0:
        rounded = await round(sent)
        sent = yield rounded
```

Unlike normal generators, async generators cannot return a value, so there is no `ReturnType` type parameter. As with *Generator*, the `SendType` behaves contravariantly.

If your generator will only yield values, set the `SendType` to `None`:

```
async def infinite_stream(start: int) -> AsyncGenerator[int, None]:
    while True:
        yield start
        start = await increment(start)
```

Alternatively, annotate your generator as having a return type of either `AsyncIterable[YieldType]` or `AsyncIterator[YieldType]`:

```
async def infinite_stream(start: int) -> AsyncIterator[int]:
    while True:
        yield start
        start = await increment(start)
```

New in version 3.5.4.

class typing.Text

`Text` is an alias for `str`. It is provided to supply a forward compatible path for Python 2 code: in Python 2, `Text` is an alias for `unicode`.

Use `Text` to indicate that a value must contain a unicode string in a manner that is compatible with both Python 2 and Python 3:

```
def add_unicode_checkmark(text: Text) -> Text:
    return text + u' \u2713'
```

New in version 3.5.2.

class typing.io

Wrapper namespace for I/O stream types.

This defines the generic type `IO[AnyStr]` and subclasses `TextIO` and `BinaryIO`, deriving from `IO[str]` and `IO[bytes]`, respectively. These represent the types of I/O streams such as returned by *open()*.

These types are also accessible directly as `typing.IO`, `typing.TextIO`, and `typing.BinaryIO`.

class typing.re

Wrapper namespace for regular expression matching types.

This defines the type aliases `Pattern` and `Match` which correspond to the return types from *re.compile()* and *re.match()*. These types (and the corresponding functions) are generic in `AnyStr` and can be made specific by writing `Pattern[str]`, `Pattern[bytes]`, `Match[str]`, or `Match[bytes]`.

These types are also accessible directly as `typing.Pattern` and `typing.Match`.

class typing.NamedTuple

Typed version of namedtuple.

Usage:

```
class Employee(NamedTuple):
    name: str
    id: int
```

This is equivalent to:

```
Employee = collections.namedtuple('Employee', ['name', 'id'])
```

To give a field a default value, you can assign to it in the class body:

```
class Employee(NamedTuple):
    name: str
    id: int = 3

employee = Employee('Guido')
assert employee.id == 3
```

Fields with a default value must come after any fields without a default.

The resulting class has two extra attributes: `_field_types`, giving a dict mapping field names to types, and `_field_defaults`, a dict mapping field names to default values. (The field names are in the `_fields` attribute, which is part of the namedtuple API.)

`NamedTuple` subclasses can also have docstrings and methods:

```
class Employee(NamedTuple):
    """Represents an employee."""
    name: str
    id: int = 3

    def __repr__(self) -> str:
        return f'<Employee {self.name}, id={self.id}>'
```

Backward-compatible usage:

```
Employee = NamedTuple('Employee', [('name', str), ('id', int)])
```

Changed in version 3.6: Added support for **PEP 526** variable annotation syntax.

Changed in version 3.6.1: Added support for default values, methods, and docstrings.

`typing.NewType(`*typ*`)`
A helper function to indicate a distinct types to a typechecker, see *NewType*. At runtime it returns a function that returns its argument. Usage:

```
UserId = NewType('UserId', int)
first_user = UserId(1)
```

New in version 3.5.2.

`typing.cast(`*typ*, *val*`)`
Cast a value to a type.

This returns the value unchanged. To the type checker this signals that the return value has the designated type, but at runtime we intentionally don't check anything (we want this to be as fast as possible).

`typing.get_type_hints(`*obj*[, *globals*[, *locals*]]`)`
Return a dictionary containing type hints for a function, method, module or class object.

This is often the same as `obj.__annotations__`. In addition, forward references encoded as string literals are handled by evaluating them in `globals` and `locals` namespaces. If necessary, `Optional[t]` is added for function and method annotations if a default value equal to `None` is set. For a class `C`, return a dictionary constructed by merging all the `__annotations__` along `C.__mro__` in reverse order.

`@typing.overload`
The `@overload` decorator allows describing functions and methods that support multiple different combinations of argument types. A series of `@overload`-decorated definitions must be followed by exactly one non-`@overload`-decorated definition (for the same function/method). The `@overload`-decorated definitions are for the benefit of the type checker only, since they will be overwritten by the non-`@overload`-decorated definition, while the latter is used at runtime but should be ignored by a type

checker. At runtime, calling a `@overload`-decorated function directly will raise `NotImplementedError`. An example of overload that gives a more precise type than can be expressed using a union or a type variable:

```
@overload
def process(response: None) -> None:
    ...
@overload
def process(response: int) -> Tuple[int, str]:
    ...
@overload
def process(response: bytes) -> str:
    ...
def process(response):
    <actual implementation>
```

See **PEP 484** for details and comparison with other typing semantics.

`@typing.no_type_check`
Decorator to indicate that annotations are not type hints.

This works as class or function *decorator*. With a class, it applies recursively to all methods defined in that class (but not to methods defined in its superclasses or subclasses).

This mutates the function(s) in place.

`@typing.no_type_check_decorator`
Decorator to give another decorator the *no_type_check()* effect.

This wraps the decorator with something that wraps the decorated function in *no_type_check()*.

`typing.Any`
Special type indicating an unconstrained type.

- Every type is compatible with *Any*.
- *Any* is compatible with every type.

`typing.NoReturn`
Special type indicating that a function never returns. For example:

```
from typing import NoReturn

def stop() -> NoReturn:
    raise RuntimeError('no way')
```

New in version 3.6.5.

`typing.Union`
Union type; `Union[X, Y]` means either X or Y.

To define a union, use e.g. `Union[int, str]`. Details:

- The arguments must be types and there must be at least one.
- Unions of unions are flattened, e.g.:

```
Union[Union[int, str], float] == Union[int, str, float]
```

- Unions of a single argument vanish, e.g.:

```
Union[int] == int  # The constructor actually returns int
```

- Redundant arguments are skipped, e.g.:

```
Union[int, str, int] == Union[int, str]
```

- When comparing unions, the argument order is ignored, e.g.:

```
Union[int, str] == Union[str, int]
```

- You cannot subclass or instantiate a union.
- You cannot write `Union[X][Y]`.
- You can use `Optional[X]` as a shorthand for `Union[X, None]`.

Changed in version 3.7: Don't remove explicit subclasses from unions at runtime.

`typing.Optional`
Optional type.

`Optional[X]` is equivalent to `Union[X, None]`.

Note that this is not the same concept as an optional argument, which is one that has a default. An optional argument with a default needn't use the `Optional` qualifier on its type annotation (although it is inferred if the default is `None`). A mandatory argument may still have an `Optional` type if an explicit value of `None` is allowed.

`typing.Tuple`
Tuple type; `Tuple[X, Y]` is the type of a tuple of two items with the first item of type X and the second of type Y.

Example: `Tuple[T1, T2]` is a tuple of two elements corresponding to type variables T1 and T2. `Tuple[int, float, str]` is a tuple of an int, a float and a string.

To specify a variable-length tuple of homogeneous type, use literal ellipsis, e.g. `Tuple[int, ...]`. A plain *Tuple* is equivalent to `Tuple[Any, ...]`, and in turn to *tuple*.

`typing.Callable`
Callable type; `Callable[[int], str]` is a function of (int) -> str.

The subscription syntax must always be used with exactly two values: the argument list and the return type. The argument list must be a list of types or an ellipsis; the return type must be a single type.

There is no syntax to indicate optional or keyword arguments; such function types are rarely used as callback types. `Callable[..., ReturnType]` (literal ellipsis) can be used to type hint a callable taking any number of arguments and returning `ReturnType`. A plain *Callable* is equivalent to `Callable[..., Any]`, and in turn to *collections.abc.Callable*.

`typing.ClassVar`
Special type construct to mark class variables.

As introduced in **PEP 526**, a variable annotation wrapped in ClassVar indicates that a given attribute is intended to be used as a class variable and should not be set on instances of that class. Usage:

```
class Starship:
    stats: ClassVar[Dict[str, int]] = {} # class variable
    damage: int = 10                     # instance variable
```

ClassVar accepts only types and cannot be further subscribed.

ClassVar is not a class itself, and should not be used with *isinstance()* or *issubclass()*. *ClassVar* does not change Python runtime behavior, but it can be used by third-party type checkers. For example, a type checker might flag the following code as an error:

```
enterprise_d = Starship(3000)
enterprise_d.stats = {} # Error, setting class variable on instance
Starship.stats = {}     # This is OK
```

New in version 3.5.3.

typing.**AnyStr**

`AnyStr` is a type variable defined as `AnyStr = TypeVar('AnyStr', str, bytes)`.

It is meant to be used for functions that may accept any kind of string without allowing different kinds of strings to mix. For example:

```
def concat(a: AnyStr, b: AnyStr) -> AnyStr:
    return a + b

concat(u"foo", u"bar")  # Ok, output has type 'unicode'
concat(b"foo", b"bar")  # Ok, output has type 'bytes'
concat(u"foo", b"bar")  # Error, cannot mix unicode and bytes
```

typing.**TYPE_CHECKING**

A special constant that is assumed to be `True` by 3rd party static type checkers. It is `False` at runtime. Usage:

```
if TYPE_CHECKING:
    import expensive_mod

def fun(arg: 'expensive_mod.SomeType') -> None:
    local_var: expensive_mod.AnotherType = other_fun()
```

Note that the first type annotation must be enclosed in quotes, making it a "forward reference", to hide the `expensive_mod` reference from the interpreter runtime. Type annotations for local variables are not evaluated, so the second annotation does not need to be enclosed in quotes.

New in version 3.5.2.

27.2 pydoc — Documentation generator and online help system

Source code: Lib/pydoc.py

The *pydoc* module automatically generates documentation from Python modules. The documentation can be presented as pages of text on the console, served to a Web browser, or saved to HTML files.

For modules, classes, functions and methods, the displayed documentation is derived from the docstring (i.e. the `__doc__` attribute) of the object, and recursively of its documentable members. If there is no docstring, *pydoc* tries to obtain a description from the block of comment lines just above the definition of the class, function or method in the source file, or at the top of the module (see *inspect.getcomments()*).

The built-in function *help()* invokes the online help system in the interactive interpreter, which uses *pydoc* to generate its documentation as text on the console. The same text documentation can also be viewed from outside the Python interpreter by running **pydoc** as a script at the operating system's command prompt. For example, running

```
pydoc sys
```

at a shell prompt will display documentation on the *sys* module, in a style similar to the manual pages shown by the Unix **man** command. The argument to **pydoc** can be the name of a function, module, or package, or a dotted reference to a class, method, or function within a module or module in a package. If the argument to **pydoc** looks like a path (that is, it contains the path separator for your operating system, such as a slash in Unix), and refers to an existing Python source file, then documentation is produced for that file.

Note: In order to find objects and their documentation, *pydoc* imports the module(s) to be documented. Therefore, any code on module level will be executed on that occasion. Use an `if __name__ == '__main__':` guard to only execute code when a file is invoked as a script and not just imported.

When printing output to the console, **pydoc** attempts to paginate the output for easier reading. If the `PAGER` environment variable is set, **pydoc** will use its value as a pagination program.

Specifying a `-w` flag before the argument will cause HTML documentation to be written out to a file in the current directory, instead of displaying text on the console.

Specifying a `-k` flag before the argument will search the synopsis lines of all available modules for the keyword given as the argument, again in a manner similar to the Unix **man** command. The synopsis line of a module is the first line of its documentation string.

You can also use **pydoc** to start an HTTP server on the local machine that will serve documentation to visiting Web browsers. **pydoc -p 1234** will start a HTTP server on port 1234, allowing you to browse the documentation at `http://localhost:1234/` in your preferred Web browser. Specifying `0` as the port number will select an arbitrary unused port.

pydoc -n <hostname> will start the server listening at the given hostname. By default the hostname is 'localhost' but if you want the server to be reached from other machines, you may want to change the host name that the server responds to. During development this is especially useful if you want to run pydoc from within a container.

pydoc -b will start the server and additionally open a web browser to a module index page. Each served page has a navigation bar at the top where you can *Get* help on an individual item, *Search* all modules with a keyword in their synopsis line, and go to the *Module index*, *Topics* and *Keywords* pages.

When **pydoc** generates documentation, it uses the current environment and path to locate modules. Thus, invoking **pydoc spam** documents precisely the version of the module you would get if you started the Python interpreter and typed `import spam`.

Module docs for core modules are assumed to reside in `https://docs.python.org/X.Y/library/` where `X` and `Y` are the major and minor version numbers of the Python interpreter. This can be overridden by setting the `PYTHONDOCS` environment variable to a different URL or to a local directory containing the Library Reference Manual pages.

Changed in version 3.2: Added the `-b` option.

Changed in version 3.3: The `-g` command line option was removed.

Changed in version 3.4: *pydoc* now uses *inspect.signature()* rather than *inspect.getfullargspec()* to extract signature information from callables.

Changed in version 3.7: Added the `-n` option.

27.3 doctest — Test interactive Python examples

Source code: Lib/doctest.py

The *doctest* module searches for pieces of text that look like interactive Python sessions, and then executes those sessions to verify that they work exactly as shown. There are several common ways to use doctest:

- To check that a module's docstrings are up-to-date by verifying that all interactive examples still work as documented.
- To perform regression testing by verifying that interactive examples from a test file or a test object work as expected.
- To write tutorial documentation for a package, liberally illustrated with input-output examples. Depending on whether the examples or the expository text are emphasized, this has the flavor of "literate testing" or "executable documentation".

Here's a complete but small example module:

```
"""
This is the "example" module.

The example module supplies one function, factorial().  For example,

>>> factorial(5)
120
"""

def factorial(n):
    """Return the factorial of n, an exact integer >= 0.

    >>> [factorial(n) for n in range(6)]
    [1, 1, 2, 6, 24, 120]
    >>> factorial(30)
    265252859812191058636308480000000
    >>> factorial(-1)
    Traceback (most recent call last):
        ...
    ValueError: n must be >= 0

    Factorials of floats are OK, but the float must be an exact integer:
    >>> factorial(30.1)
    Traceback (most recent call last):
        ...
    ValueError: n must be exact integer
    >>> factorial(30.0)
    265252859812191058636308480000000

    It must also not be ridiculously large:
    >>> factorial(1e100)
    Traceback (most recent call last):
        ...
    OverflowError: n too large
    """

    import math
    if not n >= 0:
        raise ValueError("n must be >= 0")
    if math.floor(n) != n:
        raise ValueError("n must be exact integer")
    if n+1 == n:  # catch a value like 1e300
        raise OverflowError("n too large")
    result = 1
```

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```
    factor = 2
    while factor <= n:
        result *= factor
        factor += 1
    return result


if __name__ == "__main__":
    import doctest
    doctest.testmod()
```

If you run `example.py` directly from the command line, *doctest* works its magic:

```
$ python example.py
$
```

There's no output! That's normal, and it means all the examples worked. Pass `-v` to the script, and *doctest* prints a detailed log of what it's trying, and prints a summary at the end:

```
$ python example.py -v
Trying:
    factorial(5)
Expecting:
    120
ok
Trying:
    [factorial(n) for n in range(6)]
Expecting:
    [1, 1, 2, 6, 24, 120]
ok
```

And so on, eventually ending with:

```
Trying:
    factorial(1e100)
Expecting:
    Traceback (most recent call last):
        ...
    OverflowError: n too large
ok
2 items passed all tests:
   1 tests in __main__
   8 tests in __main__.factorial
9 tests in 2 items.
9 passed and 0 failed.
Test passed.
$
```

That's all you need to know to start making productive use of *doctest*! Jump in. The following sections provide full details. Note that there are many examples of doctests in the standard Python test suite and libraries. Especially useful examples can be found in the standard test file `Lib/test/test_doctest.py`.

27.3.1 Simple Usage: Checking Examples in Docstrings

The simplest way to start using doctest (but not necessarily the way you'll continue to do it) is to end each module `M` with:

```
if __name__ == "__main__":
    import doctest
    doctest.testmod()
```

doctest then examines docstrings in module M.

Running the module as a script causes the examples in the docstrings to get executed and verified:

```
python M.py
```

This won't display anything unless an example fails, in which case the failing example(s) and the cause(s) of the failure(s) are printed to stdout, and the final line of output is `***Test Failed*** N failures.`, where *N* is the number of examples that failed.

Run it with the `-v` switch instead:

```
python M.py -v
```

and a detailed report of all examples tried is printed to standard output, along with assorted summaries at the end.

You can force verbose mode by passing `verbose=True` to *testmod()*, or prohibit it by passing `verbose=False`. In either of those cases, `sys.argv` is not examined by *testmod()* (so passing `-v` or not has no effect).

There is also a command line shortcut for running *testmod()*. You can instruct the Python interpreter to run the doctest module directly from the standard library and pass the module name(s) on the command line:

```
python -m doctest -v example.py
```

This will import `example.py` as a standalone module and run *testmod()* on it. Note that this may not work correctly if the file is part of a package and imports other submodules from that package.

For more information on *testmod()*, see section *Basic API*.

27.3.2 Simple Usage: Checking Examples in a Text File

Another simple application of doctest is testing interactive examples in a text file. This can be done with the *testfile()* function:

```
import doctest
doctest.testfile("example.txt")
```

That short script executes and verifies any interactive Python examples contained in the file `example.txt`. The file content is treated as if it were a single giant docstring; the file doesn't need to contain a Python program! For example, perhaps `example.txt` contains this:

```
The ``example`` module
======================

Using ``factorial``
-------------------

This is an example text file in reStructuredText format.  First import
``factorial`` from the ``example`` module:

    >>> from example import factorial
```

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```
Now use it:

    >>> factorial(6)
    120
```

Running `doctest.testfile("example.txt")` then finds the error in this documentation:

```
File "./example.txt", line 14, in example.txt
Failed example:
    factorial(6)
Expected:
    120
Got:
    720
```

As with *testmod()*, *testfile()* won't display anything unless an example fails. If an example does fail, then the failing example(s) and the cause(s) of the failure(s) are printed to stdout, using the same format as *testmod()*.

By default, *testfile()* looks for files in the calling module's directory. See section *Basic API* for a description of the optional arguments that can be used to tell it to look for files in other locations.

Like *testmod()*, *testfile()*'s verbosity can be set with the `-v` command-line switch or with the optional keyword argument *verbose*.

There is also a command line shortcut for running *testfile()*. You can instruct the Python interpreter to run the doctest module directly from the standard library and pass the file name(s) on the command line:

```
python -m doctest -v example.txt
```

Because the file name does not end with `.py`, *doctest* infers that it must be run with *testfile()*, not *testmod()*.

For more information on *testfile()*, see section *Basic API*.

27.3.3 How It Works

This section examines in detail how doctest works: which docstrings it looks at, how it finds interactive examples, what execution context it uses, how it handles exceptions, and how option flags can be used to control its behavior. This is the information that you need to know to write doctest examples; for information about actually running doctest on these examples, see the following sections.

Which Docstrings Are Examined?

The module docstring, and all function, class and method docstrings are searched. Objects imported into the module are not searched.

In addition, if `M.__test__` exists and "is true", it must be a dict, and each entry maps a (string) name to a function object, class object, or string. Function and class object docstrings found from `M.__test__` are searched, and strings are treated as if they were docstrings. In output, a key `K` in `M.__test__` appears with name

```
<name of M>.__test__.K
```

Any classes found are recursively searched similarly, to test docstrings in their contained methods and nested classes.

CPython implementation detail: Prior to version 3.4, extension modules written in C were not fully searched by doctest.

How are Docstring Examples Recognized?

In most cases a copy-and-paste of an interactive console session works fine, but doctest isn't trying to do an exact emulation of any specific Python shell.

```
>>> # comments are ignored
>>> x = 12
>>> x
12
>>> if x == 13:
...     print("yes")
... else:
...     print("no")
...     print("NO")
...     print("NO!!!")
...
no
NO
NO!!!
>>>
```

Any expected output must immediately follow the final `'>>> '` or `'... '` line containing the code, and the expected output (if any) extends to the next `'>>> '` or all-whitespace line.

The fine print:

- Expected output cannot contain an all-whitespace line, since such a line is taken to signal the end of expected output. If expected output does contain a blank line, put `<BLANKLINE>` in your doctest example each place a blank line is expected.
- All hard tab characters are expanded to spaces, using 8-column tab stops. Tabs in output generated by the tested code are not modified. Because any hard tabs in the sample output *are* expanded, this means that if the code output includes hard tabs, the only way the doctest can pass is if the *NORMALIZE_WHITESPACE* option or *directive* is in effect. Alternatively, the test can be rewritten to capture the output and compare it to an expected value as part of the test. This handling of tabs in the source was arrived at through trial and error, and has proven to be the least error prone way of handling them. It is possible to use a different algorithm for handling tabs by writing a custom *DocTestParser* class.
- Output to stdout is captured, but not output to stderr (exception tracebacks are captured via a different means).
- If you continue a line via backslashing in an interactive session, or for any other reason use a backslash, you should use a raw docstring, which will preserve your backslashes exactly as you type them:

  ```
  >>> def f(x):
  ...     r'''Backslashes in a raw docstring: m\n'''
  >>> print(f.__doc__)
  Backslashes in a raw docstring: m\n
  ```

  Otherwise, the backslash will be interpreted as part of the string. For example, the `\n` above would be interpreted as a newline character. Alternatively, you can double each backslash in the doctest version (and not use a raw string):

```
>>> def f(x):
...     '''Backslashes in a raw docstring: m\\n'''
>>> print(f.__doc__)
Backslashes in a raw docstring: m\n
```

- The starting column doesn't matter:

```
>>> assert "Easy!"
      >>> import math
          >>> math.floor(1.9)
          1
```

  and as many leading whitespace characters are stripped from the expected output as appeared in the initial `'>>> '` line that started the example.

What's the Execution Context?

By default, each time *doctest* finds a docstring to test, it uses a *shallow copy* of `M`'s globals, so that running tests doesn't change the module's real globals, and so that one test in `M` can't leave behind crumbs that accidentally allow another test to work. This means examples can freely use any names defined at top-level in `M`, and names defined earlier in the docstring being run. Examples cannot see names defined in other docstrings.

You can force use of your own dict as the execution context by passing `globs=your_dict` to *testmod()* or *testfile()* instead.

What About Exceptions?

No problem, provided that the traceback is the only output produced by the example: just paste in the traceback.[1] Since tracebacks contain details that are likely to change rapidly (for example, exact file paths and line numbers), this is one case where doctest works hard to be flexible in what it accepts.

Simple example:

```
>>> [1, 2, 3].remove(42)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: list.remove(x): x not in list
```

That doctest succeeds if *ValueError* is raised, with the `list.remove(x): x not in list` detail as shown.

The expected output for an exception must start with a traceback header, which may be either of the following two lines, indented the same as the first line of the example:

```
Traceback (most recent call last):
Traceback (innermost last):
```

The traceback header is followed by an optional traceback stack, whose contents are ignored by doctest. The traceback stack is typically omitted, or copied verbatim from an interactive session.

The traceback stack is followed by the most interesting part: the line(s) containing the exception type and detail. This is usually the last line of a traceback, but can extend across multiple lines if the exception has a multi-line detail:

[1] Examples containing both expected output and an exception are not supported. Trying to guess where one ends and the other begins is too error-prone, and that also makes for a confusing test.

```
>>> raise ValueError('multi\n    line\ndetail')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: multi
    line
detail
```

The last three lines (starting with *ValueError*) are compared against the exception's type and detail, and the rest are ignored.

Best practice is to omit the traceback stack, unless it adds significant documentation value to the example. So the last example is probably better as:

```
>>> raise ValueError('multi\n    line\ndetail')
Traceback (most recent call last):
    ...
ValueError: multi
    line
detail
```

Note that tracebacks are treated very specially. In particular, in the rewritten example, the use of `...` is independent of doctest's *ELLIPSIS* option. The ellipsis in that example could be left out, or could just as well be three (or three hundred) commas or digits, or an indented transcript of a Monty Python skit.

Some details you should read once, but won't need to remember:

- Doctest can't guess whether your expected output came from an exception traceback or from ordinary printing. So, e.g., an example that expects `ValueError: 42 is prime` will pass whether *ValueError* is actually raised or if the example merely prints that traceback text. In practice, ordinary output rarely begins with a traceback header line, so this doesn't create real problems.
- Each line of the traceback stack (if present) must be indented further than the first line of the example, *or* start with a non-alphanumeric character. The first line following the traceback header indented the same and starting with an alphanumeric is taken to be the start of the exception detail. Of course this does the right thing for genuine tracebacks.
- When the *IGNORE_EXCEPTION_DETAIL* doctest option is specified, everything following the leftmost colon and any module information in the exception name is ignored.
- The interactive shell omits the traceback header line for some *SyntaxError*s. But doctest uses the traceback header line to distinguish exceptions from non-exceptions. So in the rare case where you need to test a *SyntaxError* that omits the traceback header, you will need to manually add the traceback header line to your test example.
- For some *SyntaxError*s, Python displays the character position of the syntax error, using a ^ marker:

  ```
  >>> 1 1
    File "<stdin>", line 1
      1 1
        ^
  SyntaxError: invalid syntax
  ```

  Since the lines showing the position of the error come before the exception type and detail, they are not checked by doctest. For example, the following test would pass, even though it puts the ^ marker in the wrong location:

  ```
  >>> 1 1
    File "<stdin>", line 1
      1 1
  ```

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```
    ^
SyntaxError: invalid syntax
```

Option Flags

A number of option flags control various aspects of doctest's behavior. Symbolic names for the flags are supplied as module constants, which can be bitwise ORed together and passed to various functions. The names can also be used in *doctest directives*, and may be passed to the doctest command line interface via the `-o` option.

New in version 3.4: The `-o` command line option.

The first group of options define test semantics, controlling aspects of how doctest decides whether actual output matches an example's expected output:

`doctest.DONT_ACCEPT_TRUE_FOR_1`
: By default, if an expected output block contains just `1`, an actual output block containing just `1` or just `True` is considered to be a match, and similarly for `0` versus `False`. When *DONT_ACCEPT_TRUE_FOR_1* is specified, neither substitution is allowed. The default behavior caters to that Python changed the return type of many functions from integer to boolean; doctests expecting "little integer" output still work in these cases. This option will probably go away, but not for several years.

`doctest.DONT_ACCEPT_BLANKLINE`
: By default, if an expected output block contains a line containing only the string `<BLANKLINE>`, then that line will match a blank line in the actual output. Because a genuinely blank line delimits the expected output, this is the only way to communicate that a blank line is expected. When *DONT_ACCEPT_BLANKLINE* is specified, this substitution is not allowed.

`doctest.NORMALIZE_WHITESPACE`
: When specified, all sequences of whitespace (blanks and newlines) are treated as equal. Any sequence of whitespace within the expected output will match any sequence of whitespace within the actual output. By default, whitespace must match exactly. *NORMALIZE_WHITESPACE* is especially useful when a line of expected output is very long, and you want to wrap it across multiple lines in your source.

`doctest.ELLIPSIS`
: When specified, an ellipsis marker (`...`) in the expected output can match any substring in the actual output. This includes substrings that span line boundaries, and empty substrings, so it's best to keep usage of this simple. Complicated uses can lead to the same kinds of "oops, it matched too much!" surprises that `.*` is prone to in regular expressions.

`doctest.IGNORE_EXCEPTION_DETAIL`
: When specified, an example that expects an exception passes if an exception of the expected type is raised, even if the exception detail does not match. For example, an example expecting `ValueError: 42` will pass if the actual exception raised is `ValueError: 3*14`, but will fail, e.g., if *TypeError* is raised.

  It will also ignore the module name used in Python 3 doctest reports. Hence both of these variations will work with the flag specified, regardless of whether the test is run under Python 2.7 or Python 3.2 (or later versions):

```
>>> raise CustomError('message')
Traceback (most recent call last):
CustomError: message

>>> raise CustomError('message')
Traceback (most recent call last):
my_module.CustomError: message
```

Note that *ELLIPSIS* can also be used to ignore the details of the exception message, but such a test may still fail based on whether or not the module details are printed as part of the exception name. Using *IGNORE_EXCEPTION_DETAIL* and the details from Python 2.3 is also the only clear way to write a doctest that doesn't care about the exception detail yet continues to pass under Python 2.3 or earlier (those releases do not support *doctest directives* and ignore them as irrelevant comments). For example:

```
>>> (1, 2)[3] = 'moo'
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: object doesn't support item assignment
```

passes under Python 2.3 and later Python versions with the flag specified, even though the detail changed in Python 2.4 to say "does not" instead of "doesn't".

Changed in version 3.2: *IGNORE_EXCEPTION_DETAIL* now also ignores any information relating to the module containing the exception under test.

`doctest.SKIP`
When specified, do not run the example at all. This can be useful in contexts where doctest examples serve as both documentation and test cases, and an example should be included for documentation purposes, but should not be checked. E.g., the example's output might be random; or the example might depend on resources which would be unavailable to the test driver.

The SKIP flag can also be used for temporarily "commenting out" examples.

`doctest.COMPARISON_FLAGS`
A bitmask or'ing together all the comparison flags above.

The second group of options controls how test failures are reported:

`doctest.REPORT_UDIFF`
When specified, failures that involve multi-line expected and actual outputs are displayed using a unified diff.

`doctest.REPORT_CDIFF`
When specified, failures that involve multi-line expected and actual outputs will be displayed using a context diff.

`doctest.REPORT_NDIFF`
When specified, differences are computed by `difflib.Differ`, using the same algorithm as the popular `ndiff.py` utility. This is the only method that marks differences within lines as well as across lines. For example, if a line of expected output contains digit `1` where actual output contains letter `l`, a line is inserted with a caret marking the mismatching column positions.

`doctest.REPORT_ONLY_FIRST_FAILURE`
When specified, display the first failing example in each doctest, but suppress output for all remaining examples. This will prevent doctest from reporting correct examples that break because of earlier failures; but it might also hide incorrect examples that fail independently of the first failure. When *REPORT_ONLY_FIRST_FAILURE* is specified, the remaining examples are still run, and still count towards the total number of failures reported; only the output is suppressed.

`doctest.FAIL_FAST`
When specified, exit after the first failing example and don't attempt to run the remaining examples. Thus, the number of failures reported will be at most 1. This flag may be useful during debugging, since examples after the first failure won't even produce debugging output.

The doctest command line accepts the option `-f` as a shorthand for `-o FAIL_FAST`.

New in version 3.4.

`doctest.REPORTING_FLAGS`
A bitmask or'ing together all the reporting flags above.

There is also a way to register new option flag names, though this isn't useful unless you intend to extend *doctest* internals via subclassing:

doctest.**register_optionflag**(*name*)

Create a new option flag with a given name, and return the new flag's integer value. *register_optionflag()* can be used when subclassing *OutputChecker* or *DocTestRunner* to create new options that are supported by your subclasses. *register_optionflag()* should always be called using the following idiom:

```
MY_FLAG = register_optionflag('MY_FLAG')
```

Directives

Doctest directives may be used to modify the *option flags* for an individual example. Doctest directives are special Python comments following an example's source code:

```
directive             ::=   "#" "doctest:" directive_options
directive_options     ::=   directive_option ("," directive_option)\*
directive_option      ::=   on_or_off directive_option_name
on_or_off             ::=   "+" \| "-"
directive_option_name ::=   "DONT_ACCEPT_BLANKLINE" \| "NORMALIZE_WHITESPACE" \| ...
```

Whitespace is not allowed between the `+` or `-` and the directive option name. The directive option name can be any of the option flag names explained above.

An example's doctest directives modify doctest's behavior for that single example. Use `+` to enable the named behavior, or `-` to disable it.

For example, this test passes:

```
>>> print(list(range(20)))
[0,   1,  2,  3,  4,  5,  6,  7,  8,  9,
10,  11, 12, 13, 14, 15, 16, 17, 18, 19]
```

Without the directive it would fail, both because the actual output doesn't have two blanks before the single-digit list elements, and because the actual output is on a single line. This test also passes, and also requires a directive to do so:

```
>>> print(list(range(20)))
[0, 1, ..., 18, 19]
```

Multiple directives can be used on a single physical line, separated by commas:

```
>>> print(list(range(20)))
[0,    1, ...,   18,    19]
```

If multiple directive comments are used for a single example, then they are combined:

```
>>> print(list(range(20)))
...
[0,    1, ...,   18,    19]
```

As the previous example shows, you can add `...` lines to your example containing only directives. This can be useful when an example is too long for a directive to comfortably fit on the same line:

```
>>> print(list(range(5)) + list(range(10, 20)) + list(range(30, 40)))
...
[0, ..., 4, 10, ..., 19, 30, ..., 39]
```

Note that since all options are disabled by default, and directives apply only to the example they appear in, enabling options (via `+` in a directive) is usually the only meaningful choice. However, option flags can also be passed to functions that run doctests, establishing different defaults. In such cases, disabling an option via `-` in a directive can be useful.

Warnings

doctest is serious about requiring exact matches in expected output. If even a single character doesn't match, the test fails. This will probably surprise you a few times, as you learn exactly what Python does and doesn't guarantee about output. For example, when printing a dict, Python doesn't guarantee that the key-value pairs will be printed in any particular order, so a test like

```
>>> foo()
{"Hermione": "hippogryph", "Harry": "broomstick"}
```

is vulnerable! One workaround is to do

```
>>> foo() == {"Hermione": "hippogryph", "Harry": "broomstick"}
True
```

instead. Another is to do

```
>>> d = sorted(foo().items())
>>> d
[('Harry', 'broomstick'), ('Hermione', 'hippogryph')]
```

There are others, but you get the idea.

Another bad idea is to print things that embed an object address, like

```
>>> id(1.0) # certain to fail some of the time
7948648
>>> class C: pass
>>> C()   # the default repr() for instances embeds an address
<__main__.C instance at 0x00AC18F0>
```

The *ELLIPSIS* directive gives a nice approach for the last example:

```
>>> C()
<__main__.C instance at 0x...>
```

Floating-point numbers are also subject to small output variations across platforms, because Python defers to the platform C library for float formatting, and C libraries vary widely in quality here.

```
>>> 1./7  # risky
0.14285714285714285
>>> print(1./7) # safer
0.142857142857
>>> print(round(1./7, 6)) # much safer
0.142857
```

Numbers of the form `I/2.**J` are safe across all platforms, and I often contrive doctest examples to produce numbers of that form:

```
>>> 3./4  # utterly safe
0.75
```

Simple fractions are also easier for people to understand, and that makes for better documentation.

27.3.4 Basic API

The functions *testmod()* and *testfile()* provide a simple interface to doctest that should be sufficient for most basic uses. For a less formal introduction to these two functions, see sections *Simple Usage: Checking Examples in Docstrings* and *Simple Usage: Checking Examples in a Text File*.

doctest.testfile(*filename*, *module_relative=True*, *name=None*, *package=None*, *globs=None*, *verbose=None*, *report=True*, *optionflags=0*, *extraglobs=None*, *raise_on_error=False*, *parser=DocTestParser()*, *encoding=None*)

All arguments except *filename* are optional, and should be specified in keyword form.

Test examples in the file named *filename*. Return `(failure_count, test_count)`.

Optional argument *module_relative* specifies how the filename should be interpreted:

- If *module_relative* is `True` (the default), then *filename* specifies an OS-independent module-relative path. By default, this path is relative to the calling module's directory; but if the *package* argument is specified, then it is relative to that package. To ensure OS-independence, *filename* should use `/` characters to separate path segments, and may not be an absolute path (i.e., it may not begin with `/`).
- If *module_relative* is `False`, then *filename* specifies an OS-specific path. The path may be absolute or relative; relative paths are resolved with respect to the current working directory.

Optional argument *name* gives the name of the test; by default, or if `None`, `os.path.basename(filename)` is used.

Optional argument *package* is a Python package or the name of a Python package whose directory should be used as the base directory for a module-relative filename. If no package is specified, then the calling module's directory is used as the base directory for module-relative filenames. It is an error to specify *package* if *module_relative* is `False`.

Optional argument *globs* gives a dict to be used as the globals when executing examples. A new shallow copy of this dict is created for the doctest, so its examples start with a clean slate. By default, or if `None`, a new empty dict is used.

Optional argument *extraglobs* gives a dict merged into the globals used to execute examples. This works like *dict.update()*: if *globs* and *extraglobs* have a common key, the associated value in *extraglobs* appears in the combined dict. By default, or if `None`, no extra globals are used. This is an advanced feature that allows parameterization of doctests. For example, a doctest can be written for a base class, using a generic name for the class, then reused to test any number of subclasses by passing an *extraglobs* dict mapping the generic name to the subclass to be tested.

Optional argument *verbose* prints lots of stuff if true, and prints only failures if false; by default, or if `None`, it's true if and only if `'-v'` is in `sys.argv`.

Optional argument *report* prints a summary at the end when true, else prints nothing at the end. In verbose mode, the summary is detailed, else the summary is very brief (in fact, empty if all tests passed).

Optional argument *optionflags* (default value 0) takes the bitwise OR of option flags. See section *Option Flags*.

Optional argument *raise_on_error* defaults to false. If true, an exception is raised upon the first failure or unexpected exception in an example. This allows failures to be post-mortem debugged. Default behavior is to continue running examples.

Optional argument *parser* specifies a *DocTestParser* (or subclass) that should be used to extract tests from the files. It defaults to a normal parser (i.e., `DocTestParser()`).

Optional argument *encoding* specifies an encoding that should be used to convert the file to unicode.

doctest.testmod(*m=None*, *name=None*, *globs=None*, *verbose=None*, *report=True*, *optionflags=0*, *extraglobs=None*, *raise_on_error=False*, *exclude_empty=False*)

All arguments are optional, and all except for *m* should be specified in keyword form.

Test examples in docstrings in functions and classes reachable from module *m* (or module *__main__* if *m* is not supplied or is `None`), starting with `m.__doc__`.

Also test examples reachable from dict `m.__test__`, if it exists and is not `None`. `m.__test__` maps names (strings) to functions, classes and strings; function and class docstrings are searched for examples; strings are searched directly, as if they were docstrings.

Only docstrings attached to objects belonging to module *m* are searched.

Return `(failure_count, test_count)`.

Optional argument *name* gives the name of the module; by default, or if `None`, `m.__name__` is used.

Optional argument *exclude_empty* defaults to false. If true, objects for which no doctests are found are excluded from consideration. The default is a backward compatibility hack, so that code still using `doctest.master.summarize()` in conjunction with *testmod()* continues to get output for objects with no tests. The *exclude_empty* argument to the newer *DocTestFinder* constructor defaults to true.

Optional arguments *extraglobs*, *verbose*, *report*, *optionflags*, *raise_on_error*, and *globs* are the same as for function *testfile()* above, except that *globs* defaults to `m.__dict__`.

doctest.run_docstring_examples(*f*, *globs*, *verbose=False*, *name="NoName"*, *compileflags=None*, *optionflags=0*)

Test examples associated with object *f*; for example, *f* may be a string, a module, a function, or a class object.

A shallow copy of dictionary argument *globs* is used for the execution context.

Optional argument *name* is used in failure messages, and defaults to `"NoName"`.

If optional argument *verbose* is true, output is generated even if there are no failures. By default, output is generated only in case of an example failure.

Optional argument *compileflags* gives the set of flags that should be used by the Python compiler when running the examples. By default, or if `None`, flags are deduced corresponding to the set of future features found in *globs*.

Optional argument *optionflags* works as for function *testfile()* above.

27.3.5 Unittest API

As your collection of doctest'ed modules grows, you'll want a way to run all their doctests systematically. *doctest* provides two functions that can be used to create *unittest* test suites from modules and text files containing doctests. To integrate with *unittest* test discovery, include a `load_tests()` function in your test module:

```
import unittest
import doctest
import my_module_with_doctests

def load_tests(loader, tests, ignore):
    tests.addTests(doctest.DocTestSuite(my_module_with_doctests))
    return tests
```

There are two main functions for creating *unittest.TestSuite* instances from text files and modules with doctests:

doctest.DocFileSuite(**paths*, *module_relative=True*, *package=None*, *setUp=None*, *tearDown=None*, *globs=None*, *optionflags=0*, *parser=DocTestParser()*, *encoding=None*)

Convert doctest tests from one or more text files to a *unittest.TestSuite*.

The returned *unittest.TestSuite* is to be run by the unittest framework and runs the interactive examples in each file. If an example in any file fails, then the synthesized unit test fails, and a `failureException` exception is raised showing the name of the file containing the test and a (sometimes approximate) line number.

Pass one or more paths (as strings) to text files to be examined.

Options may be provided as keyword arguments:

Optional argument *module_relative* specifies how the filenames in *paths* should be interpreted:

- If *module_relative* is `True` (the default), then each filename in *paths* specifies an OS-independent module-relative path. By default, this path is relative to the calling module's directory; but if the *package* argument is specified, then it is relative to that package. To ensure OS-independence, each filename should use `/` characters to separate path segments, and may not be an absolute path (i.e., it may not begin with `/`).
- If *module_relative* is `False`, then each filename in *paths* specifies an OS-specific path. The path may be absolute or relative; relative paths are resolved with respect to the current working directory.

Optional argument *package* is a Python package or the name of a Python package whose directory should be used as the base directory for module-relative filenames in *paths*. If no package is specified, then the calling module's directory is used as the base directory for module-relative filenames. It is an error to specify *package* if *module_relative* is `False`.

Optional argument *setUp* specifies a set-up function for the test suite. This is called before running the tests in each file. The *setUp* function will be passed a *DocTest* object. The setUp function can access the test globals as the *globs* attribute of the test passed.

Optional argument *tearDown* specifies a tear-down function for the test suite. This is called after running the tests in each file. The *tearDown* function will be passed a *DocTest* object. The setUp function can access the test globals as the *globs* attribute of the test passed.

Optional argument *globs* is a dictionary containing the initial global variables for the tests. A new copy of this dictionary is created for each test. By default, *globs* is a new empty dictionary.

Optional argument *optionflags* specifies the default doctest options for the tests, created by or-ing together individual option flags. See section *Option Flags*. See function *set_unittest_reportflags()* below for a better way to set reporting options.

Optional argument *parser* specifies a *DocTestParser* (or subclass) that should be used to extract tests from the files. It defaults to a normal parser (i.e., `DocTestParser()`).

Optional argument *encoding* specifies an encoding that should be used to convert the file to unicode.

The global `__file__` is added to the globals provided to doctests loaded from a text file using *DocFileSuite()*.

doctest.DocTestSuite(*module=None*, *globs=None*, *extraglobs=None*, *test_finder=None*, *setUp=None*, *tearDown=None*, *checker=None*)

Convert doctest tests for a module to a *unittest.TestSuite*.

The returned *unittest.TestSuite* is to be run by the unittest framework and runs each doctest in the module. If any of the doctests fail, then the synthesized unit test fails, and a `failureException`

exception is raised showing the name of the file containing the test and a (sometimes approximate) line number.

Optional argument *module* provides the module to be tested. It can be a module object or a (possibly dotted) module name. If not specified, the module calling this function is used.

Optional argument *globs* is a dictionary containing the initial global variables for the tests. A new copy of this dictionary is created for each test. By default, *globs* is a new empty dictionary.

Optional argument *extraglobs* specifies an extra set of global variables, which is merged into *globs*. By default, no extra globals are used.

Optional argument *test_finder* is the *DocTestFinder* object (or a drop-in replacement) that is used to extract doctests from the module.

Optional arguments *setUp*, *tearDown*, and *optionflags* are the same as for function *DocFileSuite()* above.

This function uses the same search technique as *testmod()*.

Changed in version 3.5: *DocTestSuite()* returns an empty *unittest.TestSuite* if *module* contains no docstrings instead of raising *ValueError*.

Under the covers, *DocTestSuite()* creates a *unittest.TestSuite* out of `doctest.DocTestCase` instances, and `DocTestCase` is a subclass of *unittest.TestCase*. `DocTestCase` isn't documented here (it's an internal detail), but studying its code can answer questions about the exact details of *unittest* integration.

Similarly, *DocFileSuite()* creates a *unittest.TestSuite* out of `doctest.DocFileCase` instances, and `DocFileCase` is a subclass of `DocTestCase`.

So both ways of creating a *unittest.TestSuite* run instances of `DocTestCase`. This is important for a subtle reason: when you run *doctest* functions yourself, you can control the *doctest* options in use directly, by passing option flags to *doctest* functions. However, if you're writing a *unittest* framework, *unittest* ultimately controls when and how tests get run. The framework author typically wants to control *doctest* reporting options (perhaps, e.g., specified by command line options), but there's no way to pass options through *unittest* to *doctest* test runners.

For this reason, *doctest* also supports a notion of *doctest* reporting flags specific to *unittest* support, via this function:

`doctest.set_unittest_reportflags`(*flags*)

Set the *doctest* reporting flags to use.

Argument *flags* takes the bitwise OR of option flags. See section *Option Flags*. Only "reporting flags" can be used.

This is a module-global setting, and affects all future doctests run by module *unittest*: the `runTest()` method of `DocTestCase` looks at the option flags specified for the test case when the `DocTestCase` instance was constructed. If no reporting flags were specified (which is the typical and expected case), *doctest*'s *unittest* reporting flags are bitwise ORed into the option flags, and the option flags so augmented are passed to the *DocTestRunner* instance created to run the doctest. If any reporting flags were specified when the `DocTestCase` instance was constructed, *doctest*'s *unittest* reporting flags are ignored.

The value of the *unittest* reporting flags in effect before the function was called is returned by the function.

27.3.6 Advanced API

The basic API is a simple wrapper that's intended to make doctest easy to use. It is fairly flexible, and should meet most users' needs; however, if you require more fine-grained control over testing, or wish to extend doctest's capabilities, then you should use the advanced API.

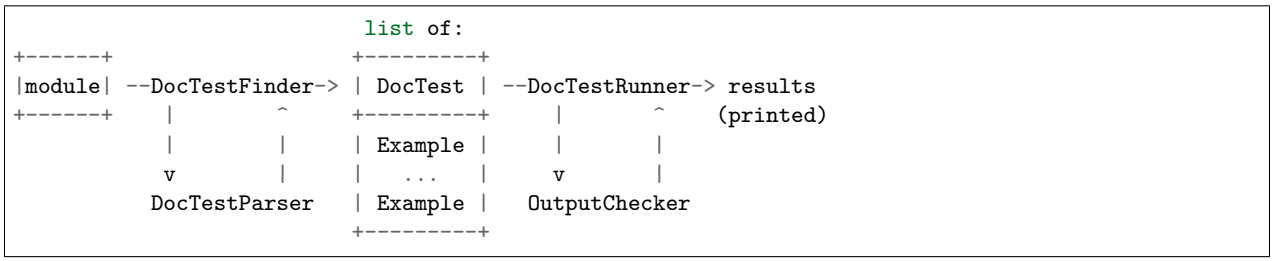
The advanced API revolves around two container classes, which are used to store the interactive examples extracted from doctest cases:

- *Example*: A single Python *statement*, paired with its expected output.
- *DocTest*: A collection of *Example*s, typically extracted from a single docstring or text file.

Additional processing classes are defined to find, parse, and run, and check doctest examples:

- *DocTestFinder*: Finds all docstrings in a given module, and uses a *DocTestParser* to create a *DocTest* from every docstring that contains interactive examples.
- *DocTestParser*: Creates a *DocTest* object from a string (such as an object's docstring).
- *DocTestRunner*: Executes the examples in a *DocTest*, and uses an *OutputChecker* to verify their output.
- *OutputChecker*: Compares the actual output from a doctest example with the expected output, and decides whether they match.

The relationships among these processing classes are summarized in the following diagram:



DocTest Objects

class doctest.DocTest(*examples*, *globs*, *name*, *filename*, *lineno*, *docstring*)

A collection of doctest examples that should be run in a single namespace. The constructor arguments are used to initialize the attributes of the same names.

DocTest defines the following attributes. They are initialized by the constructor, and should not be modified directly.

examples

A list of *Example* objects encoding the individual interactive Python examples that should be run by this test.

globs

The namespace (aka globals) that the examples should be run in. This is a dictionary mapping names to values. Any changes to the namespace made by the examples (such as binding new variables) will be reflected in *globs* after the test is run.

name

A string name identifying the *DocTest*. Typically, this is the name of the object or file that the test was extracted from.

filename

The name of the file that this *DocTest* was extracted from; or `None` if the filename is unknown, or if the *DocTest* was not extracted from a file.

lineno

The line number within *filename* where this *DocTest* begins, or `None` if the line number is unavailable. This line number is zero-based with respect to the beginning of the file.

docstring
The string that the test was extracted from, or `None` if the string is unavailable, or if the test was not extracted from a string.

Example Objects

class `doctest.Example`(*source*, *want*, *exc_msg=None*, *lineno=0*, *indent=0*, *options=None*)
A single interactive example, consisting of a Python statement and its expected output. The constructor arguments are used to initialize the attributes of the same names.

Example defines the following attributes. They are initialized by the constructor, and should not be modified directly.

source
A string containing the example's source code. This source code consists of a single Python statement, and always ends with a newline; the constructor adds a newline when necessary.

want
The expected output from running the example's source code (either from stdout, or a traceback in case of exception). *want* ends with a newline unless no output is expected, in which case it's an empty string. The constructor adds a newline when necessary.

exc_msg
The exception message generated by the example, if the example is expected to generate an exception; or `None` if it is not expected to generate an exception. This exception message is compared against the return value of *traceback.format_exception_only()*. *exc_msg* ends with a newline unless it's `None`. The constructor adds a newline if needed.

lineno
The line number within the string containing this example where the example begins. This line number is zero-based with respect to the beginning of the containing string.

indent
The example's indentation in the containing string, i.e., the number of space characters that precede the example's first prompt.

options
A dictionary mapping from option flags to `True` or `False`, which is used to override default options for this example. Any option flags not contained in this dictionary are left at their default value (as specified by the *DocTestRunner*'s `optionflags`). By default, no options are set.

DocTestFinder objects

class `doctest.DocTestFinder`(*verbose=False*, *parser=DocTestParser()*, *recurse=True*, *exclude_empty=True*)
A processing class used to extract the *DocTest*s that are relevant to a given object, from its docstring and the docstrings of its contained objects. *DocTest*s can be extracted from modules, classes, functions, methods, staticmethods, classmethods, and properties.

The optional argument *verbose* can be used to display the objects searched by the finder. It defaults to `False` (no output).

The optional argument *parser* specifies the *DocTestParser* object (or a drop-in replacement) that is used to extract doctests from docstrings.

If the optional argument *recurse* is false, then *DocTestFinder.find()* will only examine the given object, and not any contained objects.

If the optional argument *exclude_empty* is false, then *DocTestFinder.find()* will include tests for objects with empty docstrings.

DocTestFinder defines the following method:

find(*obj[, name][, module][, globs][, extraglobs]*)
Return a list of the *DocTest*s that are defined by *obj*'s docstring, or by any of its contained objects' docstrings.

The optional argument *name* specifies the object's name; this name will be used to construct names for the returned *DocTest*s. If *name* is not specified, then `obj.__name__` is used.

The optional parameter *module* is the module that contains the given object. If the module is not specified or is `None`, then the test finder will attempt to automatically determine the correct module. The object's module is used:

- As a default namespace, if *globs* is not specified.
- To prevent the DocTestFinder from extracting DocTests from objects that are imported from other modules. (Contained objects with modules other than *module* are ignored.)
- To find the name of the file containing the object.
- To help find the line number of the object within its file.

If *module* is `False`, no attempt to find the module will be made. This is obscure, of use mostly in testing doctest itself: if *module* is `False`, or is `None` but cannot be found automatically, then all objects are considered to belong to the (non-existent) module, so all contained objects will (recursively) be searched for doctests.

The globals for each *DocTest* is formed by combining *globs* and *extraglobs* (bindings in *extraglobs* override bindings in *globs*). A new shallow copy of the globals dictionary is created for each *DocTest*. If *globs* is not specified, then it defaults to the module's *__dict__*, if specified, or `{}` otherwise. If *extraglobs* is not specified, then it defaults to `{}`.

DocTestParser objects

class doctest.**DocTestParser**
A processing class used to extract interactive examples from a string, and use them to create a *DocTest* object.

DocTestParser defines the following methods:

get_doctest(*string*, *globs*, *name*, *filename*, *lineno*)
Extract all doctest examples from the given string, and collect them into a *DocTest* object.

globs, *name*, *filename*, and *lineno* are attributes for the new *DocTest* object. See the documentation for *DocTest* for more information.

get_examples(*string*, *name='<string>'*)
Extract all doctest examples from the given string, and return them as a list of *Example* objects. Line numbers are 0-based. The optional argument *name* is a name identifying this string, and is only used for error messages.

parse(*string*, *name='<string>'*)
Divide the given string into examples and intervening text, and return them as a list of alternating *Example*s and strings. Line numbers for the *Example*s are 0-based. The optional argument *name* is a name identifying this string, and is only used for error messages.

DocTestRunner objects

class doctest.DocTestRunner(*checker=None*, *verbose=None*, *optionflags=0*)

A processing class used to execute and verify the interactive examples in a *DocTest*.

The comparison between expected outputs and actual outputs is done by an *OutputChecker*. This comparison may be customized with a number of option flags; see section *Option Flags* for more information. If the option flags are insufficient, then the comparison may also be customized by passing a subclass of *OutputChecker* to the constructor.

The test runner's display output can be controlled in two ways. First, an output function can be passed to `TestRunner.run()`; this function will be called with strings that should be displayed. It defaults to `sys.stdout.write`. If capturing the output is not sufficient, then the display output can be also customized by subclassing DocTestRunner, and overriding the methods *report_start()*, *report_success()*, *report_unexpected_exception()*, and *report_failure()*.

The optional keyword argument *checker* specifies the *OutputChecker* object (or drop-in replacement) that should be used to compare the expected outputs to the actual outputs of doctest examples.

The optional keyword argument *verbose* controls the *DocTestRunner*'s verbosity. If *verbose* is `True`, then information is printed about each example, as it is run. If *verbose* is `False`, then only failures are printed. If *verbose* is unspecified, or `None`, then verbose output is used iff the command-line switch `-v` is used.

The optional keyword argument *optionflags* can be used to control how the test runner compares expected output to actual output, and how it displays failures. For more information, see section *Option Flags*.

DocTestParser defines the following methods:

report_start(*out*, *test*, *example*)

Report that the test runner is about to process the given example. This method is provided to allow subclasses of *DocTestRunner* to customize their output; it should not be called directly.

example is the example about to be processed. *test* is the test *containing example*. *out* is the output function that was passed to *DocTestRunner.run()*.

report_success(*out*, *test*, *example*, *got*)

Report that the given example ran successfully. This method is provided to allow subclasses of *DocTestRunner* to customize their output; it should not be called directly.

example is the example about to be processed. *got* is the actual output from the example. *test* is the test containing *example*. *out* is the output function that was passed to *DocTestRunner.run()*.

report_failure(*out*, *test*, *example*, *got*)

Report that the given example failed. This method is provided to allow subclasses of *DocTestRunner* to customize their output; it should not be called directly.

example is the example about to be processed. *got* is the actual output from the example. *test* is the test containing *example*. *out* is the output function that was passed to *DocTestRunner.run()*.

report_unexpected_exception(*out*, *test*, *example*, *exc_info*)

Report that the given example raised an unexpected exception. This method is provided to allow subclasses of *DocTestRunner* to customize their output; it should not be called directly.

example is the example about to be processed. *exc_info* is a tuple containing information about the unexpected exception (as returned by *sys.exc_info()*). *test* is the test containing *example*. *out* is the output function that was passed to *DocTestRunner.run()*.

run(*test*, *compileflags=None*, *out=None*, *clear_globs=True*)

Run the examples in *test* (a *DocTest* object), and display the results using the writer function *out*.

The examples are run in the namespace `test.globs`. If *clear_globs* is true (the default), then this namespace will be cleared after the test runs, to help with garbage collection. If you would like to examine the namespace after the test completes, then use *clear_globs=False*.

compileflags gives the set of flags that should be used by the Python compiler when running the examples. If not specified, then it will default to the set of future-import flags that apply to *globs*.

The output of each example is checked using the *DocTestRunner*'s output checker, and the results are formatted by the `DocTestRunner.report_*()` methods.

summarize(*verbose=None*)
Print a summary of all the test cases that have been run by this DocTestRunner, and return a *named tuple* `TestResults(failed, attempted)`.

The optional *verbose* argument controls how detailed the summary is. If the verbosity is not specified, then the *DocTestRunner*'s verbosity is used.

OutputChecker objects

class doctest.OutputChecker
A class used to check the whether the actual output from a doctest example matches the expected output. *OutputChecker* defines two methods: *check_output()*, which compares a given pair of outputs, and returns true if they match; and *output_difference()*, which returns a string describing the differences between two outputs.

OutputChecker defines the following methods:

check_output(*want*, *got*, *optionflags*)
Return `True` iff the actual output from an example (*got*) matches the expected output (*want*). These strings are always considered to match if they are identical; but depending on what option flags the test runner is using, several non-exact match types are also possible. See section *Option Flags* for more information about option flags.

output_difference(*example*, *got*, *optionflags*)
Return a string describing the differences between the expected output for a given example (*example*) and the actual output (*got*). *optionflags* is the set of option flags used to compare *want* and *got*.

27.3.7 Debugging

Doctest provides several mechanisms for debugging doctest examples:

- Several functions convert doctests to executable Python programs, which can be run under the Python debugger, *pdb*.
- The *DebugRunner* class is a subclass of *DocTestRunner* that raises an exception for the first failing example, containing information about that example. This information can be used to perform post-mortem debugging on the example.
- The *unittest* cases generated by *DocTestSuite()* support the *debug()* method defined by *unittest.TestCase*.
- You can add a call to *pdb.set_trace()* in a doctest example, and you'll drop into the Python debugger when that line is executed. Then you can inspect current values of variables, and so on. For example, suppose `a.py` contains just this module docstring:

```
"""
>>> def f(x):
...     g(x*2)
```

(continues on next page)

(continued from previous page)

```
>>> def g(x):
...     print(x+3)
...     import pdb; pdb.set_trace()
>>> f(3)
9
"""
```

Then an interactive Python session may look like this:

```
>>> import a, doctest
>>> doctest.testmod(a)
--Return--
> <doctest a[1]>(3)g()->None
-> import pdb; pdb.set_trace()
(Pdb) list
  1     def g(x):
  2         print(x+3)
  3  ->     import pdb; pdb.set_trace()
[EOF]
(Pdb) p x
6
(Pdb) step
--Return--
> <doctest a[0]>(2)f()->None
-> g(x*2)
(Pdb) list
  1     def f(x):
  2  ->     g(x*2)
[EOF]
(Pdb) p x
3
(Pdb) step
--Return--
> <doctest a[2]>(1)?()->None
-> f(3)
(Pdb) cont
(0, 3)
>>>
```

Functions that convert doctests to Python code, and possibly run the synthesized code under the debugger:

`doctest.script_from_examples(s)`

Convert text with examples to a script.

Argument *s* is a string containing doctest examples. The string is converted to a Python script, where doctest examples in *s* are converted to regular code, and everything else is converted to Python comments. The generated script is returned as a string. For example,

```
import doctest
print(doctest.script_from_examples(r"""
    Set x and y to 1 and 2.
    >>> x, y = 1, 2

    Print their sum:
    >>> print(x+y)
    3
"""))
```

displays:

```
# Set x and y to 1 and 2.
x, y = 1, 2
#
# Print their sum:
print(x+y)
# Expected:
## 3
```

This function is used internally by other functions (see below), but can also be useful when you want to transform an interactive Python session into a Python script.

doctest.testsource(*module*, *name*)

Convert the doctest for an object to a script.

Argument *module* is a module object, or dotted name of a module, containing the object whose doctests are of interest. Argument *name* is the name (within the module) of the object with the doctests of interest. The result is a string, containing the object's docstring converted to a Python script, as described for *script_from_examples()* above. For example, if module `a.py` contains a top-level function `f()`, then

```
import a, doctest
print(doctest.testsource(a, "a.f"))
```

prints a script version of function `f()`'s docstring, with doctests converted to code, and the rest placed in comments.

doctest.debug(*module*, *name*, *pm=False*)

Debug the doctests for an object.

The *module* and *name* arguments are the same as for function *testsource()* above. The synthesized Python script for the named object's docstring is written to a temporary file, and then that file is run under the control of the Python debugger, *pdb*.

A shallow copy of `module.__dict__` is used for both local and global execution context.

Optional argument *pm* controls whether post-mortem debugging is used. If *pm* has a true value, the script file is run directly, and the debugger gets involved only if the script terminates via raising an unhandled exception. If it does, then post-mortem debugging is invoked, via *pdb.post_mortem()*, passing the traceback object from the unhandled exception. If *pm* is not specified, or is false, the script is run under the debugger from the start, via passing an appropriate *exec()* call to *pdb.run()*.

doctest.debug_src(*src*, *pm=False*, *globs=None*)

Debug the doctests in a string.

This is like function *debug()* above, except that a string containing doctest examples is specified directly, via the *src* argument.

Optional argument *pm* has the same meaning as in function *debug()* above.

Optional argument *globs* gives a dictionary to use as both local and global execution context. If not specified, or `None`, an empty dictionary is used. If specified, a shallow copy of the dictionary is used.

The *DebugRunner* class, and the special exceptions it may raise, are of most interest to testing framework authors, and will only be sketched here. See the source code, and especially *DebugRunner*'s docstring (which is a doctest!) for more details:

class doctest.DebugRunner(*checker=None*, *verbose=None*, *optionflags=0*)

A subclass of *DocTestRunner* that raises an exception as soon as a failure is encountered. If an unexpected exception occurs, an *UnexpectedException* exception is raised, containing the test, the

example, and the original exception. If the output doesn't match, then a *DocTestFailure* exception is raised, containing the test, the example, and the actual output.

For information about the constructor parameters and methods, see the documentation for *DocTestRunner* in section *Advanced API*.

There are two exceptions that may be raised by *DebugRunner* instances:

exception doctest.DocTestFailure(*test*, *example*, *got*)
An exception raised by *DocTestRunner* to signal that a doctest example's actual output did not match its expected output. The constructor arguments are used to initialize the attributes of the same names.

DocTestFailure defines the following attributes:

DocTestFailure.test
The *DocTest* object that was being run when the example failed.

DocTestFailure.example
The *Example* that failed.

DocTestFailure.got
The example's actual output.

exception doctest.UnexpectedException(*test*, *example*, *exc_info*)
An exception raised by *DocTestRunner* to signal that a doctest example raised an unexpected exception. The constructor arguments are used to initialize the attributes of the same names.

UnexpectedException defines the following attributes:

UnexpectedException.test
The *DocTest* object that was being run when the example failed.

UnexpectedException.example
The *Example* that failed.

UnexpectedException.exc_info
A tuple containing information about the unexpected exception, as returned by *sys.exc_info()*.

27.3.8 Soapbox

As mentioned in the introduction, *doctest* has grown to have three primary uses:

1. Checking examples in docstrings.
2. Regression testing.
3. Executable documentation / literate testing.

These uses have different requirements, and it is important to distinguish them. In particular, filling your docstrings with obscure test cases makes for bad documentation.

When writing a docstring, choose docstring examples with care. There's an art to this that needs to be learned—it may not be natural at first. Examples should add genuine value to the documentation. A good example can often be worth many words. If done with care, the examples will be invaluable for your users, and will pay back the time it takes to collect them many times over as the years go by and things change. I'm still amazed at how often one of my *doctest* examples stops working after a "harmless" change.

Doctest also makes an excellent tool for regression testing, especially if you don't skimp on explanatory text. By interleaving prose and examples, it becomes much easier to keep track of what's actually being tested, and why. When a test fails, good prose can make it much easier to figure out what the problem is, and how it should be fixed. It's true that you could write extensive comments in code-based testing, but few programmers do. Many have found that using doctest approaches instead leads to much clearer tests. Perhaps this is simply because doctest makes writing prose a little easier than writing code, while writing comments in code is a little harder. I think it goes deeper than just that: the natural attitude when

writing a doctest-based test is that you want to explain the fine points of your software, and illustrate them with examples. This in turn naturally leads to test files that start with the simplest features, and logically progress to complications and edge cases. A coherent narrative is the result, instead of a collection of isolated functions that test isolated bits of functionality seemingly at random. It's a different attitude, and produces different results, blurring the distinction between testing and explaining.

Regression testing is best confined to dedicated objects or files. There are several options for organizing tests:

- Write text files containing test cases as interactive examples, and test the files using *testfile()* or *DocFileSuite()*. This is recommended, although is easiest to do for new projects, designed from the start to use doctest.
- Define functions named `_regrtest_topic` that consist of single docstrings, containing test cases for the named topics. These functions can be included in the same file as the module, or separated out into a separate test file.
- Define a `__test__` dictionary mapping from regression test topics to docstrings containing test cases.

When you have placed your tests in a module, the module can itself be the test runner. When a test fails, you can arrange for your test runner to re-run only the failing doctest while you debug the problem. Here is a minimal example of such a test runner:

```
if __name__ == '__main__':
    import doctest
    flags = doctest.REPORT_NDIFF|doctest.FAIL_FAST
    if len(sys.argv) > 1:
        name = sys.argv[1]
        if name in globals():
            obj = globals()[name]
        else:
            obj = __test__[name]
        doctest.run_docstring_examples(obj, globals(), name=name,
                                       optionflags=flags)
    else:
        fail, total = doctest.testmod(optionflags=flags)
        print("{} failures out of {} tests".format(fail, total))
```

27.4 `unittest` — Unit testing framework

Source code: Lib/unittest/__init__.py

(If you are already familiar with the basic concepts of testing, you might want to skip to *the list of assert methods*.)

The *unittest* unit testing framework was originally inspired by JUnit and has a similar flavor as major unit testing frameworks in other languages. It supports test automation, sharing of setup and shutdown code for tests, aggregation of tests into collections, and independence of the tests from the reporting framework.

To achieve this, *unittest* supports some important concepts in an object-oriented way:

test fixture A *test fixture* represents the preparation needed to perform one or more tests, and any associate cleanup actions. This may involve, for example, creating temporary or proxy databases, directories, or starting a server process.

test case A *test case* is the individual unit of testing. It checks for a specific response to a particular set of inputs. *unittest* provides a base class, *TestCase*, which may be used to create new test cases.

test suite A *test suite* is a collection of test cases, test suites, or both. It is used to aggregate tests that should be executed together.

test runner A *test runner* is a component which orchestrates the execution of tests and provides the outcome to the user. The runner may use a graphical interface, a textual interface, or return a special value to indicate the results of executing the tests.

See also:

Module *doctest* Another test-support module with a very different flavor.

Simple Smalltalk Testing: With Patterns Kent Beck's original paper on testing frameworks using the pattern shared by *unittest*.

Nose and py.test Third-party unittest frameworks with a lighter-weight syntax for writing tests. For example, `assert func(10) == 42`.

The Python Testing Tools Taxonomy An extensive list of Python testing tools including functional testing frameworks and mock object libraries.

Testing in Python Mailing List A special-interest-group for discussion of testing, and testing tools, in Python.

The script `Tools/unittestgui/unittestgui.py` in the Python source distribution is a GUI tool for test discovery and execution. This is intended largely for ease of use for those new to unit testing. For production environments it is recommended that tests be driven by a continuous integration system such as Buildbot, Jenkins or Hudson.

27.4.1 Basic example

The *unittest* module provides a rich set of tools for constructing and running tests. This section demonstrates that a small subset of the tools suffice to meet the needs of most users.

Here is a short script to test three string methods:

```
import unittest

class TestStringMethods(unittest.TestCase):

    def test_upper(self):
        self.assertEqual('foo'.upper(), 'FOO')

    def test_isupper(self):
        self.assertTrue('FOO'.isupper())
        self.assertFalse('Foo'.isupper())

    def test_split(self):
        s = 'hello world'
        self.assertEqual(s.split(), ['hello', 'world'])
        # check that s.split fails when the separator is not a string
        with self.assertRaises(TypeError):
            s.split(2)

if __name__ == '__main__':
    unittest.main()
```

A testcase is created by subclassing *unittest.TestCase*. The three individual tests are defined with methods whose names start with the letters `test`. This naming convention informs the test runner about which methods represent tests.

The crux of each test is a call to *assertEqual()* to check for an expected result; *assertTrue()* or *assertFalse()* to verify a condition; or *assertRaises()* to verify that a specific exception gets raised. These methods are used instead of the **assert** statement so the test runner can accumulate all test results and produce a report.

The *setUp()* and *tearDown()* methods allow you to define instructions that will be executed before and after each test method. They are covered in more detail in the section *Organizing test code*.

The final block shows a simple way to run the tests. *unittest.main()* provides a command-line interface to the test script. When run from the command line, the above script produces an output that looks like this:

```
...
----------------------------------------------------------------------
Ran 3 tests in 0.000s

OK
```

Passing the **-v** option to your test script will instruct *unittest.main()* to enable a higher level of verbosity, and produce the following output:

```
test_isupper (__main__.TestStringMethods) ... ok
test_split (__main__.TestStringMethods) ... ok
test_upper (__main__.TestStringMethods) ... ok

----------------------------------------------------------------------
Ran 3 tests in 0.001s

OK
```

The above examples show the most commonly used *unittest* features which are sufficient to meet many everyday testing needs. The remainder of the documentation explores the full feature set from first principles.

27.4.2 Command-Line Interface

The unittest module can be used from the command line to run tests from modules, classes or even individual test methods:

```
python -m unittest test_module1 test_module2
python -m unittest test_module.TestClass
python -m unittest test_module.TestClass.test_method
```

You can pass in a list with any combination of module names, and fully qualified class or method names.

Test modules can be specified by file path as well:

```
python -m unittest tests/test_something.py
```

This allows you to use the shell filename completion to specify the test module. The file specified must still be importable as a module. The path is converted to a module name by removing the '.py' and converting path separators into '.'. If you want to execute a test file that isn't importable as a module you should execute the file directly instead.

You can run tests with more detail (higher verbosity) by passing in the -v flag:

```
python -m unittest -v test_module
```

When executed without arguments *Test Discovery* is started:

```
python -m unittest
```

For a list of all the command-line options:

```
python -m unittest -h
```

Changed in version 3.2: In earlier versions it was only possible to run individual test methods and not modules or classes.

Command-line options

unittest supports these command-line options:

-b, --buffer
The standard output and standard error streams are buffered during the test run. Output during a passing test is discarded. Output is echoed normally on test fail or error and is added to the failure messages.

-c, --catch
`Control-C` during the test run waits for the current test to end and then reports all the results so far. A second `Control-C` raises the normal *KeyboardInterrupt* exception.

See *Signal Handling* for the functions that provide this functionality.

-f, --failfast
Stop the test run on the first error or failure.

-k
Only run test methods and classes that match the pattern or substring. This option may be used multiple times, in which case all test cases that match of the given patterns are included.

Patterns that contain a wildcard character (`*`) are matched against the test name using *fnmatch.fnmatchcase()*; otherwise simple case-sensitive substring matching is used.

Patterns are matched against the fully qualified test method name as imported by the test loader.

For example, `-k foo` matches `foo_tests.SomeTest.test_something`, `bar_tests.SomeTest.test_foo`, but not `bar_tests.FooTest.test_something`.

--locals
Show local variables in tracebacks.

New in version 3.2: The command-line options `-b`, `-c` and `-f` were added.

New in version 3.5: The command-line option `--locals`.

New in version 3.7: The command-line option `-k`.

The command line can also be used for test discovery, for running all of the tests in a project or just a subset.

27.4.3 Test Discovery

New in version 3.2.

Unittest supports simple test discovery. In order to be compatible with test discovery, all of the test files must be modules or packages (including *namespace packages*) importable from the top-level directory of the project (this means that their filenames must be valid identifiers).

Test discovery is implemented in *TestLoader.discover()*, but can also be used from the command line. The basic command-line usage is:

```
cd project_directory
python -m unittest discover
```

Note: As a shortcut, `python -m unittest` is the equivalent of `python -m unittest discover`. If you want to pass arguments to test discovery the `discover` sub-command must be used explicitly.

The `discover` sub-command has the following options:

`-v, --verbose`
Verbose output

`-s, --start-directory directory`
Directory to start discovery (`.` default)

`-p, --pattern pattern`
Pattern to match test files (`test*.py` default)

`-t, --top-level-directory directory`
Top level directory of project (defaults to start directory)

The *-s*, *-p*, and *-t* options can be passed in as positional arguments in that order. The following two command lines are equivalent:

```
python -m unittest discover -s project_directory -p "*_test.py"
python -m unittest discover project_directory "*_test.py"
```

As well as being a path it is possible to pass a package name, for example `myproject.subpackage.test`, as the start directory. The package name you supply will then be imported and its location on the filesystem will be used as the start directory.

Caution: Test discovery loads tests by importing them. Once test discovery has found all the test files from the start directory you specify it turns the paths into package names to import. For example `foo/bar/baz.py` will be imported as `foo.bar.baz`.

If you have a package installed globally and attempt test discovery on a different copy of the package then the import *could* happen from the wrong place. If this happens test discovery will warn you and exit.

If you supply the start directory as a package name rather than a path to a directory then discover assumes that whichever location it imports from is the location you intended, so you will not get the warning.

Test modules and packages can customize test loading and discovery by through the *load_tests protocol*.

Changed in version 3.4: Test discovery supports *namespace packages*.

27.4.4 Organizing test code

The basic building blocks of unit testing are *test cases* — single scenarios that must be set up and checked for correctness. In *unittest*, test cases are represented by *unittest.TestCase* instances. To make your own test cases you must write subclasses of *TestCase* or use *FunctionTestCase*.

The testing code of a *TestCase* instance should be entirely self contained, such that it can be run either in isolation or in arbitrary combination with any number of other test cases.

The simplest *TestCase* subclass will simply implement a test method (i.e. a method whose name starts with `test`) in order to perform specific testing code:

```
import unittest

class DefaultWidgetSizeTestCase(unittest.TestCase):
    def test_default_widget_size(self):
        widget = Widget('The widget')
        self.assertEqual(widget.size(), (50, 50))
```

Note that in order to test something, we use one of the `assert*()` methods provided by the *TestCase* base class. If the test fails, an exception will be raised with an explanatory message, and *unittest* will identify the test case as a *failure*. Any other exceptions will be treated as *errors*.

Tests can be numerous, and their set-up can be repetitive. Luckily, we can factor out set-up code by implementing a method called *setUp()*, which the testing framework will automatically call for every single test we run:

```
import unittest

class WidgetTestCase(unittest.TestCase):
    def setUp(self):
        self.widget = Widget('The widget')

    def test_default_widget_size(self):
        self.assertEqual(self.widget.size(), (50,50),
                         'incorrect default size')

    def test_widget_resize(self):
        self.widget.resize(100,150)
        self.assertEqual(self.widget.size(), (100,150),
                         'wrong size after resize')
```

Note: The order in which the various tests will be run is determined by sorting the test method names with respect to the built-in ordering for strings.

If the *setUp()* method raises an exception while the test is running, the framework will consider the test to have suffered an error, and the test method will not be executed.

Similarly, we can provide a *tearDown()* method that tidies up after the test method has been run:

```
import unittest

class WidgetTestCase(unittest.TestCase):
    def setUp(self):
        self.widget = Widget('The widget')

    def tearDown(self):
        self.widget.dispose()
```

If *setUp()* succeeded, *tearDown()* will be run whether the test method succeeded or not.

Such a working environment for the testing code is called a *test fixture*. A new TestCase instance is created as a unique test fixture used to execute each individual test method. Thus *~TestCase.setUp*, *~TestCase.tearDown*, and *~TestCase.___init___* will be called once per test.

It is recommended that you use TestCase implementations to group tests together according to the features they test. *unittest* provides a mechanism for this: the *test suite*, represented by *unittest*'s *TestSuite* class. In most cases, calling *unittest.main()* will do the right thing and collect all the module's test cases for you and execute them.

However, should you want to customize the building of your test suite, you can do it yourself:

```
def suite():
    suite = unittest.TestSuite()
    suite.addTest(WidgetTestCase('test_default_widget_size'))
    suite.addTest(WidgetTestCase('test_widget_resize'))
    return suite

if __name__ == '__main__':
    runner = unittest.TextTestRunner()
    runner.run(suite())
```

You can place the definitions of test cases and test suites in the same modules as the code they are to test (such as `widget.py`), but there are several advantages to placing the test code in a separate module, such as `test_widget.py`:

- The test module can be run standalone from the command line.
- The test code can more easily be separated from shipped code.
- There is less temptation to change test code to fit the code it tests without a good reason.
- Test code should be modified much less frequently than the code it tests.
- Tested code can be refactored more easily.
- Tests for modules written in C must be in separate modules anyway, so why not be consistent?
- If the testing strategy changes, there is no need to change the source code.

27.4.5 Re-using old test code

Some users will find that they have existing test code that they would like to run from *unittest*, without converting every old test function to a *TestCase* subclass.

For this reason, *unittest* provides a *FunctionTestCase* class. This subclass of *TestCase* can be used to wrap an existing test function. Set-up and tear-down functions can also be provided.

Given the following test function:

```
def testSomething():
    something = makeSomething()
    assert something.name is not None
    # ...
```

one can create an equivalent test case instance as follows, with optional set-up and tear-down methods:

```
testcase = unittest.FunctionTestCase(testSomething,
                                     setUp=makeSomethingDB,
                                     tearDown=deleteSomethingDB)
```

Note: Even though *FunctionTestCase* can be used to quickly convert an existing test base over to a *unittest*-based system, this approach is not recommended. Taking the time to set up proper *TestCase* subclasses will make future test refactorings infinitely easier.

In some cases, the existing tests may have been written using the *doctest* module. If so, *doctest* provides a `DocTestSuite` class that can automatically build *unittest.TestSuite* instances from the existing *doctest*-based tests.

27.4.6 Skipping tests and expected failures

New in version 3.1.

Unittest supports skipping individual test methods and even whole classes of tests. In addition, it supports marking a test as an "expected failure," a test that is broken and will fail, but shouldn't be counted as a failure on a *TestResult*.

Skipping a test is simply a matter of using the *skip() decorator* or one of its conditional variants.

Basic skipping looks like this:

```
class MyTestCase(unittest.TestCase):

    @unittest.skip("demonstrating skipping")
    def test_nothing(self):
        self.fail("shouldn't happen")

    @unittest.skipIf(mylib.__version__ < (1, 3),
                     "not supported in this library version")
    def test_format(self):
        # Tests that work for only a certain version of the library.
        pass

    @unittest.skipUnless(sys.platform.startswith("win"), "requires Windows")
    def test_windows_support(self):
        # windows specific testing code
        pass
```

This is the output of running the example above in verbose mode:

```
test_format (__main__.MyTestCase) ... skipped 'not supported in this library version'
test_nothing (__main__.MyTestCase) ... skipped 'demonstrating skipping'
test_windows_support (__main__.MyTestCase) ... skipped 'requires Windows'

----------------------------------------------------------------------
Ran 3 tests in 0.005s

OK (skipped=3)
```

Classes can be skipped just like methods:

```
@unittest.skip("showing class skipping")
class MySkippedTestCase(unittest.TestCase):
    def test_not_run(self):
        pass
```

TestCase.setUp() can also skip the test. This is useful when a resource that needs to be set up is not available.

Expected failures use the *expectedFailure()* decorator.

```
class ExpectedFailureTestCase(unittest.TestCase):
    @unittest.expectedFailure
    def test_fail(self):
        self.assertEqual(1, 0, "broken")
```

It's easy to roll your own skipping decorators by making a decorator that calls *skip()* on the test when it wants it to be skipped. This decorator skips the test unless the passed object has a certain attribute:

```
def skipUnlessHasattr(obj, attr):
    if hasattr(obj, attr):
        return lambda func: func
    return unittest.skip("{!r} doesn't have {!r}".format(obj, attr))
```

The following decorators implement test skipping and expected failures:

@unittest.skip(*reason*)
Unconditionally skip the decorated test. *reason* should describe why the test is being skipped.

@unittest.skipIf(*condition*, *reason*)
Skip the decorated test if *condition* is true.

@unittest.skipUnless(*condition*, *reason*)
Skip the decorated test unless *condition* is true.

@unittest.expectedFailure
Mark the test as an expected failure. If the test fails when run, the test is not counted as a failure.

exception unittest.SkipTest(*reason*)
This exception is raised to skip a test.

Usually you can use *TestCase.skipTest()* or one of the skipping decorators instead of raising this directly.

Skipped tests will not have *setUp()* or *tearDown()* run around them. Skipped classes will not have *setUpClass()* or *tearDownClass()* run. Skipped modules will not have `setUpModule()` or `tearDownModule()` run.

27.4.7 Distinguishing test iterations using subtests

New in version 3.4.

When some of your tests differ only by a some very small differences, for instance some parameters, unittest allows you to distinguish them inside the body of a test method using the *subTest()* context manager.

For example, the following test:

```
class NumbersTest(unittest.TestCase):

    def test_even(self):
        """
        Test that numbers between 0 and 5 are all even.
        """
        for i in range(0, 6):
            with self.subTest(i=i):
                self.assertEqual(i % 2, 0)
```

will produce the following output:

```
======================================================================
FAIL: test_even (__main__.NumbersTest) (i=1)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "subtests.py", line 32, in test_even
    self.assertEqual(i % 2, 0)
AssertionError: 1 != 0

======================================================================
```

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```
FAIL: test_even (__main__.NumbersTest) (i=3)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "subtests.py", line 32, in test_even
    self.assertEqual(i % 2, 0)
AssertionError: 1 != 0

======================================================================
FAIL: test_even (__main__.NumbersTest) (i=5)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "subtests.py", line 32, in test_even
    self.assertEqual(i % 2, 0)
AssertionError: 1 != 0
```

Without using a subtest, execution would stop after the first failure, and the error would be less easy to diagnose because the value of `i` wouldn't be displayed:

```
======================================================================
FAIL: test_even (__main__.NumbersTest)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "subtests.py", line 32, in test_even
    self.assertEqual(i % 2, 0)
AssertionError: 1 != 0
```

27.4.8 Classes and functions

This section describes in depth the API of *unittest*.

Test cases

class unittest.TestCase(*methodName='runTest'*)

Instances of the *TestCase* class represent the logical test units in the *unittest* universe. This class is intended to be used as a base class, with specific tests being implemented by concrete subclasses. This class implements the interface needed by the test runner to allow it to drive the tests, and methods that the test code can use to check for and report various kinds of failure.

Each instance of *TestCase* will run a single base method: the method named *methodName*. In most uses of *TestCase*, you will neither change the *methodName* nor reimplement the default `runTest()` method.

Changed in version 3.2: *TestCase* can be instantiated successfully without providing a *methodName*. This makes it easier to experiment with *TestCase* from the interactive interpreter.

TestCase instances provide three groups of methods: one group used to run the test, another used by the test implementation to check conditions and report failures, and some inquiry methods allowing information about the test itself to be gathered.

Methods in the first group (running the test) are:

setUp()

Method called to prepare the test fixture. This is called immediately before calling the test method; other than *AssertionError* or *SkipTest*, any exception raised by this method will be considered an error rather than a test failure. The default implementation does nothing.

tearDown()
Method called immediately after the test method has been called and the result recorded. This is called even if the test method raised an exception, so the implementation in subclasses may need to be particularly careful about checking internal state. Any exception, other than *AssertionError* or *SkipTest*, raised by this method will be considered an additional error rather than a test failure (thus increasing the total number of reported errors). This method will only be called if the *setUp()* succeeds, regardless of the outcome of the test method. The default implementation does nothing.

setUpClass()
A class method called before tests in an individual class run. **setUpClass** is called with the class as the only argument and must be decorated as a *classmethod()*:

```
@classmethod
def setUpClass(cls):
    ...
```

See *Class and Module Fixtures* for more details.

New in version 3.2.

tearDownClass()
A class method called after tests in an individual class have run. **tearDownClass** is called with the class as the only argument and must be decorated as a *classmethod()*:

```
@classmethod
def tearDownClass(cls):
    ...
```

See *Class and Module Fixtures* for more details.

New in version 3.2.

run(*result=None*)
Run the test, collecting the result into the *TestResult* object passed as *result*. If *result* is omitted or **None**, a temporary result object is created (by calling the *defaultTestResult()* method) and used. The result object is returned to *run()*'s caller.

The same effect may be had by simply calling the *TestCase* instance.

Changed in version 3.3: Previous versions of **run** did not return the result. Neither did calling an instance.

skipTest(*reason*)
Calling this during a test method or *setUp()* skips the current test. See *Skipping tests and expected failures* for more information.

New in version 3.1.

subTest(*msg=None*, ***params*)
Return a context manager which executes the enclosed code block as a subtest. *msg* and *params* are optional, arbitrary values which are displayed whenever a subtest fails, allowing you to identify them clearly.

A test case can contain any number of subtest declarations, and they can be arbitrarily nested.

See *Distinguishing test iterations using subtests* for more information.

New in version 3.4.

debug()
Run the test without collecting the result. This allows exceptions raised by the test to be propagated to the caller, and can be used to support running tests under a debugger.

The *TestCase* class provides several assert methods to check for and report failures. The following table lists the most commonly used methods (see the tables below for more assert methods):

Method	Checks that	New in
assertEqual(a, b)	`a == b`	
assertNotEqual(a, b)	`a != b`	
assertTrue(x)	`bool(x) is True`	
assertFalse(x)	`bool(x) is False`	
assertIs(a, b)	`a is b`	3.1
assertIsNot(a, b)	`a is not b`	3.1
assertIsNone(x)	`x is None`	3.1
assertIsNotNone(x)	`x is not None`	3.1
assertIn(a, b)	`a in b`	3.1
assertNotIn(a, b)	`a not in b`	3.1
assertIsInstance(a, b)	`isinstance(a, b)`	3.2
assertNotIsInstance(a, b)	`not isinstance(a, b)`	3.2

All the assert methods accept a *msg* argument that, if specified, is used as the error message on failure (see also *longMessage*). Note that the *msg* keyword argument can be passed to *assertRaises()*, *assertRaisesRegex()*, *assertWarns()*, *assertWarnsRegex()* only when they are used as a context manager.

assertEqual(*first*, *second*, *msg=None*)

Test that *first* and *second* are equal. If the values do not compare equal, the test will fail.

In addition, if *first* and *second* are the exact same type and one of list, tuple, dict, set, frozenset or str or any type that a subclass registers with *addTypeEqualityFunc()* the type-specific equality function will be called in order to generate a more useful default error message (see also the *list of type-specific methods*).

Changed in version 3.1: Added the automatic calling of type-specific equality function.

Changed in version 3.2: *assertMultiLineEqual()* added as the default type equality function for comparing strings.

assertNotEqual(*first*, *second*, *msg=None*)

Test that *first* and *second* are not equal. If the values do compare equal, the test will fail.

assertTrue(*expr*, *msg=None*)
assertFalse(*expr*, *msg=None*)

Test that *expr* is true (or false).

Note that this is equivalent to `bool(expr) is True` and not to `expr is True` (use `assertIs(expr, True)` for the latter). This method should also be avoided when more specific methods are available (e.g. `assertEqual(a, b)` instead of `assertTrue(a == b)`), because they provide a better error message in case of failure.

assertIs(*first*, *second*, *msg=None*)
assertIsNot(*first*, *second*, *msg=None*)

Test that *first* and *second* evaluate (or don't evaluate) to the same object.

New in version 3.1.

assertIsNone(*expr*, *msg=None*)
assertIsNotNone(*expr*, *msg=None*)

Test that *expr* is (or is not) `None`.

New in version 3.1.

assertIn(*first*, *second*, *msg=None*)

assertNotIn(*first*, *second*, *msg=None*)
Test that *first* is (or is not) in *second*.

New in version 3.1.

assertIsInstance(*obj*, *cls*, *msg=None*)
assertNotIsInstance(*obj*, *cls*, *msg=None*)
Test that *obj* is (or is not) an instance of *cls* (which can be a class or a tuple of classes, as supported by *isinstance()*). To check for the exact type, use *assertIs(type(obj), cls)*.

New in version 3.2.

It is also possible to check the production of exceptions, warnings, and log messages using the following methods:

Method	Checks that	New in
*assertRaises(exc, fun, *args, **kwds)*	`fun(*args, **kwds)` raises *exc*	
*assertRaisesRegex(exc, r, fun, *args, **kwds)*	`fun(*args, **kwds)` raises *exc* and the message matches regex *r*	3.1
*assertWarns(warn, fun, *args, **kwds)*	`fun(*args, **kwds)` raises *warn*	3.2
*assertWarnsRegex(warn, r, fun, *args, **kwds)*	`fun(*args, **kwds)` raises *warn* and the message matches regex *r*	3.2
assertLogs(logger, level)	The `with` block logs on *logger* with minimum *level*	3.4

assertRaises(*exception*, *callable*, **args*, ***kwds*)
assertRaises(*exception*, *msg=None*)
Test that an exception is raised when *callable* is called with any positional or keyword arguments that are also passed to *assertRaises()*. The test passes if *exception* is raised, is an error if another exception is raised, or fails if no exception is raised. To catch any of a group of exceptions, a tuple containing the exception classes may be passed as *exception*.

If only the *exception* and possibly the *msg* arguments are given, return a context manager so that the code under test can be written inline rather than as a function:

```
with self.assertRaises(SomeException):
    do_something()
```

When used as a context manager, *assertRaises()* accepts the additional keyword argument *msg*.

The context manager will store the caught exception object in its `exception` attribute. This can be useful if the intention is to perform additional checks on the exception raised:

```
with self.assertRaises(SomeException) as cm:
    do_something()

the_exception = cm.exception
self.assertEqual(the_exception.error_code, 3)
```

Changed in version 3.1: Added the ability to use *assertRaises()* as a context manager.

Changed in version 3.2: Added the `exception` attribute.

Changed in version 3.3: Added the *msg* keyword argument when used as a context manager.

assertRaisesRegex(*exception*, *regex*, *callable*, **args*, ***kwds*)
assertRaisesRegex(*exception*, *regex*, *msg=None*)
Like *assertRaises()* but also tests that *regex* matches on the string representation of the raised

exception. *regex* may be a regular expression object or a string containing a regular expression suitable for use by *re.search()*. Examples:

```
self.assertRaisesRegex(ValueError, "invalid literal for.*XYZ'$",
                       int, 'XYZ')
```

or:

```
with self.assertRaisesRegex(ValueError, 'literal'):
   int('XYZ')
```

New in version 3.1: under the name `assertRaisesRegexp`.

Changed in version 3.2: Renamed to *assertRaisesRegex()*.

Changed in version 3.3: Added the *msg* keyword argument when used as a context manager.

assertWarns(*warning*, *callable*, **args*, ***kwds*)
assertWarns(*warning*, *msg=None*)

Test that a warning is triggered when *callable* is called with any positional or keyword arguments that are also passed to *assertWarns()*. The test passes if *warning* is triggered and fails if it isn't. Any exception is an error. To catch any of a group of warnings, a tuple containing the warning classes may be passed as *warnings*.

If only the *warning* and possibly the *msg* arguments are given, return a context manager so that the code under test can be written inline rather than as a function:

```
with self.assertWarns(SomeWarning):
    do_something()
```

When used as a context manager, *assertWarns()* accepts the additional keyword argument *msg*.

The context manager will store the caught warning object in its `warning` attribute, and the source line which triggered the warnings in the `filename` and `lineno` attributes. This can be useful if the intention is to perform additional checks on the warning caught:

```
with self.assertWarns(SomeWarning) as cm:
    do_something()

self.assertIn('myfile.py', cm.filename)
self.assertEqual(320, cm.lineno)
```

This method works regardless of the warning filters in place when it is called.

New in version 3.2.

Changed in version 3.3: Added the *msg* keyword argument when used as a context manager.

assertWarnsRegex(*warning*, *regex*, *callable*, **args*, ***kwds*)
assertWarnsRegex(*warning*, *regex*, *msg=None*)

Like *assertWarns()* but also tests that *regex* matches on the message of the triggered warning. *regex* may be a regular expression object or a string containing a regular expression suitable for use by *re.search()*. Example:

```
self.assertWarnsRegex(DeprecationWarning,
                      r'legacy_function\(\) is deprecated',
                      legacy_function, 'XYZ')
```

or:

```
with self.assertWarnsRegex(RuntimeWarning, 'unsafe frobnicating'):
    frobnicate('/etc/passwd')
```

New in version 3.2.

Changed in version 3.3: Added the *msg* keyword argument when used as a context manager.

assertLogs(*logger=None*, *level=None*)

A context manager to test that at least one message is logged on the *logger* or one of its children, with at least the given *level*.

If given, *logger* should be a *logging.Logger* object or a *str* giving the name of a logger. The default is the root logger, which will catch all messages.

If given, *level* should be either a numeric logging level or its string equivalent (for example either `"ERROR"` or `logging.ERROR`). The default is `logging.INFO`.

The test passes if at least one message emitted inside the `with` block matches the *logger* and *level* conditions, otherwise it fails.

The object returned by the context manager is a recording helper which keeps tracks of the matching log messages. It has two attributes:

records
A list of *logging.LogRecord* objects of the matching log messages.

output
A list of *str* objects with the formatted output of matching messages.

Example:

```
with self.assertLogs('foo', level='INFO') as cm:
   logging.getLogger('foo').info('first message')
   logging.getLogger('foo.bar').error('second message')
self.assertEqual(cm.output, ['INFO:foo:first message',
                             'ERROR:foo.bar:second message'])
```

New in version 3.4.

There are also other methods used to perform more specific checks, such as:

Method	Checks that	New in
assertAlmostEqual(a, b)	`round(a-b, 7) == 0`	
assertNotAlmostEqual(a, b)	`round(a-b, 7) != 0`	
assertGreater(a, b)	`a > b`	3.1
assertGreaterEqual(a, b)	`a >= b`	3.1
assertLess(a, b)	`a < b`	3.1
assertLessEqual(a, b)	`a <= b`	3.1
assertRegex(s, r)	`r.search(s)`	3.1
assertNotRegex(s, r)	`not r.search(s)`	3.2
assertCountEqual(a, b)	*a* and *b* have the same elements in the same number, regardless of their order	3.2

assertAlmostEqual(*first*, *second*, *places=7*, *msg=None*, *delta=None*)

assertNotAlmostEqual(*first*, *second*, *places=7*, *msg=None*, *delta=None*)
Test that *first* and *second* are approximately (or not approximately) equal by computing the difference, rounding to the given number of decimal *places* (default 7), and comparing to zero. Note that these methods round the values to the given number of *decimal places* (i.e. like the *round()* function) and not *significant digits*.

If *delta* is supplied instead of *places* then the difference between *first* and *second* must be less or equal to (or greater than) *delta*.

Supplying both *delta* and *places* raises a `TypeError`.

Changed in version 3.2: *assertAlmostEqual()* automatically considers almost equal objects that compare equal. *assertNotAlmostEqual()* automatically fails if the objects compare equal. Added the *delta* keyword argument.

assertGreater(*first*, *second*, *msg=None*)
assertGreaterEqual(*first*, *second*, *msg=None*)
assertLess(*first*, *second*, *msg=None*)
assertLessEqual(*first*, *second*, *msg=None*)
Test that *first* is respectively >, >=, < or <= than *second* depending on the method name. If not, the test will fail:

```
>>> self.assertGreaterEqual(3, 4)
AssertionError: "3" unexpectedly not greater than or equal to "4"
```

New in version 3.1.

assertRegex(*text*, *regex*, *msg=None*)
assertNotRegex(*text*, *regex*, *msg=None*)
Test that a *regex* search matches (or does not match) *text*. In case of failure, the error message will include the pattern and the *text* (or the pattern and the part of *text* that unexpectedly matched). *regex* may be a regular expression object or a string containing a regular expression suitable for use by *re.search()*.

New in version 3.1: under the name `assertRegexpMatches`.

Changed in version 3.2: The method `assertRegexpMatches()` has been renamed to *assertRegex()*.

New in version 3.2: *assertNotRegex()*.

New in version 3.5: The name `assertNotRegexpMatches` is a deprecated alias for *assertNotRegex()*.

assertCountEqual(*first*, *second*, *msg=None*)
Test that sequence *first* contains the same elements as *second*, regardless of their order. When they don't, an error message listing the differences between the sequences will be generated.

Duplicate elements are *not* ignored when comparing *first* and *second*. It verifies whether each element has the same count in both sequences. Equivalent to: `assertEqual(Counter(list(first)), Counter(list(second)))` but works with sequences of unhashable objects as well.

New in version 3.2.

The *assertEqual()* method dispatches the equality check for objects of the same type to different type-specific methods. These methods are already implemented for most of the built-in types, but it's also possible to register new methods using *addTypeEqualityFunc()*:

addTypeEqualityFunc(*typeobj*, *function*)
Registers a type-specific method called by *assertEqual()* to check if two objects of exactly the same *typeobj* (not subclasses) compare equal. *function* must take two positional arguments

and a third msg=None keyword argument just as *assertEqual()* does. It must raise *self.failureException(msg)* when inequality between the first two parameters is detected – possibly providing useful information and explaining the inequalities in details in the error message.

New in version 3.1.

The list of type-specific methods automatically used by *assertEqual()* are summarized in the following table. Note that it's usually not necessary to invoke these methods directly.

Method	Used to compare	New in
assertMultiLineEqual(a, b)	strings	3.1
assertSequenceEqual(a, b)	sequences	3.1
assertListEqual(a, b)	lists	3.1
assertTupleEqual(a, b)	tuples	3.1
assertSetEqual(a, b)	sets or frozensets	3.1
assertDictEqual(a, b)	dicts	3.1

assertMultiLineEqual(*first*, *second*, *msg=None*)

Test that the multiline string *first* is equal to the string *second*. When not equal a diff of the two strings highlighting the differences will be included in the error message. This method is used by default when comparing strings with *assertEqual()*.

New in version 3.1.

assertSequenceEqual(*first*, *second*, *msg=None*, *seq_type=None*)

Tests that two sequences are equal. If a *seq_type* is supplied, both *first* and *second* must be instances of *seq_type* or a failure will be raised. If the sequences are different an error message is constructed that shows the difference between the two.

This method is not called directly by *assertEqual()*, but it's used to implement *assertListEqual()* and *assertTupleEqual()*.

New in version 3.1.

assertListEqual(*first*, *second*, *msg=None*)

assertTupleEqual(*first*, *second*, *msg=None*)

Tests that two lists or tuples are equal. If not, an error message is constructed that shows only the differences between the two. An error is also raised if either of the parameters are of the wrong type. These methods are used by default when comparing lists or tuples with *assertEqual()*.

New in version 3.1.

assertSetEqual(*first*, *second*, *msg=None*)

Tests that two sets are equal. If not, an error message is constructed that lists the differences between the sets. This method is used by default when comparing sets or frozensets with *assertEqual()*.

Fails if either of *first* or *second* does not have a `set.difference()` method.

New in version 3.1.

assertDictEqual(*first*, *second*, *msg=None*)

Test that two dictionaries are equal. If not, an error message is constructed that shows the differences in the dictionaries. This method will be used by default to compare dictionaries in calls to *assertEqual()*.

New in version 3.1.

Finally the *TestCase* provides the following methods and attributes:

fail(*msg=None*)

Signals a test failure unconditionally, with *msg* or `None` for the error message.

failureException
This class attribute gives the exception raised by the test method. If a test framework needs to use a specialized exception, possibly to carry additional information, it must subclass this exception in order to "play fair" with the framework. The initial value of this attribute is *AssertionError*.

longMessage
This class attribute determines what happens when a custom failure message is passed as the msg argument to an assertXYY call that fails. `True` is the default value. In this case, the custom message is appended to the end of the standard failure message. When set to `False`, the custom message replaces the standard message.

The class setting can be overridden in individual test methods by assigning an instance attribute, self.longMessage, to `True` or `False` before calling the assert methods.

The class setting gets reset before each test call.

New in version 3.1.

maxDiff
This attribute controls the maximum length of diffs output by assert methods that report diffs on failure. It defaults to 80*8 characters. Assert methods affected by this attribute are *assertSequenceEqual()* (including all the sequence comparison methods that delegate to it), *assertDictEqual()* and *assertMultiLineEqual()*.

Setting `maxDiff` to `None` means that there is no maximum length of diffs.

New in version 3.2.

Testing frameworks can use the following methods to collect information on the test:

countTestCases()
Return the number of tests represented by this test object. For *TestCase* instances, this will always be `1`.

defaultTestResult()
Return an instance of the test result class that should be used for this test case class (if no other result instance is provided to the *run()* method).

For *TestCase* instances, this will always be an instance of *TestResult*; subclasses of *TestCase* should override this as necessary.

id()
Return a string identifying the specific test case. This is usually the full name of the test method, including the module and class name.

shortDescription()
Returns a description of the test, or `None` if no description has been provided. The default implementation of this method returns the first line of the test method's docstring, if available, or `None`.

Changed in version 3.1: In 3.1 this was changed to add the test name to the short description even in the presence of a docstring. This caused compatibility issues with unittest extensions and adding the test name was moved to the *TextTestResult* in Python 3.2.

addCleanup(*function*, **args*, ***kwargs*)
Add a function to be called after *tearDown()* to cleanup resources used during the test. Functions will be called in reverse order to the order they are added (LIFO). They are called with any arguments and keyword arguments passed into *addCleanup()* when they are added.

If *setUp()* fails, meaning that *tearDown()* is not called, then any cleanup functions added will still be called.

New in version 3.1.

doCleanups()

This method is called unconditionally after *tearDown()*, or after *setUp()* if *setUp()* raises an exception.

It is responsible for calling all the cleanup functions added by *addCleanup()*. If you need cleanup functions to be called *prior* to *tearDown()* then you can call *doCleanups()* yourself.

doCleanups() pops methods off the stack of cleanup functions one at a time, so it can be called at any time.

New in version 3.1.

class unittest.FunctionTestCase(*testFunc*, *setUp=None*, *tearDown=None*, *description=None*)

This class implements the portion of the *TestCase* interface which allows the test runner to drive the test, but does not provide the methods which test code can use to check and report errors. This is used to create test cases using legacy test code, allowing it to be integrated into a *unittest*-based test framework.

Deprecated aliases

For historical reasons, some of the *TestCase* methods had one or more aliases that are now deprecated. The following table lists the correct names along with their deprecated aliases:

Method Name	Deprecated alias	Deprecated alias
assertEqual()	failUnlessEqual	assertEquals
assertNotEqual()	failIfEqual	assertNotEquals
assertTrue()	failUnless	assert_
assertFalse()	failIf	
assertRaises()	failUnlessRaises	
assertAlmostEqual()	failUnlessAlmostEqual	assertAlmostEquals
assertNotAlmostEqual()	failIfAlmostEqual	assertNotAlmostEquals
assertRegex()		assertRegexpMatches
assertNotRegex()		assertNotRegexpMatches
assertRaisesRegex()		assertRaisesRegexp

Deprecated since version 3.1: the fail* aliases listed in the second column.

Deprecated since version 3.2: the assert* aliases listed in the third column.

Deprecated since version 3.2: `assertRegexpMatches` and `assertRaisesRegexp` have been renamed to *assertRegex()* and *assertRaisesRegex()*.

Deprecated since version 3.5: the `assertNotRegexpMatches` name in favor of *assertNotRegex()*.

Grouping tests

class unittest.TestSuite(*tests=()*)

This class represents an aggregation of individual test cases and test suites. The class presents the interface needed by the test runner to allow it to be run as any other test case. Running a *TestSuite* instance is the same as iterating over the suite, running each test individually.

If *tests* is given, it must be an iterable of individual test cases or other test suites that will be used to build the suite initially. Additional methods are provided to add test cases and suites to the collection later on.

TestSuite objects behave much like *TestCase* objects, except they do not actually implement a test. Instead, they are used to aggregate tests into groups of tests that should be run together. Some additional methods are available to add tests to *TestSuite* instances:

addTest(*test*)
Add a *TestCase* or *TestSuite* to the suite.

addTests(*tests*)
Add all the tests from an iterable of *TestCase* and *TestSuite* instances to this test suite.

This is equivalent to iterating over *tests*, calling *addTest()* for each element.

TestSuite shares the following methods with *TestCase*:

run(*result*)
Run the tests associated with this suite, collecting the result into the test result object passed as *result*. Note that unlike *TestCase.run()*, *TestSuite.run()* requires the result object to be passed in.

debug()
Run the tests associated with this suite without collecting the result. This allows exceptions raised by the test to be propagated to the caller and can be used to support running tests under a debugger.

countTestCases()
Return the number of tests represented by this test object, including all individual tests and sub-suites.

__iter__()
Tests grouped by a *TestSuite* are always accessed by iteration. Subclasses can lazily provide tests by overriding *__iter__()*. Note that this method may be called several times on a single suite (for example when counting tests or comparing for equality) so the tests returned by repeated iterations before *TestSuite.run()* must be the same for each call iteration. After *TestSuite.run()*, callers should not rely on the tests returned by this method unless the caller uses a subclass that overrides `TestSuite._removeTestAtIndex()` to preserve test references.

Changed in version 3.2: In earlier versions the *TestSuite* accessed tests directly rather than through iteration, so overriding *__iter__()* wasn't sufficient for providing tests.

Changed in version 3.4: In earlier versions the *TestSuite* held references to each *TestCase* after *TestSuite.run()*. Subclasses can restore that behavior by overriding `TestSuite._removeTestAtIndex()`.

In the typical usage of a *TestSuite* object, the *run()* method is invoked by a `TestRunner` rather than by the end-user test harness.

Loading and running tests

class unittest.TestLoader
The *TestLoader* class is used to create test suites from classes and modules. Normally, there is no need to create an instance of this class; the *unittest* module provides an instance that can be shared as *unittest.defaultTestLoader*. Using a subclass or instance, however, allows customization of some configurable properties.

TestLoader objects have the following attributes:

errors
A list of the non-fatal errors encountered while loading tests. Not reset by the loader at any point. Fatal errors are signalled by the relevant a method raising an exception to the caller. Non-fatal errors are also indicated by a synthetic test that will raise the original error when run.

New in version 3.5.

TestLoader objects have the following methods:

loadTestsFromTestCase(*testCaseClass*)
Return a suite of all test cases contained in the *TestCase*-derived `testCaseClass`.

A test case instance is created for each method named by *getTestCaseNames()*. By default these are the method names beginning with `test`. If *getTestCaseNames()* returns no methods, but the `runTest()` method is implemented, a single test case is created for that method instead.

loadTestsFromModule(*module*, *pattern=None*)
Return a suite of all test cases contained in the given module. This method searches *module* for classes derived from *TestCase* and creates an instance of the class for each test method defined for the class.

Note: While using a hierarchy of *TestCase*-derived classes can be convenient in sharing fixtures and helper functions, defining test methods on base classes that are not intended to be instantiated directly does not play well with this method. Doing so, however, can be useful when the fixtures are different and defined in subclasses.

If a module provides a `load_tests` function it will be called to load the tests. This allows modules to customize test loading. This is the *load_tests protocol*. The *pattern* argument is passed as the third argument to `load_tests`.

Changed in version 3.2: Support for `load_tests` added.

Changed in version 3.5: The undocumented and unofficial *use_load_tests* default argument is deprecated and ignored, although it is still accepted for backward compatibility. The method also now accepts a keyword-only argument *pattern* which is passed to `load_tests` as the third argument.

loadTestsFromName(*name*, *module=None*)
Return a suite of all test cases given a string specifier.

The specifier *name* is a "dotted name" that may resolve either to a module, a test case class, a test method within a test case class, a *TestSuite* instance, or a callable object which returns a *TestCase* or *TestSuite* instance. These checks are applied in the order listed here; that is, a method on a possible test case class will be picked up as "a test method within a test case class", rather than "a callable object".

For example, if you have a module `SampleTests` containing a *TestCase*-derived class `SampleTestCase` with three test methods (`test_one()`, `test_two()`, and `test_three()`), the specifier `'SampleTests.SampleTestCase'` would cause this method to return a suite which will run all three test methods. Using the specifier `'SampleTests.SampleTestCase.test_two'` would cause it to return a test suite which will run only the `test_two()` test method. The specifier can refer to modules and packages which have not been imported; they will be imported as a side-effect.

The method optionally resolves *name* relative to the given *module*.

Changed in version 3.5: If an *ImportError* or *AttributeError* occurs while traversing *name* then a synthetic test that raises that error when run will be returned. These errors are included in the errors accumulated by self.errors.

loadTestsFromNames(*names*, *module=None*)
Similar to *loadTestsFromName()*, but takes a sequence of names rather than a single name. The return value is a test suite which supports all the tests defined for each name.

getTestCaseNames(*testCaseClass*)
Return a sorted sequence of method names found within *testCaseClass*; this should be a subclass of *TestCase*.

`discover`(*start_dir*, *pattern='test*.py'*, *top_level_dir=None*)

Find all the test modules by recursing into subdirectories from the specified start directory, and return a TestSuite object containing them. Only test files that match *pattern* will be loaded. (Using shell style pattern matching.) Only module names that are importable (i.e. are valid Python identifiers) will be loaded.

All test modules must be importable from the top level of the project. If the start directory is not the top level directory then the top level directory must be specified separately.

If importing a module fails, for example due to a syntax error, then this will be recorded as a single error and discovery will continue. If the import failure is due to *SkipTest* being raised, it will be recorded as a skip instead of an error.

If a package (a directory containing a file named `__init__.py`) is found, the package will be checked for a `load_tests` function. If this exists then it will be called `package.load_tests(loader, tests, pattern)`. Test discovery takes care to ensure that a package is only checked for tests once during an invocation, even if the load_tests function itself calls `loader.discover`.

If `load_tests` exists then discovery does *not* recurse into the package, `load_tests` is responsible for loading all tests in the package.

The pattern is deliberately not stored as a loader attribute so that packages can continue discovery themselves. *top_level_dir* is stored so `load_tests` does not need to pass this argument in to `loader.discover()`.

start_dir can be a dotted module name as well as a directory.

New in version 3.2.

Changed in version 3.4: Modules that raise *SkipTest* on import are recorded as skips, not errors. Discovery works for *namespace packages*. Paths are sorted before being imported so that execution order is the same even if the underlying file system's ordering is not dependent on file name.

Changed in version 3.5: Found packages are now checked for `load_tests` regardless of whether their path matches *pattern*, because it is impossible for a package name to match the default pattern.

The following attributes of a *TestLoader* can be configured either by subclassing or assignment on an instance:

`testMethodPrefix`

String giving the prefix of method names which will be interpreted as test methods. The default value is `'test'`.

This affects *getTestCaseNames()* and all the `loadTestsFrom*()` methods.

`sortTestMethodsUsing`

Function to be used to compare method names when sorting them in *getTestCaseNames()* and all the `loadTestsFrom*()` methods.

`suiteClass`

Callable object that constructs a test suite from a list of tests. No methods on the resulting object are needed. The default value is the *TestSuite* class.

This affects all the `loadTestsFrom*()` methods.

`testNamePatterns`

List of Unix shell-style wildcard test name patterns that test methods have to match to be included in test suites (see `-v` option).

If this attribute is not `None` (the default), all test methods to be included in test suites must match one of the patterns in this list. Note that matches are always performed using *fnmatch.*

fnmatchcase(), so unlike patterns passed to the `-v` option, simple substring patterns will have to be converted using `*` wildcards.

This affects all the `loadTestsFrom*()` methods.

New in version 3.7.

class unittest.TestResult

This class is used to compile information about which tests have succeeded and which have failed.

A *TestResult* object stores the results of a set of tests. The *TestCase* and *TestSuite* classes ensure that results are properly recorded; test authors do not need to worry about recording the outcome of tests.

Testing frameworks built on top of *unittest* may want access to the *TestResult* object generated by running a set of tests for reporting purposes; a *TestResult* instance is returned by the `TestRunner.run()` method for this purpose.

TestResult instances have the following attributes that will be of interest when inspecting the results of running a set of tests:

errors
A list containing 2-tuples of *TestCase* instances and strings holding formatted tracebacks. Each tuple represents a test which raised an unexpected exception.

failures
A list containing 2-tuples of *TestCase* instances and strings holding formatted tracebacks. Each tuple represents a test where a failure was explicitly signalled using the `TestCase.assert*()` methods.

skipped
A list containing 2-tuples of *TestCase* instances and strings holding the reason for skipping the test.

New in version 3.1.

expectedFailures
A list containing 2-tuples of *TestCase* instances and strings holding formatted tracebacks. Each tuple represents an expected failure of the test case.

unexpectedSuccesses
A list containing *TestCase* instances that were marked as expected failures, but succeeded.

shouldStop
Set to `True` when the execution of tests should stop by *stop()*.

testsRun
The total number of tests run so far.

buffer
If set to true, `sys.stdout` and `sys.stderr` will be buffered in between *startTest()* and *stopTest()* being called. Collected output will only be echoed onto the real `sys.stdout` and `sys.stderr` if the test fails or errors. Any output is also attached to the failure / error message.

New in version 3.2.

failfast
If set to true *stop()* will be called on the first failure or error, halting the test run.

New in version 3.2.

tb_locals
If set to true then local variables will be shown in tracebacks.

New in version 3.5.

wasSuccessful()
Return `True` if all tests run so far have passed, otherwise returns `False`.

Changed in version 3.4: Returns `False` if there were any *unexpectedSuccesses* from tests marked with the *expectedFailure()* decorator.

stop()
This method can be called to signal that the set of tests being run should be aborted by setting the *shouldStop* attribute to `True`. `TestRunner` objects should respect this flag and return without running any additional tests.

For example, this feature is used by the *TextTestRunner* class to stop the test framework when the user signals an interrupt from the keyboard. Interactive tools which provide `TestRunner` implementations can use this in a similar manner.

The following methods of the *TestResult* class are used to maintain the internal data structures, and may be extended in subclasses to support additional reporting requirements. This is particularly useful in building tools which support interactive reporting while tests are being run.

startTest(*test*)
Called when the test case *test* is about to be run.

stopTest(*test*)
Called after the test case *test* has been executed, regardless of the outcome.

startTestRun()
Called once before any tests are executed.

New in version 3.1.

stopTestRun()
Called once after all tests are executed.

New in version 3.1.

addError(*test*, *err*)
Called when the test case *test* raises an unexpected exception. *err* is a tuple of the form returned by *sys.exc_info()*: `(type, value, traceback)`.

The default implementation appends a tuple `(test, formatted_err)` to the instance's *errors* attribute, where *formatted_err* is a formatted traceback derived from *err*.

addFailure(*test*, *err*)
Called when the test case *test* signals a failure. *err* is a tuple of the form returned by *sys.exc_info()*: `(type, value, traceback)`.

The default implementation appends a tuple `(test, formatted_err)` to the instance's *failures* attribute, where *formatted_err* is a formatted traceback derived from *err*.

addSuccess(*test*)
Called when the test case *test* succeeds.

The default implementation does nothing.

addSkip(*test*, *reason*)
Called when the test case *test* is skipped. *reason* is the reason the test gave for skipping.

The default implementation appends a tuple `(test, reason)` to the instance's *skipped* attribute.

addExpectedFailure(*test*, *err*)
Called when the test case *test* fails, but was marked with the *expectedFailure()* decorator.

The default implementation appends a tuple `(test, formatted_err)` to the instance's *expectedFailures* attribute, where *formatted_err* is a formatted traceback derived from *err*.

addUnexpectedSuccess(*test*)
Called when the test case *test* was marked with the *expectedFailure()* decorator, but succeeded.

The default implementation appends the test to the instance's *unexpectedSuccesses* attribute.

addSubTest(*test*, *subtest*, *outcome*)
Called when a subtest finishes. *test* is the test case corresponding to the test method. *subtest* is a custom *TestCase* instance describing the subtest.

If *outcome* is *None*, the subtest succeeded. Otherwise, it failed with an exception where *outcome* is a tuple of the form returned by *sys.exc_info()*: `(type, value, traceback)`.

The default implementation does nothing when the outcome is a success, and records subtest failures as normal failures.

New in version 3.4.

class unittest.TextTestResult(*stream*, *descriptions*, *verbosity*)
A concrete implementation of *TestResult* used by the *TextTestRunner*.

New in version 3.2: This class was previously named `_TextTestResult`. The old name still exists as an alias but is deprecated.

unittest.defaultTestLoader
Instance of the *TestLoader* class intended to be shared. If no customization of the *TestLoader* is needed, this instance can be used instead of repeatedly creating new instances.

class unittest.TextTestRunner(*stream=None*, *descriptions=True*, *verbosity=1*, *failfast=False*, *buffer=False*, *resultclass=None*, *warnings=None*, ***, *tb_locals=False*)
A basic test runner implementation that outputs results to a stream. If *stream* is `None`, the default, *sys.stderr* is used as the output stream. This class has a few configurable parameters, but is essentially very simple. Graphical applications which run test suites should provide alternate implementations. Such implementations should accept `**kwargs` as the interface to construct runners changes when features are added to unittest.

By default this runner shows *DeprecationWarning*, *PendingDeprecationWarning*, *ResourceWarning* and *ImportWarning* even if they are *ignored by default*. Deprecation warnings caused by *deprecated unittest methods* are also special-cased and, when the warning filters are `'default'` or `'always'`, they will appear only once per-module, in order to avoid too many warning messages. This behavior can be overridden using Python's `-Wd` or `-Wa` options (see Warning control) and leaving *warnings* to `None`.

Changed in version 3.2: Added the `warnings` argument.

Changed in version 3.2: The default stream is set to *sys.stderr* at instantiation time rather than import time.

Changed in version 3.5: Added the tb_locals parameter.

_makeResult()
This method returns the instance of `TestResult` used by *run()*. It is not intended to be called directly, but can be overridden in subclasses to provide a custom `TestResult`.

`_makeResult()` instantiates the class or callable passed in the `TextTestRunner` constructor as the `resultclass` argument. It defaults to *TextTestResult* if no `resultclass` is provided. The result class is instantiated with the following arguments:

```
stream, descriptions, verbosity
```

run(*test*)
This method is the main public interface to the *TextTestRunner*. This method takes a *TestSuite* or *TestCase* instance. A *TestResult* is created by calling *_makeResult()* and the test(s) are run and the results printed to stdout.

unittest.main(*module='__main__', defaultTest=None, argv=None, testRunner=None, testLoader=unittest.defaultTestLoader, exit=True, verbosity=1, failfast=None, catchbreak=None, buffer=None, warnings=None*)

A command-line program that loads a set of tests from *module* and runs them; this is primarily for making test modules conveniently executable. The simplest use for this function is to include the following line at the end of a test script:

```
if __name__ == '__main__':
    unittest.main()
```

You can run tests with more detailed information by passing in the verbosity argument:

```
if __name__ == '__main__':
    unittest.main(verbosity=2)
```

The *defaultTest* argument is either the name of a single test or an iterable of test names to run if no test names are specified via *argv*. If not specified or `None` and no test names are provided via *argv*, all tests found in *module* are run.

The *argv* argument can be a list of options passed to the program, with the first element being the program name. If not specified or `None`, the values of *sys.argv* are used.

The *testRunner* argument can either be a test runner class or an already created instance of it. By default `main` calls *sys.exit()* with an exit code indicating success or failure of the tests run.

The *testLoader* argument has to be a *TestLoader* instance, and defaults to *defaultTestLoader*.

`main` supports being used from the interactive interpreter by passing in the argument `exit=False`. This displays the result on standard output without calling *sys.exit()*:

```
>>> from unittest import main
>>> main(module='test_module', exit=False)
```

The *failfast*, *catchbreak* and *buffer* parameters have the same effect as the same-name *command-line options*.

The *warnings* argument specifies the *warning filter* that should be used while running the tests. If it's not specified, it will remain `None` if a `-W` option is passed to `python` (see Warning control), otherwise it will be set to `'default'`.

Calling `main` actually returns an instance of the `TestProgram` class. This stores the result of the tests run as the `result` attribute.

Changed in version 3.1: The *exit* parameter was added.

Changed in version 3.2: The *verbosity*, *failfast*, *catchbreak*, *buffer* and *warnings* parameters were added.

Changed in version 3.4: The *defaultTest* parameter was changed to also accept an iterable of test names.

load_tests Protocol

New in version 3.2.

Modules or packages can customize how tests are loaded from them during normal test runs or test discovery by implementing a function called `load_tests`.

If a test module defines `load_tests` it will be called by *TestLoader.loadTestsFromModule()* with the following arguments:

```
load_tests(loader, standard_tests, pattern)
```

where *pattern* is passed straight through from `loadTestsFromModule`. It defaults to `None`.

It should return a *TestSuite*.

loader is the instance of *TestLoader* doing the loading. *standard_tests* are the tests that would be loaded by default from the module. It is common for test modules to only want to add or remove tests from the standard set of tests. The third argument is used when loading packages as part of test discovery.

A typical `load_tests` function that loads tests from a specific set of *TestCase* classes may look like:

```
test_cases = (TestCase1, TestCase2, TestCase3)

def load_tests(loader, tests, pattern):
    suite = TestSuite()
    for test_class in test_cases:
        tests = loader.loadTestsFromTestCase(test_class)
        suite.addTests(tests)
    return suite
```

If discovery is started in a directory containing a package, either from the command line or by calling *TestLoader.discover()*, then the package `__init__.py` will be checked for `load_tests`. If that function does not exist, discovery will recurse into the package as though it were just another directory. Otherwise, discovery of the package's tests will be left up to `load_tests` which is called with the following arguments:

```
load_tests(loader, standard_tests, pattern)
```

This should return a *TestSuite* representing all the tests from the package. (`standard_tests` will only contain tests collected from `__init__.py`.)

Because the pattern is passed into `load_tests` the package is free to continue (and potentially modify) test discovery. A 'do nothing' `load_tests` function for a test package would look like:

```
def load_tests(loader, standard_tests, pattern):
    # top level directory cached on loader instance
    this_dir = os.path.dirname(__file__)
    package_tests = loader.discover(start_dir=this_dir, pattern=pattern)
    standard_tests.addTests(package_tests)
    return standard_tests
```

Changed in version 3.5: Discovery no longer checks package names for matching *pattern* due to the impossibility of package names matching the default pattern.

27.4.9 Class and Module Fixtures

Class and module level fixtures are implemented in *TestSuite*. When the test suite encounters a test from a new class then `tearDownClass()` from the previous class (if there is one) is called, followed by `setUpClass()` from the new class.

Similarly if a test is from a different module from the previous test then `tearDownModule` from the previous module is run, followed by `setUpModule` from the new module.

After all the tests have run the final `tearDownClass` and `tearDownModule` are run.

Note that shared fixtures do not play well with [potential] features like test parallelization and they break test isolation. They should be used with care.

The default ordering of tests created by the unittest test loaders is to group all tests from the same modules and classes together. This will lead to `setUpClass` / `setUpModule` (etc) being called exactly once per class

and module. If you randomize the order, so that tests from different modules and classes are adjacent to each other, then these shared fixture functions may be called multiple times in a single test run.

Shared fixtures are not intended to work with suites with non-standard ordering. A `BaseTestSuite` still exists for frameworks that don't want to support shared fixtures.

If there are any exceptions raised during one of the shared fixture functions the test is reported as an error. Because there is no corresponding test instance an `_ErrorHolder` object (that has the same interface as a *TestCase*) is created to represent the error. If you are just using the standard unittest test runner then this detail doesn't matter, but if you are a framework author it may be relevant.

setUpClass and tearDownClass

These must be implemented as class methods:

```
import unittest

class Test(unittest.TestCase):
    @classmethod
    def setUpClass(cls):
        cls._connection = createExpensiveConnectionObject()

    @classmethod
    def tearDownClass(cls):
        cls._connection.destroy()
```

If you want the `setUpClass` and `tearDownClass` on base classes called then you must call up to them yourself. The implementations in *TestCase* are empty.

If an exception is raised during a `setUpClass` then the tests in the class are not run and the `tearDownClass` is not run. Skipped classes will not have `setUpClass` or `tearDownClass` run. If the exception is a *SkipTest* exception then the class will be reported as having been skipped instead of as an error.

setUpModule and tearDownModule

These should be implemented as functions:

```
def setUpModule():
    createConnection()

def tearDownModule():
    closeConnection()
```

If an exception is raised in a `setUpModule` then none of the tests in the module will be run and the `tearDownModule` will not be run. If the exception is a *SkipTest* exception then the module will be reported as having been skipped instead of as an error.

27.4.10 Signal Handling

New in version 3.2.

The *-c/--catch* command-line option to unittest, along with the `catchbreak` parameter to *unittest.main()*, provide more friendly handling of control-C during a test run. With catch break behavior enabled control-C will allow the currently running test to complete, and the test run will then end and report all the results so far. A second control-c will raise a *KeyboardInterrupt* in the usual way.

The control-c handling signal handler attempts to remain compatible with code or tests that install their own `signal.SIGINT` handler. If the `unittest` handler is called but *isn't* the installed `signal.SIGINT` handler, i.e. it has been replaced by the system under test and delegated to, then it calls the default handler. This will normally be the expected behavior by code that replaces an installed handler and delegates to it. For individual tests that need `unittest` control-c handling disabled the *removeHandler()* decorator can be used.

There are a few utility functions for framework authors to enable control-c handling functionality within test frameworks.

unittest.installHandler()
Install the control-c handler. When a `signal.SIGINT` is received (usually in response to the user pressing control-c) all registered results have *stop()* called.

unittest.registerResult(*result*)
Register a *TestResult* object for control-c handling. Registering a result stores a weak reference to it, so it doesn't prevent the result from being garbage collected.

Registering a *TestResult* object has no side-effects if control-c handling is not enabled, so test frameworks can unconditionally register all results they create independently of whether or not handling is enabled.

unittest.removeResult(*result*)
Remove a registered result. Once a result has been removed then *stop()* will no longer be called on that result object in response to a control-c.

unittest.removeHandler(*function=None*)
When called without arguments this function removes the control-c handler if it has been installed. This function can also be used as a test decorator to temporarily remove the handler while the test is being executed:

```
@unittest.removeHandler
def test_signal_handling(self):
    ...
```

27.5 unittest.mock — mock object library

New in version 3.3.

Source code: Lib/unittest/mock.py

---

unittest.mock is a library for testing in Python. It allows you to replace parts of your system under test with mock objects and make assertions about how they have been used.

unittest.mock provides a core *Mock* class removing the need to create a host of stubs throughout your test suite. After performing an action, you can make assertions about which methods / attributes were used and arguments they were called with. You can also specify return values and set needed attributes in the normal way.

Additionally, mock provides a *patch()* decorator that handles patching module and class level attributes within the scope of a test, along with *sentinel* for creating unique objects. See the *quick guide* for some examples of how to use *Mock*, *MagicMock* and *patch()*.

Mock is very easy to use and is designed for use with *unittest*. Mock is based on the 'action -> assertion' pattern instead of 'record -> replay' used by many mocking frameworks.

There is a backport of *unittest.mock* for earlier versions of Python, available as mock on PyPI.

27.5.1 Quick Guide

Mock and *MagicMock* objects create all attributes and methods as you access them and store details of how they have been used. You can configure them, to specify return values or limit what attributes are available, and then make assertions about how they have been used:

```
>>> from unittest.mock import MagicMock
>>> thing = ProductionClass()
>>> thing.method = MagicMock(return_value=3)
>>> thing.method(3, 4, 5, key='value')
3
>>> thing.method.assert_called_with(3, 4, 5, key='value')
```

`side_effect` allows you to perform side effects, including raising an exception when a mock is called:

```
>>> mock = Mock(side_effect=KeyError('foo'))
>>> mock()
Traceback (most recent call last):
 ...
KeyError: 'foo'
```

```
>>> values = {'a': 1, 'b': 2, 'c': 3}
>>> def side_effect(arg):
...     return values[arg]
...
>>> mock.side_effect = side_effect
>>> mock('a'), mock('b'), mock('c')
(1, 2, 3)
>>> mock.side_effect = [5, 4, 3, 2, 1]
>>> mock(), mock(), mock()
(5, 4, 3)
```

Mock has many other ways you can configure it and control its behaviour. For example the *spec* argument configures the mock to take its specification from another object. Attempting to access attributes or methods on the mock that don't exist on the spec will fail with an *AttributeError*.

The *patch()* decorator / context manager makes it easy to mock classes or objects in a module under test. The object you specify will be replaced with a mock (or other object) during the test and restored when the test ends:

```
>>> from unittest.mock import patch
>>> @patch('module.ClassName2')
... @patch('module.ClassName1')
... def test(MockClass1, MockClass2):
...     module.ClassName1()
...     module.ClassName2()
...     assert MockClass1 is module.ClassName1
...     assert MockClass2 is module.ClassName2
...     assert MockClass1.called
...     assert MockClass2.called
...
>>> test()
```

Note: When you nest patch decorators the mocks are passed in to the decorated function in the same order they applied (the normal *python* order that decorators are applied). This means from the bottom up, so in the example above the mock for `module.ClassName1` is passed in first.

With *patch()* it matters that you patch objects in the namespace where they are looked up. This is normally straightforward, but for a quick guide read *where to patch*.

As well as a decorator *patch()* can be used as a context manager in a with statement:

```
>>> with patch.object(ProductionClass, 'method', return_value=None) as mock_method:
...     thing = ProductionClass()
...     thing.method(1, 2, 3)
...
>>> mock_method.assert_called_once_with(1, 2, 3)
```

There is also *patch.dict()* for setting values in a dictionary just during a scope and restoring the dictionary to its original state when the test ends:

```
>>> foo = {'key': 'value'}
>>> original = foo.copy()
>>> with patch.dict(foo, {'newkey': 'newvalue'}, clear=True):
...     assert foo == {'newkey': 'newvalue'}
...
>>> assert foo == original
```

Mock supports the mocking of Python *magic methods*. The easiest way of using magic methods is with the *MagicMock* class. It allows you to do things like:

```
>>> mock = MagicMock()
>>> mock.__str__.return_value = 'foobarbaz'
>>> str(mock)
'foobarbaz'
>>> mock.__str__.assert_called_with()
```

Mock allows you to assign functions (or other Mock instances) to magic methods and they will be called appropriately. The *MagicMock* class is just a Mock variant that has all of the magic methods pre-created for you (well, all the useful ones anyway).

The following is an example of using magic methods with the ordinary Mock class:

```
>>> mock = Mock()
>>> mock.__str__ = Mock(return_value='wheeeeee')
>>> str(mock)
'wheeeeee'
```

For ensuring that the mock objects in your tests have the same api as the objects they are replacing, you can use *auto-speccing*. Auto-speccing can be done through the *autospec* argument to patch, or the *create_autospec()* function. Auto-speccing creates mock objects that have the same attributes and methods as the objects they are replacing, and any functions and methods (including constructors) have the same call signature as the real object.

This ensures that your mocks will fail in the same way as your production code if they are used incorrectly:

```
>>> from unittest.mock import create_autospec
>>> def function(a, b, c):
...     pass
...
>>> mock_function = create_autospec(function, return_value='fishy')
>>> mock_function(1, 2, 3)
'fishy'
>>> mock_function.assert_called_once_with(1, 2, 3)
>>> mock_function('wrong arguments')
```

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```
Traceback (most recent call last):
  ...
TypeError: <lambda>() takes exactly 3 arguments (1 given)
```

create_autospec() can also be used on classes, where it copies the signature of the `__init__` method, and on callable objects where it copies the signature of the `__call__` method.

27.5.2 The Mock Class

Mock is a flexible mock object intended to replace the use of stubs and test doubles throughout your code. Mocks are callable and create attributes as new mocks when you access them[1]. Accessing the same attribute will always return the same mock. Mocks record how you use them, allowing you to make assertions about what your code has done to them.

MagicMock is a subclass of *Mock* with all the magic methods pre-created and ready to use. There are also non-callable variants, useful when you are mocking out objects that aren't callable: *NonCallableMock* and *NonCallableMagicMock*

The *patch()* decorators makes it easy to temporarily replace classes in a particular module with a *Mock* object. By default *patch()* will create a *MagicMock* for you. You can specify an alternative class of *Mock* using the *new_callable* argument to *patch()*.

class unittest.mock.Mock(*spec=None*, *side_effect=None*, *return_value=DEFAULT*, *wraps=None*, *name=None*, *spec_set=None*, *unsafe=False*, ***kwargs*)

Create a new *Mock* object. *Mock* takes several optional arguments that specify the behaviour of the Mock object:

- *spec*: This can be either a list of strings or an existing object (a class or instance) that acts as the specification for the mock object. If you pass in an object then a list of strings is formed by calling dir on the object (excluding unsupported magic attributes and methods). Accessing any attribute not in this list will raise an *AttributeError*.

  If *spec* is an object (rather than a list of strings) then *__class__* returns the class of the spec object. This allows mocks to pass *isinstance()* tests.

- *spec_set*: A stricter variant of *spec*. If used, attempting to *set* or get an attribute on the mock that isn't on the object passed as *spec_set* will raise an *AttributeError*.

- *side_effect*: A function to be called whenever the Mock is called. See the *side_effect* attribute. Useful for raising exceptions or dynamically changing return values. The function is called with the same arguments as the mock, and unless it returns *DEFAULT*, the return value of this function is used as the return value.

  Alternatively *side_effect* can be an exception class or instance. In this case the exception will be raised when the mock is called.

  If *side_effect* is an iterable then each call to the mock will return the next value from the iterable.

  A *side_effect* can be cleared by setting it to `None`.

- *return_value*: The value returned when the mock is called. By default this is a new Mock (created on first access). See the *return_value* attribute.

- *unsafe*: By default if any attribute starts with *assert* or *assret* will raise an *AttributeError*. Passing `unsafe=True` will allow access to these attributes.

[1] The only exceptions are magic methods and attributes (those that have leading and trailing double underscores). Mock doesn't create these but instead raises an *AttributeError*. This is because the interpreter will often implicitly request these methods, and gets *very* confused to get a new Mock object when it expects a magic method. If you need magic method support see *magic methods*.

New in version 3.5.

- *wraps*: Item for the mock object to wrap. If *wraps* is not `None` then calling the Mock will pass the call through to the wrapped object (returning the real result). Attribute access on the mock will return a Mock object that wraps the corresponding attribute of the wrapped object (so attempting to access an attribute that doesn't exist will raise an *AttributeError*).

  If the mock has an explicit *return_value* set then calls are not passed to the wrapped object and the *return_value* is returned instead.

- *name*: If the mock has a name then it will be used in the repr of the mock. This can be useful for debugging. The name is propagated to child mocks.

Mocks can also be called with arbitrary keyword arguments. These will be used to set attributes on the mock after it is created. See the *configure_mock()* method for details.

assert_called(**args*, ***kwargs*)

Assert that the mock was called at least once.

```
>>> mock = Mock()
>>> mock.method()
<Mock name='mock.method()' id='...'>
>>> mock.method.assert_called()
```

New in version 3.6.

assert_called_once(**args*, ***kwargs*)

Assert that the mock was called exactly once.

```
>>> mock = Mock()
>>> mock.method()
<Mock name='mock.method()' id='...'>
>>> mock.method.assert_called_once()
>>> mock.method()
<Mock name='mock.method()' id='...'>
>>> mock.method.assert_called_once()
Traceback (most recent call last):
...
AssertionError: Expected 'method' to have been called once. Called 2 times.
```

New in version 3.6.

assert_called_with(**args*, ***kwargs*)

This method is a convenient way of asserting that calls are made in a particular way:

```
>>> mock = Mock()
>>> mock.method(1, 2, 3, test='wow')
<Mock name='mock.method()' id='...'>
>>> mock.method.assert_called_with(1, 2, 3, test='wow')
```

assert_called_once_with(**args*, ***kwargs*)

Assert that the mock was called exactly once and that that call was with the specified arguments.

```
>>> mock = Mock(return_value=None)
>>> mock('foo', bar='baz')
>>> mock.assert_called_once_with('foo', bar='baz')
>>> mock('other', bar='values')
>>> mock.assert_called_once_with('other', bar='values')
Traceback (most recent call last):
  ...
AssertionError: Expected 'mock' to be called once. Called 2 times.
```

assert_any_call(**args*, ***kwargs*)
assert the mock has been called with the specified arguments.

The assert passes if the mock has *ever* been called, unlike *assert_called_with()* and *assert_called_once_with()* that only pass if the call is the most recent one, and in the case of *assert_called_once_with()* it must also be the only call.

```
>>> mock = Mock(return_value=None)
>>> mock(1, 2, arg='thing')
>>> mock('some', 'thing', 'else')
>>> mock.assert_any_call(1, 2, arg='thing')
```

assert_has_calls(*calls*, *any_order=False*)
assert the mock has been called with the specified calls. The *mock_calls* list is checked for the calls.

If *any_order* is false (the default) then the calls must be sequential. There can be extra calls before or after the specified calls.

If *any_order* is true then the calls can be in any order, but they must all appear in *mock_calls*.

```
>>> mock = Mock(return_value=None)
>>> mock(1)
>>> mock(2)
>>> mock(3)
>>> mock(4)
>>> calls = [call(2), call(3)]
>>> mock.assert_has_calls(calls)
>>> calls = [call(4), call(2), call(3)]
>>> mock.assert_has_calls(calls, any_order=True)
```

assert_not_called()
Assert the mock was never called.

```
>>> m = Mock()
>>> m.hello.assert_not_called()
>>> obj = m.hello()
>>> m.hello.assert_not_called()
Traceback (most recent call last):
  ...
AssertionError: Expected 'hello' to not have been called. Called 1 times.
```

New in version 3.5.

reset_mock(***, *return_value=False*, *side_effect=False*)
The reset_mock method resets all the call attributes on a mock object:

```
>>> mock = Mock(return_value=None)
>>> mock('hello')
>>> mock.called
True
>>> mock.reset_mock()
>>> mock.called
False
```

Changed in version 3.6: Added two keyword only argument to the reset_mock function.

This can be useful where you want to make a series of assertions that reuse the same object. Note that *reset_mock() doesn't* clear the return value, *side_effect* or any child attributes you have set using normal assignment by default. In case you want to reset *return_value* or *side_effect*,

then pass the corresponding parameter as `True`. Child mocks and the return value mock (if any) are reset as well.

Note: *return_value*, and *side_effect* are keyword only argument.

mock_add_spec(*spec*, *spec_set=False*)
Add a spec to a mock. *spec* can either be an object or a list of strings. Only attributes on the *spec* can be fetched as attributes from the mock.

If *spec_set* is true then only attributes on the spec can be set.

attach_mock(*mock*, *attribute*)
Attach a mock as an attribute of this one, replacing its name and parent. Calls to the attached mock will be recorded in the *method_calls* and *mock_calls* attributes of this one.

configure_mock(***kwargs*)
Set attributes on the mock through keyword arguments.

Attributes plus return values and side effects can be set on child mocks using standard dot notation and unpacking a dictionary in the method call:

```
>>> mock = Mock()
>>> attrs = {'method.return_value': 3, 'other.side_effect': KeyError}
>>> mock.configure_mock(**attrs)
>>> mock.method()
3
>>> mock.other()
Traceback (most recent call last):
  ...
KeyError
```

The same thing can be achieved in the constructor call to mocks:

```
>>> attrs = {'method.return_value': 3, 'other.side_effect': KeyError}
>>> mock = Mock(some_attribute='eggs', **attrs)
>>> mock.some_attribute
'eggs'
>>> mock.method()
3
>>> mock.other()
Traceback (most recent call last):
  ...
KeyError
```

configure_mock() exists to make it easier to do configuration after the mock has been created.

__dir__()
Mock objects limit the results of `dir(some_mock)` to useful results. For mocks with a *spec* this includes all the permitted attributes for the mock.

See *FILTER_DIR* for what this filtering does, and how to switch it off.

_get_child_mock(***kw*)
Create the child mocks for attributes and return value. By default child mocks will be the same type as the parent. Subclasses of Mock may want to override this to customize the way child mocks are made.

For non-callable mocks the callable variant will be used (rather than any custom subclass).

called
A boolean representing whether or not the mock object has been called:

```
>>> mock = Mock(return_value=None)
>>> mock.called
False
>>> mock()
>>> mock.called
True
```

call_count

An integer telling you how many times the mock object has been called:

```
>>> mock = Mock(return_value=None)
>>> mock.call_count
0
>>> mock()
>>> mock()
>>> mock.call_count
2
```

return_value

Set this to configure the value returned by calling the mock:

```
>>> mock = Mock()
>>> mock.return_value = 'fish'
>>> mock()
'fish'
```

The default return value is a mock object and you can configure it in the normal way:

```
>>> mock = Mock()
>>> mock.return_value.attribute = sentinel.Attribute
>>> mock.return_value()
<Mock name='mock()()' id='...'>
>>> mock.return_value.assert_called_with()
```

return_value can also be set in the constructor:

```
>>> mock = Mock(return_value=3)
>>> mock.return_value
3
>>> mock()
3
```

side_effect

This can either be a function to be called when the mock is called, an iterable or an exception (class or instance) to be raised.

If you pass in a function it will be called with same arguments as the mock and unless the function returns the *DEFAULT* singleton the call to the mock will then return whatever the function returns. If the function returns *DEFAULT* then the mock will return its normal value (from the *return_value*).

If you pass in an iterable, it is used to retrieve an iterator which must yield a value on every call. This value can either be an exception instance to be raised, or a value to be returned from the call to the mock (*DEFAULT* handling is identical to the function case).

An example of a mock that raises an exception (to test exception handling of an API):

```
>>> mock = Mock()
>>> mock.side_effect = Exception('Boom!')
>>> mock()
Traceback (most recent call last):
  ...
Exception: Boom!
```

Using *side_effect* to return a sequence of values:

```
>>> mock = Mock()
>>> mock.side_effect = [3, 2, 1]
>>> mock(), mock(), mock()
(3, 2, 1)
```

Using a callable:

```
>>> mock = Mock(return_value=3)
>>> def side_effect(*args, **kwargs):
...     return DEFAULT
...
>>> mock.side_effect = side_effect
>>> mock()
3
```

side_effect can be set in the constructor. Here's an example that adds one to the value the mock is called with and returns it:

```
>>> side_effect = lambda value: value + 1
>>> mock = Mock(side_effect=side_effect)
>>> mock(3)
4
>>> mock(-8)
-7
```

Setting *side_effect* to `None` clears it:

```
>>> m = Mock(side_effect=KeyError, return_value=3)
>>> m()
Traceback (most recent call last):
 ...
KeyError
>>> m.side_effect = None
>>> m()
3
```

call_args

This is either `None` (if the mock hasn't been called), or the arguments that the mock was last called with. This will be in the form of a tuple: the first member is any ordered arguments the mock was called with (or an empty tuple) and the second member is any keyword arguments (or an empty dictionary).

```
>>> mock = Mock(return_value=None)
>>> print(mock.call_args)
None
>>> mock()
>>> mock.call_args
call()
```

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```
>>> mock.call_args == ()
True
>>> mock(3, 4)
>>> mock.call_args
call(3, 4)
>>> mock.call_args == ((3, 4),)
True
>>> mock(3, 4, 5, key='fish', next='w00t!')
>>> mock.call_args
call(3, 4, 5, key='fish', next='w00t!')
```

call_args, along with members of the lists *call_args_list*, *method_calls* and *mock_calls* are *call* objects. These are tuples, so they can be unpacked to get at the individual arguments and make more complex assertions. See *calls as tuples*.

call_args_list

This is a list of all the calls made to the mock object in sequence (so the length of the list is the number of times it has been called). Before any calls have been made it is an empty list. The *call* object can be used for conveniently constructing lists of calls to compare with *call_args_list*.

```
>>> mock = Mock(return_value=None)
>>> mock()
>>> mock(3, 4)
>>> mock(key='fish', next='w00t!')
>>> mock.call_args_list
[call(), call(3, 4), call(key='fish', next='w00t!')]
>>> expected = [(), ((3, 4),), ({'key': 'fish', 'next': 'w00t!'},)]
>>> mock.call_args_list == expected
True
```

Members of *call_args_list* are *call* objects. These can be unpacked as tuples to get at the individual arguments. See *calls as tuples*.

method_calls

As well as tracking calls to themselves, mocks also track calls to methods and attributes, and *their* methods and attributes:

```
>>> mock = Mock()
>>> mock.method()
<Mock name='mock.method()' id='...'>
>>> mock.property.method.attribute()
<Mock name='mock.property.method.attribute()' id='...'>
>>> mock.method_calls
[call.method(), call.property.method.attribute()]
```

Members of *method_calls* are *call* objects. These can be unpacked as tuples to get at the individual arguments. See *calls as tuples*.

mock_calls

mock_calls records *all* calls to the mock object, its methods, magic methods *and* return value mocks.

```
>>> mock = MagicMock()
>>> result = mock(1, 2, 3)
>>> mock.first(a=3)
<MagicMock name='mock.first()' id='...'>
>>> mock.second()
```

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```
<MagicMock name='mock.second()' id='...'>
>>> int(mock)
1
>>> result(1)
<MagicMock name='mock()()' id='...'>
>>> expected = [call(1, 2, 3), call.first(a=3), call.second(),
... call.__int__(), call()(1)]
>>> mock.mock_calls == expected
True
```

Members of *mock_calls* are *call* objects. These can be unpacked as tuples to get at the individual arguments. See *calls as tuples*.

__class__

Normally the *__class__* attribute of an object will return its type. For a mock object with a `spec`, `__class__` returns the spec class instead. This allows mock objects to pass *isinstance()* tests for the object they are replacing / masquerading as:

```
>>> mock = Mock(spec=3)
>>> isinstance(mock, int)
True
```

__class__ is assignable to, this allows a mock to pass an *isinstance()* check without forcing you to use a spec:

```
>>> mock = Mock()
>>> mock.__class__ = dict
>>> isinstance(mock, dict)
True
```

class unittest.mock.NonCallableMock(*spec=None*, *wraps=None*, *name=None*, *spec_set=None*, ***kwargs*)

A non-callable version of *Mock*. The constructor parameters have the same meaning of *Mock*, with the exception of *return_value* and *side_effect* which have no meaning on a non-callable mock.

Mock objects that use a class or an instance as a `spec` or `spec_set` are able to pass *isinstance()* tests:

```
>>> mock = Mock(spec=SomeClass)
>>> isinstance(mock, SomeClass)
True
>>> mock = Mock(spec_set=SomeClass())
>>> isinstance(mock, SomeClass)
True
```

The *Mock* classes have support for mocking magic methods. See *magic methods* for the full details.

The mock classes and the *patch()* decorators all take arbitrary keyword arguments for configuration. For the *patch()* decorators the keywords are passed to the constructor of the mock being created. The keyword arguments are for configuring attributes of the mock:

```
>>> m = MagicMock(attribute=3, other='fish')
>>> m.attribute
3
>>> m.other
'fish'
```

The return value and side effect of child mocks can be set in the same way, using dotted notation. As you can't use dotted names directly in a call you have to create a dictionary and unpack it using `**`:

```
>>> attrs = {'method.return_value': 3, 'other.side_effect': KeyError}
>>> mock = Mock(some_attribute='eggs', **attrs)
>>> mock.some_attribute
'eggs'
>>> mock.method()
3
>>> mock.other()
Traceback (most recent call last):
  ...
KeyError
```

A callable mock which was created with a *spec* (or a *spec_set*) will introspect the specification object's signature when matching calls to the mock. Therefore, it can match the actual call's arguments regardless of whether they were passed positionally or by name:

```
>>> def f(a, b, c): pass
...
>>> mock = Mock(spec=f)
>>> mock(1, 2, c=3)
<Mock name='mock()' id='140161580456576'>
>>> mock.assert_called_with(1, 2, 3)
>>> mock.assert_called_with(a=1, b=2, c=3)
```

This applies to *assert_called_with()*, *assert_called_once_with()*, *assert_has_calls()* and *assert_any_call()*. When *Autospeccing*, it will also apply to method calls on the mock object.

Changed in version 3.4: Added signature introspection on specced and autospecced mock objects.

class unittest.mock.PropertyMock(**args*, ***kwargs*)

A mock intended to be used as a property, or other descriptor, on a class. *PropertyMock* provides `__get__()` and `__set__()` methods so you can specify a return value when it is fetched.

Fetching a *PropertyMock* instance from an object calls the mock, with no args. Setting it calls the mock with the value being set.

```
>>> class Foo:
...     @property
...     def foo(self):
...         return 'something'
...     @foo.setter
...     def foo(self, value):
...         pass
...
>>> with patch('__main__.Foo.foo', new_callable=PropertyMock) as mock_foo:
...     mock_foo.return_value = 'mockity-mock'
...     this_foo = Foo()
...     print(this_foo.foo)
...     this_foo.foo = 6
...
mockity-mock
>>> mock_foo.mock_calls
[call(), call(6)]
```

Because of the way mock attributes are stored you can't directly attach a *PropertyMock* to a mock object. Instead you can attach it to the mock type object:

```
>>> m = MagicMock()
>>> p = PropertyMock(return_value=3)
```

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```
>>> type(m).foo = p
>>> m.foo
3
>>> p.assert_called_once_with()
```

Calling

Mock objects are callable. The call will return the value set as the *return_value* attribute. The default return value is a new Mock object; it is created the first time the return value is accessed (either explicitly or by calling the Mock) - but it is stored and the same one returned each time.

Calls made to the object will be recorded in the attributes like *call_args* and *call_args_list*.

If *side_effect* is set then it will be called after the call has been recorded, so if `side_effect` raises an exception the call is still recorded.

The simplest way to make a mock raise an exception when called is to make *side_effect* an exception class or instance:

```
>>> m = MagicMock(side_effect=IndexError)
>>> m(1, 2, 3)
Traceback (most recent call last):
  ...
IndexError
>>> m.mock_calls
[call(1, 2, 3)]
>>> m.side_effect = KeyError('Bang!')
>>> m('two', 'three', 'four')
Traceback (most recent call last):
  ...
KeyError: 'Bang!'
>>> m.mock_calls
[call(1, 2, 3), call('two', 'three', 'four')]
```

If `side_effect` is a function then whatever that function returns is what calls to the mock return. The `side_effect` function is called with the same arguments as the mock. This allows you to vary the return value of the call dynamically, based on the input:

```
>>> def side_effect(value):
...     return value + 1
...
>>> m = MagicMock(side_effect=side_effect)
>>> m(1)
2
>>> m(2)
3
>>> m.mock_calls
[call(1), call(2)]
```

If you want the mock to still return the default return value (a new mock), or any set return value, then there are two ways of doing this. Either return `mock.return_value` from inside `side_effect`, or return *DEFAULT*:

```
>>> m = MagicMock()
>>> def side_effect(*args, **kwargs):
...     return m.return_value
```

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```
...
>>> m.side_effect = side_effect
>>> m.return_value = 3
>>> m()
3
>>> def side_effect(*args, **kwargs):
...     return DEFAULT
...
>>> m.side_effect = side_effect
>>> m()
3
```

To remove a `side_effect`, and return to the default behaviour, set the `side_effect` to `None`:

```
>>> m = MagicMock(return_value=6)
>>> def side_effect(*args, **kwargs):
...     return 3
...
>>> m.side_effect = side_effect
>>> m()
3
>>> m.side_effect = None
>>> m()
6
```

The `side_effect` can also be any iterable object. Repeated calls to the mock will return values from the iterable (until the iterable is exhausted and a *StopIteration* is raised):

```
>>> m = MagicMock(side_effect=[1, 2, 3])
>>> m()
1
>>> m()
2
>>> m()
3
>>> m()
Traceback (most recent call last):
  ...
StopIteration
```

If any members of the iterable are exceptions they will be raised instead of returned:

```
>>> iterable = (33, ValueError, 66)
>>> m = MagicMock(side_effect=iterable)
>>> m()
33
>>> m()
Traceback (most recent call last):
 ...
ValueError
>>> m()
66
```

Deleting Attributes

Mock objects create attributes on demand. This allows them to pretend to be objects of any type.

You may want a mock object to return `False` to a *hasattr()* call, or raise an *AttributeError* when an attribute is fetched. You can do this by providing an object as a `spec` for a mock, but that isn't always convenient.

You "block" attributes by deleting them. Once deleted, accessing an attribute will raise an *AttributeError*.

```
>>> mock = MagicMock()
>>> hasattr(mock, 'm')
True
>>> del mock.m
>>> hasattr(mock, 'm')
False
>>> del mock.f
>>> mock.f
Traceback (most recent call last):
    ...
AttributeError: f
```

Mock names and the name attribute

Since "name" is an argument to the *Mock* constructor, if you want your mock object to have a "name" attribute you can't just pass it in at creation time. There are two alternatives. One option is to use *configure_mock()*:

```
>>> mock = MagicMock()
>>> mock.configure_mock(name='my_name')
>>> mock.name
'my_name'
```

A simpler option is to simply set the "name" attribute after mock creation:

```
>>> mock = MagicMock()
>>> mock.name = "foo"
```

Attaching Mocks as Attributes

When you attach a mock as an attribute of another mock (or as the return value) it becomes a "child" of that mock. Calls to the child are recorded in the *method_calls* and *mock_calls* attributes of the parent. This is useful for configuring child mocks and then attaching them to the parent, or for attaching mocks to a parent that records all calls to the children and allows you to make assertions about the order of calls between mocks:

```
>>> parent = MagicMock()
>>> child1 = MagicMock(return_value=None)
>>> child2 = MagicMock(return_value=None)
>>> parent.child1 = child1
>>> parent.child2 = child2
>>> child1(1)
>>> child2(2)
>>> parent.mock_calls
[call.child1(1), call.child2(2)]
```

The exception to this is if the mock has a name. This allows you to prevent the "parenting" if for some reason you don't want it to happen.

```
>>> mock = MagicMock()
>>> not_a_child = MagicMock(name='not-a-child')
>>> mock.attribute = not_a_child
>>> mock.attribute()
<MagicMock name='not-a-child()' id='...'>
>>> mock.mock_calls
[]
```

Mocks created for you by *patch()* are automatically given names. To attach mocks that have names to a parent you use the *attach_mock()* method:

```
>>> thing1 = object()
>>> thing2 = object()
>>> parent = MagicMock()
>>> with patch('__main__.thing1', return_value=None) as child1:
...     with patch('__main__.thing2', return_value=None) as child2:
...         parent.attach_mock(child1, 'child1')
...         parent.attach_mock(child2, 'child2')
...         child1('one')
...         child2('two')
...
>>> parent.mock_calls
[call.child1('one'), call.child2('two')]
```

27.5.3 The patchers

The patch decorators are used for patching objects only within the scope of the function they decorate. They automatically handle the unpatching for you, even if exceptions are raised. All of these functions can also be used in with statements or as class decorators.

patch

Note: *patch()* is straightforward to use. The key is to do the patching in the right namespace. See the section *where to patch*.

---

unittest.mock.**patch**(*target*, *new=DEFAULT*, *spec=None*, *create=False*, *spec_set=None*, *autospec=None*, *new_callable=None*, ***kwargs*)

patch() acts as a function decorator, class decorator or a context manager. Inside the body of the function or with statement, the *target* is patched with a *new* object. When the function/with statement exits the patch is undone.

If *new* is omitted, then the target is replaced with a *MagicMock*. If *patch()* is used as a decorator and *new* is omitted, the created mock is passed in as an extra argument to the decorated function. If *patch()* is used as a context manager the created mock is returned by the context manager.

target should be a string in the form `'package.module.ClassName'`. The *target* is imported and the specified object replaced with the *new* object, so the *target* must be importable from the environment you are calling *patch()* from. The target is imported when the decorated function is executed, not at decoration time.

The *spec* and *spec_set* keyword arguments are passed to the *MagicMock* if patch is creating one for you.

In addition you can pass `spec=True` or `spec_set=True`, which causes patch to pass in the object being mocked as the spec/spec_set object.

new_callable allows you to specify a different class, or callable object, that will be called to create the *new* object. By default *MagicMock* is used.

A more powerful form of *spec* is *autospec*. If you set `autospec=True` then the mock will be created with a spec from the object being replaced. All attributes of the mock will also have the spec of the corresponding attribute of the object being replaced. Methods and functions being mocked will have their arguments checked and will raise a *TypeError* if they are called with the wrong signature. For mocks replacing a class, their return value (the 'instance') will have the same spec as the class. See the *create_autospec()* function and *Autospeccing*.

Instead of `autospec=True` you can pass `autospec=some_object` to use an arbitrary object as the spec instead of the one being replaced.

By default *patch()* will fail to replace attributes that don't exist. If you pass in `create=True`, and the attribute doesn't exist, patch will create the attribute for you when the patched function is called, and delete it again afterwards. This is useful for writing tests against attributes that your production code creates at runtime. It is off by default because it can be dangerous. With it switched on you can write passing tests against APIs that don't actually exist!

Note: Changed in version 3.5: If you are patching builtins in a module then you don't need to pass `create=True`, it will be added by default.

Patch can be used as a `TestCase` class decorator. It works by decorating each test method in the class. This reduces the boilerplate code when your test methods share a common patchings set. *patch()* finds tests by looking for method names that start with `patch.TEST_PREFIX`. By default this is `'test'`, which matches the way *unittest* finds tests. You can specify an alternative prefix by setting `patch.TEST_PREFIX`.

Patch can be used as a context manager, with the with statement. Here the patching applies to the indented block after the with statement. If you use "as" then the patched object will be bound to the name after the "as"; very useful if *patch()* is creating a mock object for you.

patch() takes arbitrary keyword arguments. These will be passed to the *Mock* (or *new_callable*) on construction.

`patch.dict(...)`, `patch.multiple(...)` and `patch.object(...)` are available for alternate use-cases.

patch() as function decorator, creating the mock for you and passing it into the decorated function:

```
>>> @patch('__main__.SomeClass')
... def function(normal_argument, mock_class):
...     print(mock_class is SomeClass)
...
>>> function(None)
True
```

Patching a class replaces the class with a *MagicMock* *instance*. If the class is instantiated in the code under test then it will be the *return_value* of the mock that will be used.

If the class is instantiated multiple times you could use *side_effect* to return a new mock each time. Alternatively you can set the *return_value* to be anything you want.

To configure return values on methods of *instances* on the patched class you must do this on the `return_value`. For example:

```
>>> class Class:
...     def method(self):
...         pass
```

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```
...
>>> with patch('__main__.Class') as MockClass:
...     instance = MockClass.return_value
...     instance.method.return_value = 'foo'
...     assert Class() is instance
...     assert Class().method() == 'foo'
...
```

If you use *spec* or *spec_set* and *patch()* is replacing a *class*, then the return value of the created mock will have the same spec.

```
>>> Original = Class
>>> patcher = patch('__main__.Class', spec=True)
>>> MockClass = patcher.start()
>>> instance = MockClass()
>>> assert isinstance(instance, Original)
>>> patcher.stop()
```

The *new_callable* argument is useful where you want to use an alternative class to the default *MagicMock* for the created mock. For example, if you wanted a *NonCallableMock* to be used:

```
>>> thing = object()
>>> with patch('__main__.thing', new_callable=NonCallableMock) as mock_thing:
...     assert thing is mock_thing
...     thing()
...
Traceback (most recent call last):
  ...
TypeError: 'NonCallableMock' object is not callable
```

Another use case might be to replace an object with an *io.StringIO* instance:

```
>>> from io import StringIO
>>> def foo():
...     print('Something')
...
>>> @patch('sys.stdout', new_callable=StringIO)
... def test(mock_stdout):
...     foo()
...     assert mock_stdout.getvalue() == 'Something\n'
...
>>> test()
```

When *patch()* is creating a mock for you, it is common that the first thing you need to do is to configure the mock. Some of that configuration can be done in the call to patch. Any arbitrary keywords you pass into the call will be used to set attributes on the created mock:

```
>>> patcher = patch('__main__.thing', first='one', second='two')
>>> mock_thing = patcher.start()
>>> mock_thing.first
'one'
>>> mock_thing.second
'two'
```

As well as attributes on the created mock attributes, like the *return_value* and *side_effect*, of child mocks can also be configured. These aren't syntactically valid to pass in directly as keyword arguments, but a dictionary with these as keys can still be expanded into a *patch()* call using **:

```
>>> config = {'method.return_value': 3, 'other.side_effect': KeyError}
>>> patcher = patch('__main__.thing', **config)
>>> mock_thing = patcher.start()
>>> mock_thing.method()
3
>>> mock_thing.other()
Traceback (most recent call last):
  ...
KeyError
```

patch.object

patch.object(*target*, *attribute*, *new=DEFAULT*, *spec=None*, *create=False*, *spec_set=None*, *autospec=None*, *new_callable=None*, ***kwargs*)

patch the named member (*attribute*) on an object (*target*) with a mock object.

patch.object() can be used as a decorator, class decorator or a context manager. Arguments *new*, *spec*, *create*, *spec_set*, *autospec* and *new_callable* have the same meaning as for *patch()*. Like *patch()*, *patch.object()* takes arbitrary keyword arguments for configuring the mock object it creates.

When used as a class decorator *patch.object()* honours `patch.TEST_PREFIX` for choosing which methods to wrap.

You can either call *patch.object()* with three arguments or two arguments. The three argument form takes the object to be patched, the attribute name and the object to replace the attribute with.

When calling with the two argument form you omit the replacement object, and a mock is created for you and passed in as an extra argument to the decorated function:

```
>>> @patch.object(SomeClass, 'class_method')
... def test(mock_method):
...     SomeClass.class_method(3)
...     mock_method.assert_called_with(3)
...
>>> test()
```

spec, *create* and the other arguments to *patch.object()* have the same meaning as they do for *patch()*.

patch.dict

patch.dict(*in_dict*, *values=()*, *clear=False*, ***kwargs*)

Patch a dictionary, or dictionary like object, and restore the dictionary to its original state after the test.

in_dict can be a dictionary or a mapping like container. If it is a mapping then it must at least support getting, setting and deleting items plus iterating over keys.

in_dict can also be a string specifying the name of the dictionary, which will then be fetched by importing it.

values can be a dictionary of values to set in the dictionary. *values* can also be an iterable of `(key, value)` pairs.

If *clear* is true then the dictionary will be cleared before the new values are set.

patch.dict() can also be called with arbitrary keyword arguments to set values in the dictionary.

patch.dict() can be used as a context manager, decorator or class decorator. When used as a class decorator *patch.dict()* honours `patch.TEST_PREFIX` for choosing which methods to wrap.

patch.dict() can be used to add members to a dictionary, or simply let a test change a dictionary, and ensure the dictionary is restored when the test ends.

```
>>> foo = {}
>>> with patch.dict(foo, {'newkey': 'newvalue'}):
...     assert foo == {'newkey': 'newvalue'}
...
>>> assert foo == {}
```

```
>>> import os
>>> with patch.dict('os.environ', {'newkey': 'newvalue'}):
...     print(os.environ['newkey'])
...
newvalue
>>> assert 'newkey' not in os.environ
```

Keywords can be used in the *patch.dict()* call to set values in the dictionary:

```
>>> mymodule = MagicMock()
>>> mymodule.function.return_value = 'fish'
>>> with patch.dict('sys.modules', mymodule=mymodule):
...     import mymodule
...     mymodule.function('some', 'args')
...
'fish'
```

patch.dict() can be used with dictionary like objects that aren't actually dictionaries. At the very minimum they must support item getting, setting, deleting and either iteration or membership test. This corresponds to the magic methods `__getitem__()`, `__setitem__()`, `__delitem__()` and either `__iter__()` or `__contains__()`.

```
>>> class Container:
...     def __init__(self):
...         self.values = {}
...     def __getitem__(self, name):
...         return self.values[name]
...     def __setitem__(self, name, value):
...         self.values[name] = value
...     def __delitem__(self, name):
...         del self.values[name]
...     def __iter__(self):
...         return iter(self.values)
...
>>> thing = Container()
>>> thing['one'] = 1
>>> with patch.dict(thing, one=2, two=3):
...     assert thing['one'] == 2
...     assert thing['two'] == 3
...
>>> assert thing['one'] == 1
>>> assert list(thing) == ['one']
```

patch.multiple

patch.multiple(*target*, *spec=None*, *create=False*, *spec_set=None*, *autospec=None*, *new_callable=None*, ***kwargs*)

Perform multiple patches in a single call. It takes the object to be patched (either as an object or a

string to fetch the object by importing) and keyword arguments for the patches:

```
with patch.multiple(settings, FIRST_PATCH='one', SECOND_PATCH='two'):
    ...
```

Use *DEFAULT* as the value if you want *patch.multiple()* to create mocks for you. In this case the created mocks are passed into a decorated function by keyword, and a dictionary is returned when *patch.multiple()* is used as a context manager.

patch.multiple() can be used as a decorator, class decorator or a context manager. The arguments *spec*, *spec_set*, *create*, *autospec* and *new_callable* have the same meaning as for *patch()*. These arguments will be applied to *all* patches done by *patch.multiple()*.

When used as a class decorator *patch.multiple()* honours `patch.TEST_PREFIX` for choosing which methods to wrap.

If you want *patch.multiple()* to create mocks for you, then you can use *DEFAULT* as the value. If you use *patch.multiple()* as a decorator then the created mocks are passed into the decorated function by keyword.

```
>>> thing = object()
>>> other = object()
```

```
>>> @patch.multiple('__main__', thing=DEFAULT, other=DEFAULT)
... def test_function(thing, other):
...     assert isinstance(thing, MagicMock)
...     assert isinstance(other, MagicMock)
...
>>> test_function()
```

patch.multiple() can be nested with other `patch` decorators, but put arguments passed by keyword *after* any of the standard arguments created by *patch()*:

```
>>> @patch('sys.exit')
... @patch.multiple('__main__', thing=DEFAULT, other=DEFAULT)
... def test_function(mock_exit, other, thing):
...     assert 'other' in repr(other)
...     assert 'thing' in repr(thing)
...     assert 'exit' in repr(mock_exit)
...
>>> test_function()
```

If *patch.multiple()* is used as a context manager, the value returned by the context manger is a dictionary where created mocks are keyed by name:

```
>>> with patch.multiple('__main__', thing=DEFAULT, other=DEFAULT) as values:
...     assert 'other' in repr(values['other'])
...     assert 'thing' in repr(values['thing'])
...     assert values['thing'] is thing
...     assert values['other'] is other
...
```

patch methods: start and stop

All the patchers have `start()` and `stop()` methods. These make it simpler to do patching in `setUp` methods or where you want to do multiple patches without nesting decorators or with statements.

To use them call *patch()*, *patch.object()* or *patch.dict()* as normal and keep a reference to the returned `patcher` object. You can then call `start()` to put the patch in place and `stop()` to undo it.

If you are using *patch()* to create a mock for you then it will be returned by the call to `patcher.start`.

```
>>> patcher = patch('package.module.ClassName')
>>> from package import module
>>> original = module.ClassName
>>> new_mock = patcher.start()
>>> assert module.ClassName is not original
>>> assert module.ClassName is new_mock
>>> patcher.stop()
>>> assert module.ClassName is original
>>> assert module.ClassName is not new_mock
```

A typical use case for this might be for doing multiple patches in the `setUp` method of a `TestCase`:

```
>>> class MyTest(TestCase):
...     def setUp(self):
...         self.patcher1 = patch('package.module.Class1')
...         self.patcher2 = patch('package.module.Class2')
...         self.MockClass1 = self.patcher1.start()
...         self.MockClass2 = self.patcher2.start()
...
...     def tearDown(self):
...         self.patcher1.stop()
...         self.patcher2.stop()
...
...     def test_something(self):
...         assert package.module.Class1 is self.MockClass1
...         assert package.module.Class2 is self.MockClass2
...
>>> MyTest('test_something').run()
```

Caution: If you use this technique you must ensure that the patching is "undone" by calling `stop`. This can be fiddlier than you might think, because if an exception is raised in the `setUp` then `tearDown` is not called. *unittest.TestCase.addCleanup()* makes this easier:

```
>>> class MyTest(TestCase):
...     def setUp(self):
...         patcher = patch('package.module.Class')
...         self.MockClass = patcher.start()
...         self.addCleanup(patcher.stop)
...
...     def test_something(self):
...         assert package.module.Class is self.MockClass
...
```

As an added bonus you no longer need to keep a reference to the `patcher` object.

It is also possible to stop all patches which have been started by using *patch.stopall()*.

`patch.stopall()`
Stop all active patches. Only stops patches started with `start`.

patch builtins

You can patch any builtins within a module. The following example patches builtin *ord()*:

```
>>> @patch('__main__.ord')
... def test(mock_ord):
...     mock_ord.return_value = 101
...     print(ord('c'))
...
>>> test()
101
```

TEST_PREFIX

All of the patchers can be used as class decorators. When used in this way they wrap every test method on the class. The patchers recognise methods that start with `'test'` as being test methods. This is the same way that the *unittest.TestLoader* finds test methods by default.

It is possible that you want to use a different prefix for your tests. You can inform the patchers of the different prefix by setting `patch.TEST_PREFIX`:

```
>>> patch.TEST_PREFIX = 'foo'
>>> value = 3
>>>
>>> @patch('__main__.value', 'not three')
... class Thing:
...     def foo_one(self):
...         print(value)
...     def foo_two(self):
...         print(value)
...
>>>
>>> Thing().foo_one()
not three
>>> Thing().foo_two()
not three
>>> value
3
```

Nesting Patch Decorators

If you want to perform multiple patches then you can simply stack up the decorators.

You can stack up multiple patch decorators using this pattern:

```
>>> @patch.object(SomeClass, 'class_method')
... @patch.object(SomeClass, 'static_method')
... def test(mock1, mock2):
...     assert SomeClass.static_method is mock1
...     assert SomeClass.class_method is mock2
...     SomeClass.static_method('foo')
...     SomeClass.class_method('bar')
...     return mock1, mock2
...
>>> mock1, mock2 = test()
```

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```
>>> mock1.assert_called_once_with('foo')
>>> mock2.assert_called_once_with('bar')
```

Note that the decorators are applied from the bottom upwards. This is the standard way that Python applies decorators. The order of the created mocks passed into your test function matches this order.

Where to patch

patch() works by (temporarily) changing the object that a *name* points to with another one. There can be many names pointing to any individual object, so for patching to work you must ensure that you patch the name used by the system under test.

The basic principle is that you patch where an object is *looked up*, which is not necessarily the same place as where it is defined. A couple of examples will help to clarify this.

Imagine we have a project that we want to test with the following structure:

```
a.py
    -> Defines SomeClass

b.py
    -> from a import SomeClass
    -> some_function instantiates SomeClass
```

Now we want to test `some_function` but we want to mock out `SomeClass` using *patch()*. The problem is that when we import module b, which we will have to do then it imports `SomeClass` from module a. If we use *patch()* to mock out `a.SomeClass` then it will have no effect on our test; module b already has a reference to the *real* `SomeClass` and it looks like our patching had no effect.

The key is to patch out `SomeClass` where it is used (or where it is looked up). In this case `some_function` will actually look up `SomeClass` in module b, where we have imported it. The patching should look like:

```
@patch('b.SomeClass')
```

However, consider the alternative scenario where instead of `from a import SomeClass` module b does `import a` and `some_function` uses `a.SomeClass`. Both of these import forms are common. In this case the class we want to patch is being looked up in the module and so we have to patch `a.SomeClass` instead:

```
@patch('a.SomeClass')
```

Patching Descriptors and Proxy Objects

Both *patch* and *patch.object* correctly patch and restore descriptors: class methods, static methods and properties. You should patch these on the *class* rather than an instance. They also work with *some* objects that proxy attribute access, like the django settings object.

27.5.4 MagicMock and magic method support

Mocking Magic Methods

Mock supports mocking the Python protocol methods, also known as "magic methods". This allows mock objects to replace containers or other objects that implement Python protocols.

Because magic methods are looked up differently from normal methods[2], this support has been specially implemented. This means that only specific magic methods are supported. The supported list includes *almost* all of them. If there are any missing that you need please let us know.

You mock magic methods by setting the method you are interested in to a function or a mock instance. If you are using a function then it *must* take `self` as the first argument[3].

```
>>> def __str__(self):
...     return 'fooble'
...
>>> mock = Mock()
>>> mock.__str__ = __str__
>>> str(mock)
'fooble'
```

```
>>> mock = Mock()
>>> mock.__str__ = Mock()
>>> mock.__str__.return_value = 'fooble'
>>> str(mock)
'fooble'
```

```
>>> mock = Mock()
>>> mock.__iter__ = Mock(return_value=iter([]))
>>> list(mock)
[]
```

One use case for this is for mocking objects used as context managers in a `with` statement:

```
>>> mock = Mock()
>>> mock.__enter__ = Mock(return_value='foo')
>>> mock.__exit__ = Mock(return_value=False)
>>> with mock as m:
...     assert m == 'foo'
...
>>> mock.__enter__.assert_called_with()
>>> mock.__exit__.assert_called_with(None, None, None)
```

Calls to magic methods do not appear in *method_calls*, but they are recorded in *mock_calls*.

Note: If you use the *spec* keyword argument to create a mock then attempting to set a magic method that isn't in the spec will raise an *AttributeError*.

The full list of supported magic methods is:

- `__hash__`, `__sizeof__`, `__repr__` and `__str__`
- `__dir__`, `__format__` and `__subclasses__`
- `__floor__`, `__trunc__` and `__ceil__`
- Comparisons: `__lt__`, `__gt__`, `__le__`, `__ge__`, `__eq__` and `__ne__`
- Container methods: `__getitem__`, `__setitem__`, `__delitem__`, `__contains__`, `__len__`, `__iter__`, `__reversed__` and `__missing__`
- Context manager: `__enter__` and `__exit__`

[2] Magic methods *should* be looked up on the class rather than the instance. Different versions of Python are inconsistent about applying this rule. The supported protocol methods should work with all supported versions of Python.

[3] The function is basically hooked up to the class, but each `Mock` instance is kept isolated from the others.

- Unary numeric methods: `__neg__`, `__pos__` and `__invert__`
- The numeric methods (including right hand and in-place variants): `__add__`, `__sub__`, `__mul__`, `__matmul__`, `__div__`, `__truediv__`, `__floordiv__`, `__mod__`, `__divmod__`, `__lshift__`, `__rshift__`, `__and__`, `__xor__`, `__or__`, and `__pow__`
- Numeric conversion methods: `__complex__`, `__int__`, `__float__` and `__index__`
- Descriptor methods: `__get__`, `__set__` and `__delete__`
- Pickling: `__reduce__`, `__reduce_ex__`, `__getinitargs__`, `__getnewargs__`, `__getstate__` and `__setstate__`

The following methods exist but are *not* supported as they are either in use by mock, can't be set dynamically, or can cause problems:

- `__getattr__`, `__setattr__`, `__init__` and `__new__`
- `__prepare__`, `__instancecheck__`, `__subclasscheck__`, `__del__`

Magic Mock

There are two `MagicMock` variants: *MagicMock* and *NonCallableMagicMock*.

class unittest.mock.MagicMock(**args*, ***kw*)

`MagicMock` is a subclass of *Mock* with default implementations of most of the magic methods. You can use `MagicMock` without having to configure the magic methods yourself.

The constructor parameters have the same meaning as for *Mock*.

If you use the *spec* or *spec_set* arguments then *only* magic methods that exist in the spec will be created.

class unittest.mock.NonCallableMagicMock(**args*, ***kw*)

A non-callable version of *MagicMock*.

The constructor parameters have the same meaning as for *MagicMock*, with the exception of *return_value* and *side_effect* which have no meaning on a non-callable mock.

The magic methods are setup with *MagicMock* objects, so you can configure them and use them in the usual way:

```
>>> mock = MagicMock()
>>> mock[3] = 'fish'
>>> mock.__setitem__.assert_called_with(3, 'fish')
>>> mock.__getitem__.return_value = 'result'
>>> mock[2]
'result'
```

By default many of the protocol methods are required to return objects of a specific type. These methods are preconfigured with a default return value, so that they can be used without you having to do anything if you aren't interested in the return value. You can still *set* the return value manually if you want to change the default.

Methods and their defaults:

- `__lt__`: NotImplemented
- `__gt__`: NotImplemented
- `__le__`: NotImplemented
- `__ge__`: NotImplemented
- `__int__`: 1

- `__contains__`: False
- `__len__`: 0
- `__iter__`: iter([])
- `__exit__`: False
- `__complex__`: 1j
- `__float__`: 1.0
- `__bool__`: True
- `__index__`: 1
- `__hash__`: default hash for the mock
- `__str__`: default str for the mock
- `__sizeof__`: default sizeof for the mock

For example:

```
>>> mock = MagicMock()
>>> int(mock)
1
>>> len(mock)
0
>>> list(mock)
[]
>>> object() in mock
False
```

The two equality methods, `__eq__()` and `__ne__()`, are special. They do the default equality comparison on identity, using the *side_effect* attribute, unless you change their return value to return something else:

```
>>> MagicMock() == 3
False
>>> MagicMock() != 3
True
>>> mock = MagicMock()
>>> mock.__eq__.return_value = True
>>> mock == 3
True
```

The return value of `MagicMock.__iter__()` can be any iterable object and isn't required to be an iterator:

```
>>> mock = MagicMock()
>>> mock.__iter__.return_value = ['a', 'b', 'c']
>>> list(mock)
['a', 'b', 'c']
>>> list(mock)
['a', 'b', 'c']
```

If the return value *is* an iterator, then iterating over it once will consume it and subsequent iterations will result in an empty list:

```
>>> mock.__iter__.return_value = iter(['a', 'b', 'c'])
>>> list(mock)
['a', 'b', 'c']
>>> list(mock)
[]
```

MagicMock has all of the supported magic methods configured except for some of the obscure and obsolete ones. You can still set these up if you want.

Magic methods that are supported but not setup by default in MagicMock are:

- __subclasses__
- __dir__
- __format__
- __get__, __set__ and __delete__
- __reversed__ and __missing__
- __reduce__, __reduce_ex__, __getinitargs__, __getnewargs__, __getstate__ and __setstate__
- __getformat__ and __setformat__

27.5.5 Helpers

sentinel

unittest.mock.**sentinel**

The sentinel object provides a convenient way of providing unique objects for your tests.

Attributes are created on demand when you access them by name. Accessing the same attribute will always return the same object. The objects returned have a sensible repr so that test failure messages are readable.

Changed in version 3.7: The sentinel attributes now preserve their identity when they are *copied* or *pickled*.

Sometimes when testing you need to test that a specific object is passed as an argument to another method, or returned. It can be common to create named sentinel objects to test this. *sentinel* provides a convenient way of creating and testing the identity of objects like this.

In this example we monkey patch method to return sentinel.some_object:

```
>>> real = ProductionClass()
>>> real.method = Mock(name="method")
>>> real.method.return_value = sentinel.some_object
>>> result = real.method()
>>> assert result is sentinel.some_object
>>> sentinel.some_object
sentinel.some_object
```

DEFAULT

unittest.mock.**DEFAULT**

The *DEFAULT* object is a pre-created sentinel (actually sentinel.DEFAULT). It can be used by *side_effect* functions to indicate that the normal return value should be used.

call

unittest.mock.**call**(**args*, ***kwargs*)

call() is a helper object for making simpler assertions, for comparing with *call_args*, *call_args_list*, *mock_calls* and *method_calls*. *call()* can also be used with *assert_has_calls()*.

```
>>> m = MagicMock(return_value=None)
>>> m(1, 2, a='foo', b='bar')
>>> m()
>>> m.call_args_list == [call(1, 2, a='foo', b='bar'), call()]
True
```

`call.call_list()`
: For a call object that represents multiple calls, *call_list()* returns a list of all the intermediate calls as well as the final call.

`call_list` is particularly useful for making assertions on "chained calls". A chained call is multiple calls on a single line of code. This results in multiple entries in *mock_calls* on a mock. Manually constructing the sequence of calls can be tedious.

call_list() can construct the sequence of calls from the same chained call:

```
>>> m = MagicMock()
>>> m(1).method(arg='foo').other('bar')(2.0)
<MagicMock name='mock().method().other()()' id='...'>
>>> kall = call(1).method(arg='foo').other('bar')(2.0)
>>> kall.call_list()
[call(1),
 call().method(arg='foo'),
 call().method().other('bar'),
 call().method().other()(2.0)]
>>> m.mock_calls == kall.call_list()
True
```

A `call` object is either a tuple of (positional args, keyword args) or (name, positional args, keyword args) depending on how it was constructed. When you construct them yourself this isn't particularly interesting, but the `call` objects that are in the *Mock.call_args*, *Mock.call_args_list* and *Mock.mock_calls* attributes can be introspected to get at the individual arguments they contain.

The `call` objects in *Mock.call_args* and *Mock.call_args_list* are two-tuples of (positional args, keyword args) whereas the `call` objects in *Mock.mock_calls*, along with ones you construct yourself, are three-tuples of (name, positional args, keyword args).

You can use their "tupleness" to pull out the individual arguments for more complex introspection and assertions. The positional arguments are a tuple (an empty tuple if there are no positional arguments) and the keyword arguments are a dictionary:

```
>>> m = MagicMock(return_value=None)
>>> m(1, 2, 3, arg='one', arg2='two')
>>> kall = m.call_args
>>> args, kwargs = kall
>>> args
(1, 2, 3)
>>> kwargs
{'arg2': 'two', 'arg': 'one'}
>>> args is kall[0]
True
>>> kwargs is kall[1]
True
```

```
>>> m = MagicMock()
>>> m.foo(4, 5, 6, arg='two', arg2='three')
<MagicMock name='mock.foo()' id='...'>
>>> kall = m.mock_calls[0]
```

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```
>>> name, args, kwargs = kall
>>> name
'foo'
>>> args
(4, 5, 6)
>>> kwargs
{'arg2': 'three', 'arg': 'two'}
>>> name is m.mock_calls[0][0]
True
```

create_autospec

unittest.mock.**create_autospec**(*spec*, *spec_set=False*, *instance=False*, ***kwargs*)

Create a mock object using another object as a spec. Attributes on the mock will use the corresponding attribute on the *spec* object as their spec.

Functions or methods being mocked will have their arguments checked to ensure that they are called with the correct signature.

If *spec_set* is `True` then attempting to set attributes that don't exist on the spec object will raise an *AttributeError*.

If a class is used as a spec then the return value of the mock (the instance of the class) will have the same spec. You can use a class as the spec for an instance object by passing `instance=True`. The returned mock will only be callable if instances of the mock are callable.

create_autospec() also takes arbitrary keyword arguments that are passed to the constructor of the created mock.

See *Autospeccing* for examples of how to use auto-speccing with *create_autospec()* and the *autospec* argument to *patch()*.

ANY

unittest.mock.**ANY**

Sometimes you may need to make assertions about *some* of the arguments in a call to mock, but either not care about some of the arguments or want to pull them individually out of *call_args* and make more complex assertions on them.

To ignore certain arguments you can pass in objects that compare equal to *everything*. Calls to *assert_called_with()* and *assert_called_once_with()* will then succeed no matter what was passed in.

```
>>> mock = Mock(return_value=None)
>>> mock('foo', bar=object())
>>> mock.assert_called_once_with('foo', bar=ANY)
```

ANY can also be used in comparisons with call lists like *mock_calls*:

```
>>> m = MagicMock(return_value=None)
>>> m(1)
>>> m(1, 2)
>>> m(object())
>>> m.mock_calls == [call(1), call(1, 2), ANY]
True
```

FILTER_DIR

unittest.mock.FILTER_DIR

FILTER_DIR is a module level variable that controls the way mock objects respond to *dir()* (only for Python 2.6 or more recent). The default is `True`, which uses the filtering described below, to only show useful members. If you dislike this filtering, or need to switch it off for diagnostic purposes, then set `mock.FILTER_DIR = False`.

With filtering on, `dir(some_mock)` shows only useful attributes and will include any dynamically created attributes that wouldn't normally be shown. If the mock was created with a *spec* (or *autospec* of course) then all the attributes from the original are shown, even if they haven't been accessed yet:

```
>>> dir(Mock())
['assert_any_call',
 'assert_called_once_with',
 'assert_called_with',
 'assert_has_calls',
 'attach_mock',
 ...
>>> from urllib import request
>>> dir(Mock(spec=request))
['AbstractBasicAuthHandler',
 'AbstractDigestAuthHandler',
 'AbstractHTTPHandler',
 'BaseHandler',
 ...
```

Many of the not-very-useful (private to *Mock* rather than the thing being mocked) underscore and double underscore prefixed attributes have been filtered from the result of calling *dir()* on a *Mock*. If you dislike this behaviour you can switch it off by setting the module level switch *FILTER_DIR*:

```
>>> from unittest import mock
>>> mock.FILTER_DIR = False
>>> dir(mock.Mock())
['_NonCallableMock__get_return_value',
 '_NonCallableMock__get_side_effect',
 '_NonCallableMock__return_value_doc',
 '_NonCallableMock__set_return_value',
 '_NonCallableMock__set_side_effect',
 '__call__',
 '__class__',
 ...
```

Alternatively you can just use `vars(my_mock)` (instance members) and `dir(type(my_mock))` (type members) to bypass the filtering irrespective of `mock.FILTER_DIR`.

mock_open

unittest.mock.**mock_open**(*mock=None*, *read_data=None*)

A helper function to create a mock to replace the use of *open()*. It works for *open()* called directly or used as a context manager.

The *mock* argument is the mock object to configure. If `None` (the default) then a *MagicMock* will be created for you, with the API limited to methods or attributes available on standard file handles.

read_data is a string for the `read()`, *readline()*, and *readlines()* methods of the file handle to return. Calls to those methods will take data from *read_data* until it is depleted. The mock of these methods is pretty simplistic: every time the *mock* is called, the *read_data* is rewound to the start. If you need more control over the data that you are feeding to the tested code you will need to customize this mock for yourself. When that is insufficient, one of the in-memory filesystem packages on PyPI can offer a realistic filesystem for testing.

Changed in version 3.4: Added *readline()* and *readlines()* support. The mock of `read()` changed to consume *read_data* rather than returning it on each call.

Changed in version 3.5: *read_data* is now reset on each call to the *mock*.

Using *open()* as a context manager is a great way to ensure your file handles are closed properly and is becoming common:

```
with open('/some/path', 'w') as f:
    f.write('something')
```

The issue is that even if you mock out the call to *open()* it is the *returned object* that is used as a context manager (and has `__enter__()` and `__exit__()` called).

Mocking context managers with a *MagicMock* is common enough and fiddly enough that a helper function is useful.

```
>>> m = mock_open()
>>> with patch('__main__.open', m):
...     with open('foo', 'w') as h:
...         h.write('some stuff')
...
>>> m.mock_calls
[call('foo', 'w'),
 call().__enter__(),
 call().write('some stuff'),
 call().__exit__(None, None, None)]
>>> m.assert_called_once_with('foo', 'w')
>>> handle = m()
>>> handle.write.assert_called_once_with('some stuff')
```

And for reading files:

```
>>> with patch('__main__.open', mock_open(read_data='bibble')) as m:
...     with open('foo') as h:
...         result = h.read()
...
>>> m.assert_called_once_with('foo')
>>> assert result == 'bibble'
```

Autospeccing

Autospeccing is based on the existing `spec` feature of mock. It limits the api of mocks to the api of an original object (the spec), but it is recursive (implemented lazily) so that attributes of mocks only have the same api as the attributes of the spec. In addition mocked functions / methods have the same call signature as the original so they raise a *TypeError* if they are called incorrectly.

Before I explain how auto-speccing works, here's why it is needed.

Mock is a very powerful and flexible object, but it suffers from two flaws when used to mock out objects from a system under test. One of these flaws is specific to the *Mock* api and the other is a more general problem with using mock objects.

First the problem specific to *Mock*. *Mock* has two assert methods that are extremely handy: *assert_called_with()* and *assert_called_once_with()*.

```
>>> mock = Mock(name='Thing', return_value=None)
>>> mock(1, 2, 3)
>>> mock.assert_called_once_with(1, 2, 3)
>>> mock(1, 2, 3)
>>> mock.assert_called_once_with(1, 2, 3)
Traceback (most recent call last):
 ...
AssertionError: Expected 'mock' to be called once. Called 2 times.
```

Because mocks auto-create attributes on demand, and allow you to call them with arbitrary arguments, if you misspell one of these assert methods then your assertion is gone:

```
>>> mock = Mock(name='Thing', return_value=None)
>>> mock(1, 2, 3)
>>> mock.assret_called_once_with(4, 5, 6)
```

Your tests can pass silently and incorrectly because of the typo.

The second issue is more general to mocking. If you refactor some of your code, rename members and so on, any tests for code that is still using the *old api* but uses mocks instead of the real objects will still pass. This means your tests can all pass even though your code is broken.

Note that this is another reason why you need integration tests as well as unit tests. Testing everything in isolation is all fine and dandy, but if you don't test how your units are "wired together" there is still lots of room for bugs that tests might have caught.

`mock` already provides a feature to help with this, called speccing. If you use a class or instance as the `spec` for a mock then you can only access attributes on the mock that exist on the real class:

```
>>> from urllib import request
>>> mock = Mock(spec=request.Request)
>>> mock.assret_called_with
Traceback (most recent call last):
 ...
AttributeError: Mock object has no attribute 'assret_called_with'
```

The spec only applies to the mock itself, so we still have the same issue with any methods on the mock:

```
>>> mock.has_data()
<mock.Mock object at 0x...>
>>> mock.has_data.assret_called_with()
```

Auto-speccing solves this problem. You can either pass `autospec=True` to *patch()* / *patch.object()* or use the *create_autospec()* function to create a mock with a spec. If you use the `autospec=True` argument to *patch()* then the object that is being replaced will be used as the spec object. Because the speccing is done "lazily" (the spec is created as attributes on the mock are accessed) you can use it with very complex or deeply nested objects (like modules that import modules that import modules) without a big performance hit.

Here's an example of it in use:

```
>>> from urllib import request
>>> patcher = patch('__main__.request', autospec=True)
>>> mock_request = patcher.start()
>>> request is mock_request
True
```

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```
>>> mock_request.Request
<MagicMock name='request.Request' spec='Request' id='...'>
```

You can see that `request.Request` has a spec. `request.Request` takes two arguments in the constructor (one of which is *self*). Here's what happens if we try to call it incorrectly:

```
>>> req = request.Request()
Traceback (most recent call last):
 ...
TypeError: <lambda>() takes at least 2 arguments (1 given)
```

The spec also applies to instantiated classes (i.e. the return value of specced mocks):

```
>>> req = request.Request('foo')
>>> req
<NonCallableMagicMock name='request.Request()' spec='Request' id='...'>
```

`Request` objects are not callable, so the return value of instantiating our mocked out `request.Request` is a non-callable mock. With the spec in place any typos in our asserts will raise the correct error:

```
>>> req.add_header('spam', 'eggs')
<MagicMock name='request.Request().add_header()' id='...'>
>>> req.add_header.assret_called_with
Traceback (most recent call last):
 ...
AttributeError: Mock object has no attribute 'assret_called_with'
>>> req.add_header.assert_called_with('spam', 'eggs')
```

In many cases you will just be able to add `autospec=True` to your existing *patch()* calls and then be protected against bugs due to typos and api changes.

As well as using *autospec* through *patch()* there is a *create_autospec()* for creating autospecced mocks directly:

```
>>> from urllib import request
>>> mock_request = create_autospec(request)
>>> mock_request.Request('foo', 'bar')
<NonCallableMagicMock name='mock.Request()' spec='Request' id='...'>
```

This isn't without caveats and limitations however, which is why it is not the default behaviour. In order to know what attributes are available on the spec object, autospec has to introspect (access attributes) the spec. As you traverse attributes on the mock a corresponding traversal of the original object is happening under the hood. If any of your specced objects have properties or descriptors that can trigger code execution then you may not be able to use autospec. On the other hand it is much better to design your objects so that introspection is safe[4].

A more serious problem is that it is common for instance attributes to be created in the `__init__()` method and not to exist on the class at all. *autospec* can't know about any dynamically created attributes and restricts the api to visible attributes.

```
>>> class Something:
...   def __init__(self):
...     self.a = 33
...
```

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[4] This only applies to classes or already instantiated objects. Calling a mocked class to create a mock instance *does not* create a real instance. It is only attribute lookups - along with calls to *dir()* - that are done.

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```
>>> with patch('__main__.Something', autospec=True):
...   thing = Something()
...   thing.a
...
Traceback (most recent call last):
  ...
AttributeError: Mock object has no attribute 'a'
```

There are a few different ways of resolving this problem. The easiest, but not necessarily the least annoying, way is to simply set the required attributes on the mock after creation. Just because *autospec* doesn't allow you to fetch attributes that don't exist on the spec it doesn't prevent you setting them:

```
>>> with patch('__main__.Something', autospec=True):
...   thing = Something()
...   thing.a = 33
...
```

There is a more aggressive version of both *spec* and *autospec* that *does* prevent you setting non-existent attributes. This is useful if you want to ensure your code only *sets* valid attributes too, but obviously it prevents this particular scenario:

```
>>> with patch('__main__.Something', autospec=True, spec_set=True):
...   thing = Something()
...   thing.a = 33
...
Traceback (most recent call last):
 ...
AttributeError: Mock object has no attribute 'a'
```

Probably the best way of solving the problem is to add class attributes as default values for instance members initialised in `__init__()`. Note that if you are only setting default attributes in `__init__()` then providing them via class attributes (shared between instances of course) is faster too. e.g.

```
class Something:
    a = 33
```

This brings up another issue. It is relatively common to provide a default value of `None` for members that will later be an object of a different type. `None` would be useless as a spec because it wouldn't let you access *any* attributes or methods on it. As `None` is *never* going to be useful as a spec, and probably indicates a member that will normally of some other type, autospec doesn't use a spec for members that are set to `None`. These will just be ordinary mocks (well - MagicMocks):

```
>>> class Something:
...     member = None
...
>>> mock = create_autospec(Something)
>>> mock.member.foo.bar.baz()
<MagicMock name='mock.member.foo.bar.baz()' id='...'>
```

If modifying your production classes to add defaults isn't to your liking then there are more options. One of these is simply to use an instance as the spec rather than the class. The other is to create a subclass of the production class and add the defaults to the subclass without affecting the production class. Both of these require you to use an alternative object as the spec. Thankfully *patch()* supports this - you can simply pass the alternative object as the *autospec* argument:

```
>>> class Something:
...   def __init__(self):
...     self.a = 33
...
>>> class SomethingForTest(Something):
...   a = 33
...
>>> p = patch('__main__.Something', autospec=SomethingForTest)
>>> mock = p.start()
>>> mock.a
<NonCallableMagicMock name='Something.a' spec='int' id='...'>
```

Sealing mocks

unittest.mock.**seal**(*mock*)

Seal will disable the creation of mock children by preventing getting or setting of any new attribute on the sealed mock. The sealing process is performed recursively.

If a mock instance is assigned to an attribute instead of being dynamically created it won't be considered in the sealing chain. This allows one to prevent seal from fixing part of the mock object.

```
>>> mock = Mock()
>>> mock.submock.attribute1 = 2
>>> mock.not_submock = mock.Mock()
>>> seal(mock)
>>> mock.submock.attribute2  # This will raise AttributeError.
>>> mock.not_submock.attribute2  # This won't raise.
```

New in version 3.7.

27.6 unittest.mock — getting started

New in version 3.3.

27.6.1 Using Mock

Mock Patching Methods

Common uses for *Mock* objects include:

- Patching methods
- Recording method calls on objects

You might want to replace a method on an object to check that it is called with the correct arguments by another part of the system:

```
>>> real = SomeClass()
>>> real.method = MagicMock(name='method')
>>> real.method(3, 4, 5, key='value')
<MagicMock name='method()' id='...'>
```

Once our mock has been used (`real.method` in this example) it has methods and attributes that allow you to make assertions about how it has been used.

Note: In most of these examples the *Mock* and *MagicMock* classes are interchangeable. As the `MagicMock` is the more capable class it makes a sensible one to use by default.

Once the mock has been called its *called* attribute is set to `True`. More importantly we can use the *assert_called_with()* or *assert_called_once_with()* method to check that it was called with the correct arguments.

This example tests that calling `ProductionClass().method` results in a call to the `something` method:

```
>>> class ProductionClass:
...     def method(self):
...         self.something(1, 2, 3)
...     def something(self, a, b, c):
...         pass
...
>>> real = ProductionClass()
>>> real.something = MagicMock()
>>> real.method()
>>> real.something.assert_called_once_with(1, 2, 3)
```

Mock for Method Calls on an Object

In the last example we patched a method directly on an object to check that it was called correctly. Another common use case is to pass an object into a method (or some part of the system under test) and then check that it is used in the correct way.

The simple `ProductionClass` below has a `closer` method. If it is called with an object then it calls `close` on it.

```
>>> class ProductionClass:
...     def closer(self, something):
...         something.close()
...
```

So to test it we need to pass in an object with a `close` method and check that it was called correctly.

```
>>> real = ProductionClass()
>>> mock = Mock()
>>> real.closer(mock)
>>> mock.close.assert_called_with()
```

We don't have to do any work to provide the 'close' method on our mock. Accessing close creates it. So, if 'close' hasn't already been called then accessing it in the test will create it, but *assert_called_with()* will raise a failure exception.

Mocking Classes

A common use case is to mock out classes instantiated by your code under test. When you patch a class, then that class is replaced with a mock. Instances are created by *calling the class*. This means you access the "mock instance" by looking at the return value of the mocked class.

In the example below we have a function `some_function` that instantiates `Foo` and calls a method on it. The call to *patch()* replaces the class `Foo` with a mock. The `Foo` instance is the result of calling the mock, so it is configured by modifying the mock *return_value*.

```
>>> def some_function():
...     instance = module.Foo()
...     return instance.method()
...
>>> with patch('module.Foo') as mock:
...     instance = mock.return_value
...     instance.method.return_value = 'the result'
...     result = some_function()
...     assert result == 'the result'
```

Naming your mocks

It can be useful to give your mocks a name. The name is shown in the repr of the mock and can be helpful when the mock appears in test failure messages. The name is also propagated to attributes or methods of the mock:

```
>>> mock = MagicMock(name='foo')
>>> mock
<MagicMock name='foo' id='...'>
>>> mock.method
<MagicMock name='foo.method' id='...'>
```

Tracking all Calls

Often you want to track more than a single call to a method. The *mock_calls* attribute records all calls to child attributes of the mock - and also to their children.

```
>>> mock = MagicMock()
>>> mock.method()
<MagicMock name='mock.method()' id='...'>
>>> mock.attribute.method(10, x=53)
<MagicMock name='mock.attribute.method()' id='...'>
>>> mock.mock_calls
[call.method(), call.attribute.method(10, x=53)]
```

If you make an assertion about `mock_calls` and any unexpected methods have been called, then the assertion will fail. This is useful because as well as asserting that the calls you expected have been made, you are also checking that they were made in the right order and with no additional calls:

You use the *call* object to construct lists for comparing with `mock_calls`:

```
>>> expected = [call.method(), call.attribute.method(10, x=53)]
>>> mock.mock_calls == expected
True
```

Setting Return Values and Attributes

Setting the return values on a mock object is trivially easy:

```
>>> mock = Mock()
>>> mock.return_value = 3
>>> mock()
3
```

Of course you can do the same for methods on the mock:

```
>>> mock = Mock()
>>> mock.method.return_value = 3
>>> mock.method()
3
```

The return value can also be set in the constructor:

```
>>> mock = Mock(return_value=3)
>>> mock()
3
```

If you need an attribute setting on your mock, just do it:

```
>>> mock = Mock()
>>> mock.x = 3
>>> mock.x
3
```

Sometimes you want to mock up a more complex situation, like for example `mock.connection.cursor().execute("SELECT 1")`. If we wanted this call to return a list, then we have to configure the result of the nested call.

We can use *call* to construct the set of calls in a "chained call" like this for easy assertion afterwards:

```
>>> mock = Mock()
>>> cursor = mock.connection.cursor.return_value
>>> cursor.execute.return_value = ['foo']
>>> mock.connection.cursor().execute("SELECT 1")
['foo']
>>> expected = call.connection.cursor().execute("SELECT 1").call_list()
>>> mock.mock_calls
[call.connection.cursor(), call.connection.cursor().execute('SELECT 1')]
>>> mock.mock_calls == expected
True
```

It is the call to `.call_list()` that turns our call object into a list of calls representing the chained calls.

Raising exceptions with mocks

A useful attribute is *side_effect*. If you set this to an exception class or instance then the exception will be raised when the mock is called.

```
>>> mock = Mock(side_effect=Exception('Boom!'))
>>> mock()
Traceback (most recent call last):
  ...
Exception: Boom!
```

Side effect functions and iterables

`side_effect` can also be set to a function or an iterable. The use case for `side_effect` as an iterable is where your mock is going to be called several times, and you want each call to return a different value. When you set `side_effect` to an iterable every call to the mock returns the next value from the iterable:

```
>>> mock = MagicMock(side_effect=[4, 5, 6])
>>> mock()
4
>>> mock()
5
>>> mock()
6
```

For more advanced use cases, like dynamically varying the return values depending on what the mock is called with, `side_effect` can be a function. The function will be called with the same arguments as the mock. Whatever the function returns is what the call returns:

```
>>> vals = {(1, 2): 1, (2, 3): 2}
>>> def side_effect(*args):
...     return vals[args]
...
>>> mock = MagicMock(side_effect=side_effect)
>>> mock(1, 2)
1
>>> mock(2, 3)
2
```

Creating a Mock from an Existing Object

One problem with over use of mocking is that it couples your tests to the implementation of your mocks rather than your real code. Suppose you have a class that implements `some_method`. In a test for another class, you provide a mock of this object that *also* provides `some_method`. If later you refactor the first class, so that it no longer has `some_method` - then your tests will continue to pass even though your code is now broken!

Mock allows you to provide an object as a specification for the mock, using the *spec* keyword argument. Accessing methods / attributes on the mock that don't exist on your specification object will immediately raise an attribute error. If you change the implementation of your specification, then tests that use that class will start failing immediately without you having to instantiate the class in those tests.

```
>>> mock = Mock(spec=SomeClass)
>>> mock.old_method()
Traceback (most recent call last):
   ...
AttributeError: object has no attribute 'old_method'
```

Using a specification also enables a smarter matching of calls made to the mock, regardless of whether some parameters were passed as positional or named arguments:

```
>>> def f(a, b, c): pass
...
>>> mock = Mock(spec=f)
>>> mock(1, 2, 3)
<Mock name='mock()' id='140161580456576'>
>>> mock.assert_called_with(a=1, b=2, c=3)
```

If you want this smarter matching to also work with method calls on the mock, you can use *auto-speccing*.

If you want a stronger form of specification that prevents the setting of arbitrary attributes as well as the getting of them then you can use *spec_set* instead of *spec*.

27.6.2 Patch Decorators

Note: With *patch()* it matters that you patch objects in the namespace where they are looked up. This is normally straightforward, but for a quick guide read *where to patch*.

A common need in tests is to patch a class attribute or a module attribute, for example patching a builtin or patching a class in a module to test that it is instantiated. Modules and classes are effectively global, so patching on them has to be undone after the test or the patch will persist into other tests and cause hard to diagnose problems.

mock provides three convenient decorators for this: *patch()*, *patch.object()* and *patch.dict()*. `patch` takes a single string, of the form `package.module.Class.attribute` to specify the attribute you are patching. It also optionally takes a value that you want the attribute (or class or whatever) to be replaced with. 'patch.object' takes an object and the name of the attribute you would like patched, plus optionally the value to patch it with.

`patch.object`:

```
>>> original = SomeClass.attribute
>>> @patch.object(SomeClass, 'attribute', sentinel.attribute)
... def test():
...     assert SomeClass.attribute == sentinel.attribute
...
>>> test()
>>> assert SomeClass.attribute == original
```

```
>>> @patch('package.module.attribute', sentinel.attribute)
... def test():
...     from package.module import attribute
...     assert attribute is sentinel.attribute
...
>>> test()
```

If you are patching a module (including *builtins*) then use *patch()* instead of *patch.object()*:

```
>>> mock = MagicMock(return_value=sentinel.file_handle)
>>> with patch('builtins.open', mock):
...     handle = open('filename', 'r')
...
>>> mock.assert_called_with('filename', 'r')
>>> assert handle == sentinel.file_handle, "incorrect file handle returned"
```

The module name can be 'dotted', in the form `package.module` if needed:

```
>>> @patch('package.module.ClassName.attribute', sentinel.attribute)
... def test():
...     from package.module import ClassName
...     assert ClassName.attribute == sentinel.attribute
...
>>> test()
```

A nice pattern is to actually decorate test methods themselves:

```
>>> class MyTest(unittest.TestCase):
...     @patch.object(SomeClass, 'attribute', sentinel.attribute)
...     def test_something(self):
```

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```
...         self.assertEqual(SomeClass.attribute, sentinel.attribute)
...
>>> original = SomeClass.attribute
>>> MyTest('test_something').test_something()
>>> assert SomeClass.attribute == original
```

If you want to patch with a Mock, you can use *patch()* with only one argument (or *patch.object()* with two arguments). The mock will be created for you and passed into the test function / method:

```
>>> class MyTest(unittest.TestCase):
...     @patch.object(SomeClass, 'static_method')
...     def test_something(self, mock_method):
...         SomeClass.static_method()
...         mock_method.assert_called_with()
...
>>> MyTest('test_something').test_something()
```

You can stack up multiple patch decorators using this pattern:

```
>>> class MyTest(unittest.TestCase):
...     @patch('package.module.ClassName1')
...     @patch('package.module.ClassName2')
...     def test_something(self, MockClass2, MockClass1):
...         self.assertIs(package.module.ClassName1, MockClass1)
...         self.assertIs(package.module.ClassName2, MockClass2)
...
>>> MyTest('test_something').test_something()
```

When you nest patch decorators the mocks are passed in to the decorated function in the same order they applied (the normal *python* order that decorators are applied). This means from the bottom up, so in the example above the mock for `test_module.ClassName2` is passed in first.

There is also *patch.dict()* for setting values in a dictionary just during a scope and restoring the dictionary to its original state when the test ends:

```
>>> foo = {'key': 'value'}
>>> original = foo.copy()
>>> with patch.dict(foo, {'newkey': 'newvalue'}, clear=True):
...     assert foo == {'newkey': 'newvalue'}
...
>>> assert foo == original
```

`patch`, `patch.object` and `patch.dict` can all be used as context managers.

Where you use *patch()* to create a mock for you, you can get a reference to the mock using the "as" form of the with statement:

```
>>> class ProductionClass:
...     def method(self):
...         pass
...
>>> with patch.object(ProductionClass, 'method') as mock_method:
...     mock_method.return_value = None
...     real = ProductionClass()
...     real.method(1, 2, 3)
...
>>> mock_method.assert_called_with(1, 2, 3)
```

As an alternative `patch`, `patch.object` and `patch.dict` can be used as class decorators. When used in this way it is the same as applying the decorator individually to every method whose name starts with "test".

27.6.3 Further Examples

Here are some more examples for some slightly more advanced scenarios.

Mocking chained calls

Mocking chained calls is actually straightforward with mock once you understand the *return_value* attribute. When a mock is called for the first time, or you fetch its `return_value` before it has been called, a new *Mock* is created.

This means that you can see how the object returned from a call to a mocked object has been used by interrogating the `return_value` mock:

```
>>> mock = Mock()
>>> mock().foo(a=2, b=3)
<Mock name='mock().foo()' id='...'>
>>> mock.return_value.foo.assert_called_with(a=2, b=3)
```

From here it is a simple step to configure and then make assertions about chained calls. Of course another alternative is writing your code in a more testable way in the first place...

So, suppose we have some code that looks a little bit like this:

```
>>> class Something:
...     def __init__(self):
...         self.backend = BackendProvider()
...     def method(self):
...         response = self.backend.get_endpoint('foobar').create_call('spam', 'eggs').start_call()
...         # more code
```

Assuming that `BackendProvider` is already well tested, how do we test `method()`? Specifically, we want to test that the code section `# more code` uses the response object in the correct way.

As this chain of calls is made from an instance attribute we can monkey patch the `backend` attribute on a `Something` instance. In this particular case we are only interested in the return value from the final call to `start_call` so we don't have much configuration to do. Let's assume the object it returns is 'file-like', so we'll ensure that our response object uses the builtin *open()* as its `spec`.

To do this we create a mock instance as our mock backend and create a mock response object for it. To set the response as the return value for that final `start_call` we could do this:

```
mock_backend.get_endpoint.return_value.create_call.return_value.start_call.return_value = mock_
↪response
```

We can do that in a slightly nicer way using the *configure_mock()* method to directly set the return value for us:

```
>>> something = Something()
>>> mock_response = Mock(spec=open)
>>> mock_backend = Mock()
>>> config = {'get_endpoint.return_value.create_call.return_value.start_call.return_value': mock_
↪response}
>>> mock_backend.configure_mock(**config)
```

With these we monkey patch the "mock backend" in place and can make the real call:

```
>>> something.backend = mock_backend
>>> something.method()
```

Using *mock_calls* we can check the chained call with a single assert. A chained call is several calls in one line of code, so there will be several entries in `mock_calls`. We can use *call.call_list()* to create this list of calls for us:

```
>>> chained = call.get_endpoint('foobar').create_call('spam', 'eggs').start_call()
>>> call_list = chained.call_list()
>>> assert mock_backend.mock_calls == call_list
```

Partial mocking

In some tests I wanted to mock out a call to *datetime.date.today()* to return a known date, but I didn't want to prevent the code under test from creating new date objects. Unfortunately *datetime.date* is written in C, and so I couldn't just monkey-patch out the static `date.today()` method.

I found a simple way of doing this that involved effectively wrapping the date class with a mock, but passing through calls to the constructor to the real class (and returning real instances).

The *patch decorator* is used here to mock out the `date` class in the module under test. The `side_effect` attribute on the mock date class is then set to a lambda function that returns a real date. When the mock date class is called a real date will be constructed and returned by `side_effect`.

```
>>> from datetime import date
>>> with patch('mymodule.date') as mock_date:
...     mock_date.today.return_value = date(2010, 10, 8)
...     mock_date.side_effect = lambda *args, **kw: date(*args, **kw)
...
...     assert mymodule.date.today() == date(2010, 10, 8)
...     assert mymodule.date(2009, 6, 8) == date(2009, 6, 8)
...
```

Note that we don't patch *datetime.date* globally, we patch `date` in the module that *uses* it. See *where to patch*.

When `date.today()` is called a known date is returned, but calls to the `date(...)` constructor still return normal dates. Without this you can find yourself having to calculate an expected result using exactly the same algorithm as the code under test, which is a classic testing anti-pattern.

Calls to the date constructor are recorded in the `mock_date` attributes (`call_count` and friends) which may also be useful for your tests.

An alternative way of dealing with mocking dates, or other builtin classes, is discussed in this blog entry.

Mocking a Generator Method

A Python generator is a function or method that uses the `yield` statement to return a series of values when iterated over[1].

A generator method / function is called to return the generator object. It is the generator object that is then iterated over. The protocol method for iteration is *__iter__()*, so we can mock this using a *MagicMock*.

Here's an example class with an "iter" method implemented as a generator:

[1] There are also generator expressions and more advanced uses of generators, but we aren't concerned about them here. A very good introduction to generators and how powerful they are is: Generator Tricks for Systems Programmers.

```
>>> class Foo:
...     def iter(self):
...         for i in [1, 2, 3]:
...             yield i
...
>>> foo = Foo()
>>> list(foo.iter())
[1, 2, 3]
```

How would we mock this class, and in particular its "iter" method?

To configure the values returned from the iteration (implicit in the call to *list*), we need to configure the object returned by the call to `foo.iter()`.

```
>>> mock_foo = MagicMock()
>>> mock_foo.iter.return_value = iter([1, 2, 3])
>>> list(mock_foo.iter())
[1, 2, 3]
```

Applying the same patch to every test method

If you want several patches in place for multiple test methods the obvious way is to apply the patch decorators to every method. This can feel like unnecessary repetition. For Python 2.6 or more recent you can use *patch()* (in all its various forms) as a class decorator. This applies the patches to all test methods on the class. A test method is identified by methods whose names start with `test`:

```
>>> @patch('mymodule.SomeClass')
... class MyTest(TestCase):
...
...     def test_one(self, MockSomeClass):
...         self.assertIs(mymodule.SomeClass, MockSomeClass)
...
...     def test_two(self, MockSomeClass):
...         self.assertIs(mymodule.SomeClass, MockSomeClass)
...
...     def not_a_test(self):
...         return 'something'
...
>>> MyTest('test_one').test_one()
>>> MyTest('test_two').test_two()
>>> MyTest('test_two').not_a_test()
'something'
```

An alternative way of managing patches is to use the *patch methods: start and stop*. These allow you to move the patching into your `setUp` and `tearDown` methods.

```
>>> class MyTest(TestCase):
...     def setUp(self):
...         self.patcher = patch('mymodule.foo')
...         self.mock_foo = self.patcher.start()
...
...     def test_foo(self):
...         self.assertIs(mymodule.foo, self.mock_foo)
...
...     def tearDown(self):
...         self.patcher.stop()
```

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```
...
>>> MyTest('test_foo').run()
```

If you use this technique you must ensure that the patching is "undone" by calling `stop`. This can be fiddlier than you might think, because if an exception is raised in the setUp then tearDown is not called. *unittest.TestCase.addCleanup()* makes this easier:

```
>>> class MyTest(TestCase):
...     def setUp(self):
...         patcher = patch('mymodule.foo')
...         self.addCleanup(patcher.stop)
...         self.mock_foo = patcher.start()
...
...     def test_foo(self):
...         self.assertIs(mymodule.foo, self.mock_foo)
...
>>> MyTest('test_foo').run()
```

Mocking Unbound Methods

Whilst writing tests today I needed to patch an *unbound method* (patching the method on the class rather than on the instance). I needed self to be passed in as the first argument because I want to make asserts about which objects were calling this particular method. The issue is that you can't patch with a mock for this, because if you replace an unbound method with a mock it doesn't become a bound method when fetched from the instance, and so it doesn't get self passed in. The workaround is to patch the unbound method with a real function instead. The *patch()* decorator makes it so simple to patch out methods with a mock that having to create a real function becomes a nuisance.

If you pass `autospec=True` to patch then it does the patching with a *real* function object. This function object has the same signature as the one it is replacing, but delegates to a mock under the hood. You still get your mock auto-created in exactly the same way as before. What it means though, is that if you use it to patch out an unbound method on a class the mocked function will be turned into a bound method if it is fetched from an instance. It will have `self` passed in as the first argument, which is exactly what I wanted:

```
>>> class Foo:
...   def foo(self):
...     pass
...
>>> with patch.object(Foo, 'foo', autospec=True) as mock_foo:
...   mock_foo.return_value = 'foo'
...   foo = Foo()
...   foo.foo()
...
'foo'
>>> mock_foo.assert_called_once_with(foo)
```

If we don't use `autospec=True` then the unbound method is patched out with a Mock instance instead, and isn't called with `self`.

Checking multiple calls with mock

mock has a nice API for making assertions about how your mock objects are used.

```
>>> mock = Mock()
>>> mock.foo_bar.return_value = None
>>> mock.foo_bar('baz', spam='eggs')
>>> mock.foo_bar.assert_called_with('baz', spam='eggs')
```

If your mock is only being called once you can use the `assert_called_once_with()` method that also asserts that the `call_count` is one.

```
>>> mock.foo_bar.assert_called_once_with('baz', spam='eggs')
>>> mock.foo_bar()
>>> mock.foo_bar.assert_called_once_with('baz', spam='eggs')
Traceback (most recent call last):
    ...
AssertionError: Expected to be called once. Called 2 times.
```

Both `assert_called_with` and `assert_called_once_with` make assertions about the *most recent* call. If your mock is going to be called several times, and you want to make assertions about *all* those calls you can use *`call_args_list`*:

```
>>> mock = Mock(return_value=None)
>>> mock(1, 2, 3)
>>> mock(4, 5, 6)
>>> mock()
>>> mock.call_args_list
[call(1, 2, 3), call(4, 5, 6), call()]
```

The *`call`* helper makes it easy to make assertions about these calls. You can build up a list of expected calls and compare it to `call_args_list`. This looks remarkably similar to the repr of the `call_args_list`:

```
>>> expected = [call(1, 2, 3), call(4, 5, 6), call()]
>>> mock.call_args_list == expected
True
```

Coping with mutable arguments

Another situation is rare, but can bite you, is when your mock is called with mutable arguments. `call_args` and `call_args_list` store *references* to the arguments. If the arguments are mutated by the code under test then you can no longer make assertions about what the values were when the mock was called.

Here's some example code that shows the problem. Imagine the following functions defined in 'mymodule':

```
def frob(val):
    pass

def grob(val):
    "First frob and then clear val"
    frob(val)
    val.clear()
```

When we try to test that `grob` calls `frob` with the correct argument look what happens:

```
>>> with patch('mymodule.frob') as mock_frob:
...     val = {6}
...     mymodule.grob(val)
...
>>> val
```

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```
set()
>>> mock_frob.assert_called_with({6})
Traceback (most recent call last):
    ...
AssertionError: Expected: (({6},), {})
Called with: ((set(),), {})
```

One possibility would be for mock to copy the arguments you pass in. This could then cause problems if you do assertions that rely on object identity for equality.

Here's one solution that uses the `side_effect` functionality. If you provide a `side_effect` function for a mock then `side_effect` will be called with the same args as the mock. This gives us an opportunity to copy the arguments and store them for later assertions. In this example I'm using *another* mock to store the arguments so that I can use the mock methods for doing the assertion. Again a helper function sets this up for me.

```
>>> from copy import deepcopy
>>> from unittest.mock import Mock, patch, DEFAULT
>>> def copy_call_args(mock):
...     new_mock = Mock()
...     def side_effect(*args, **kwargs):
...         args = deepcopy(args)
...         kwargs = deepcopy(kwargs)
...         new_mock(*args, **kwargs)
...         return DEFAULT
...     mock.side_effect = side_effect
...     return new_mock
...
>>> with patch('mymodule.frob') as mock_frob:
...     new_mock = copy_call_args(mock_frob)
...     val = {6}
...     mymodule.grob(val)
...
>>> new_mock.assert_called_with({6})
>>> new_mock.call_args
call({6})
```

`copy_call_args` is called with the mock that will be called. It returns a new mock that we do the assertion on. The `side_effect` function makes a copy of the args and calls our `new_mock` with the copy.

Note: If your mock is only going to be used once there is an easier way of checking arguments at the point they are called. You can simply do the checking inside a `side_effect` function.

```
>>> def side_effect(arg):
...     assert arg == {6}
...
>>> mock = Mock(side_effect=side_effect)
>>> mock({6})
>>> mock(set())
Traceback (most recent call last):
    ...
AssertionError
```

An alternative approach is to create a subclass of *Mock* or *MagicMock* that copies (using *copy.deepcopy()*) the arguments. Here's an example implementation:

```
>>> from copy import deepcopy
>>> class CopyingMock(MagicMock):
...     def __call__(self, *args, **kwargs):
...         args = deepcopy(args)
...         kwargs = deepcopy(kwargs)
...         return super(CopyingMock, self).__call__(*args, **kwargs)
...
>>> c = CopyingMock(return_value=None)
>>> arg = set()
>>> c(arg)
>>> arg.add(1)
>>> c.assert_called_with(set())
>>> c.assert_called_with(arg)
Traceback (most recent call last):
    ...
AssertionError: Expected call: mock({1})
Actual call: mock(set())
>>> c.foo
<CopyingMock name='mock.foo' id='...'>
```

When you subclass `Mock` or `MagicMock` all dynamically created attributes, and the `return_value` will use your subclass automatically. That means all children of a `CopyingMock` will also have the type `CopyingMock`.

Nesting Patches

Using patch as a context manager is nice, but if you do multiple patches you can end up with nested with statements indenting further and further to the right:

```
>>> class MyTest(TestCase):
...
...     def test_foo(self):
...         with patch('mymodule.Foo') as mock_foo:
...             with patch('mymodule.Bar') as mock_bar:
...                 with patch('mymodule.Spam') as mock_spam:
...                     assert mymodule.Foo is mock_foo
...                     assert mymodule.Bar is mock_bar
...                     assert mymodule.Spam is mock_spam
...
>>> original = mymodule.Foo
>>> MyTest('test_foo').test_foo()
>>> assert mymodule.Foo is original
```

With unittest `cleanup` functions and the *patch methods: start and stop* we can achieve the same effect without the nested indentation. A simple helper method, `create_patch`, puts the patch in place and returns the created mock for us:

```
>>> class MyTest(TestCase):
...
...     def create_patch(self, name):
...         patcher = patch(name)
...         thing = patcher.start()
...         self.addCleanup(patcher.stop)
...         return thing
...
...     def test_foo(self):
...         mock_foo = self.create_patch('mymodule.Foo')
```

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```
...         mock_bar = self.create_patch('mymodule.Bar')
...         mock_spam = self.create_patch('mymodule.Spam')
...
...         assert mymodule.Foo is mock_foo
...         assert mymodule.Bar is mock_bar
...         assert mymodule.Spam is mock_spam
...
>>> original = mymodule.Foo
>>> MyTest('test_foo').run()
>>> assert mymodule.Foo is original
```

Mocking a dictionary with MagicMock

You may want to mock a dictionary, or other container object, recording all access to it whilst having it still behave like a dictionary.

We can do this with *MagicMock*, which will behave like a dictionary, and using *side_effect* to delegate dictionary access to a real underlying dictionary that is under our control.

When the `__getitem__()` and `__setitem__()` methods of our `MagicMock` are called (normal dictionary access) then `side_effect` is called with the key (and in the case of `__setitem__` the value too). We can also control what is returned.

After the `MagicMock` has been used we can use attributes like *call_args_list* to assert about how the dictionary was used:

```
>>> my_dict = {'a': 1, 'b': 2, 'c': 3}
>>> def getitem(name):
...      return my_dict[name]
...
>>> def setitem(name, val):
...     my_dict[name] = val
...
>>> mock = MagicMock()
>>> mock.__getitem__.side_effect = getitem
>>> mock.__setitem__.side_effect = setitem
```

Note: An alternative to using `MagicMock` is to use `Mock` and *only* provide the magic methods you specifically want:

```
>>> mock = Mock()
>>> mock.__getitem__ = Mock(side_effect=getitem)
>>> mock.__setitem__ = Mock(side_effect=setitem)
```

A *third* option is to use `MagicMock` but passing in `dict` as the *spec* (or *spec_set*) argument so that the `MagicMock` created only has dictionary magic methods available:

```
>>> mock = MagicMock(spec_set=dict)
>>> mock.__getitem__.side_effect = getitem
>>> mock.__setitem__.side_effect = setitem
```

With these side effect functions in place, the `mock` will behave like a normal dictionary but recording the access. It even raises a *KeyError* if you try to access a key that doesn't exist.

```
>>> mock['a']
1
>>> mock['c']
3
>>> mock['d']
Traceback (most recent call last):
    ...
KeyError: 'd'
>>> mock['b'] = 'fish'
>>> mock['d'] = 'eggs'
>>> mock['b']
'fish'
>>> mock['d']
'eggs'
```

After it has been used you can make assertions about the access using the normal mock methods and attributes:

```
>>> mock.__getitem__.call_args_list
[call('a'), call('c'), call('d'), call('b'), call('d')]
>>> mock.__setitem__.call_args_list
[call('b', 'fish'), call('d', 'eggs')]
>>> my_dict
{'a': 1, 'c': 3, 'b': 'fish', 'd': 'eggs'}
```

Mock subclasses and their attributes

There are various reasons why you might want to subclass *Mock*. One reason might be to add helper methods. Here's a silly example:

```
>>> class MyMock(MagicMock):
...     def has_been_called(self):
...         return self.called
...
>>> mymock = MyMock(return_value=None)
>>> mymock
<MyMock id='...'>
>>> mymock.has_been_called()
False
>>> mymock()
>>> mymock.has_been_called()
True
```

The standard behaviour for `Mock` instances is that attributes and the return value mocks are of the same type as the mock they are accessed on. This ensures that `Mock` attributes are `Mocks` and `MagicMock` attributes are `MagicMocks`[2]. So if you're subclassing to add helper methods then they'll also be available on the attributes and return value mock of instances of your subclass.

```
>>> mymock.foo
<MyMock name='mock.foo' id='...'>
>>> mymock.foo.has_been_called()
False
>>> mymock.foo()
```

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[2] An exception to this rule are the non-callable mocks. Attributes use the callable variant because otherwise non-callable mocks couldn't have callable methods.

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```
<MyMock name='mock.foo()' id='...'>
>>> mymock.foo.has_been_called()
True
```

Sometimes this is inconvenient. For example, one user is subclassing mock to created a Twisted adaptor. Having this applied to attributes too actually causes errors.

`Mock` (in all its flavours) uses a method called `_get_child_mock` to create these "sub-mocks" for attributes and return values. You can prevent your subclass being used for attributes by overriding this method. The signature is that it takes arbitrary keyword arguments (`**kwargs`) which are then passed onto the mock constructor:

```
>>> class Subclass(MagicMock):
...     def _get_child_mock(self, **kwargs):
...         return MagicMock(**kwargs)
...
>>> mymock = Subclass()
>>> mymock.foo
<MagicMock name='mock.foo' id='...'>
>>> assert isinstance(mymock, Subclass)
>>> assert not isinstance(mymock.foo, Subclass)
>>> assert not isinstance(mymock(), Subclass)
```

Mocking imports with patch.dict

One situation where mocking can be hard is where you have a local import inside a function. These are harder to mock because they aren't using an object from the module namespace that we can patch out.

Generally local imports are to be avoided. They are sometimes done to prevent circular dependencies, for which there is *usually* a much better way to solve the problem (refactor the code) or to prevent "up front costs" by delaying the import. This can also be solved in better ways than an unconditional local import (store the module as a class or module attribute and only do the import on first use).

That aside there is a way to use `mock` to affect the results of an import. Importing fetches an *object* from the *sys.modules* dictionary. Note that it fetches an *object*, which need not be a module. Importing a module for the first time results in a module object being put in *sys.modules*, so usually when you import something you get a module back. This need not be the case however.

This means you can use *patch.dict()* to *temporarily* put a mock in place in *sys.modules*. Any imports whilst this patch is active will fetch the mock. When the patch is complete (the decorated function exits, the with statement body is complete or `patcher.stop()` is called) then whatever was there previously will be restored safely.

Here's an example that mocks out the 'fooble' module.

```
>>> mock = Mock()
>>> with patch.dict('sys.modules', {'fooble': mock}):
...     import fooble
...     fooble.blob()
...
<Mock name='mock.blob()' id='...'>
>>> assert 'fooble' not in sys.modules
>>> mock.blob.assert_called_once_with()
```

As you can see the `import fooble` succeeds, but on exit there is no 'fooble' left in *sys.modules*.

This also works for the `from module import name` form:

```
>>> mock = Mock()
>>> with patch.dict('sys.modules', {'fooble': mock}):
...    from fooble import blob
...    blob.blip()
...
<Mock name='mock.blob.blip()' id='...'>
>>> mock.blob.blip.assert_called_once_with()
```

With slightly more work you can also mock package imports:

```
>>> mock = Mock()
>>> modules = {'package': mock, 'package.module': mock.module}
>>> with patch.dict('sys.modules', modules):
...    from package.module import fooble
...    fooble()
...
<Mock name='mock.module.fooble()' id='...'>
>>> mock.module.fooble.assert_called_once_with()
```

Tracking order of calls and less verbose call assertions

The *Mock* class allows you to track the *order* of method calls on your mock objects through the *method_calls* attribute. This doesn't allow you to track the order of calls between separate mock objects, however we can use *mock_calls* to achieve the same effect.

Because mocks track calls to child mocks in `mock_calls`, and accessing an arbitrary attribute of a mock creates a child mock, we can create our separate mocks from a parent one. Calls to those child mock will then all be recorded, in order, in the `mock_calls` of the parent:

```
>>> manager = Mock()
>>> mock_foo = manager.foo
>>> mock_bar = manager.bar
```

```
>>> mock_foo.something()
<Mock name='mock.foo.something()' id='...'>
>>> mock_bar.other.thing()
<Mock name='mock.bar.other.thing()' id='...'>
```

```
>>> manager.mock_calls
[call.foo.something(), call.bar.other.thing()]
```

We can then assert about the calls, including the order, by comparing with the `mock_calls` attribute on the manager mock:

```
>>> expected_calls = [call.foo.something(), call.bar.other.thing()]
>>> manager.mock_calls == expected_calls
True
```

If `patch` is creating, and putting in place, your mocks then you can attach them to a manager mock using the *attach_mock()* method. After attaching calls will be recorded in `mock_calls` of the manager.

```
>>> manager = MagicMock()
>>> with patch('mymodule.Class1') as MockClass1:
...     with patch('mymodule.Class2') as MockClass2:
...         manager.attach_mock(MockClass1, 'MockClass1')
```

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```
...         manager.attach_mock(MockClass2, 'MockClass2')
...         MockClass1().foo()
...         MockClass2().bar()
...
<MagicMock name='mock.MockClass1().foo()' id='...'>
<MagicMock name='mock.MockClass2().bar()' id='...'>
>>> manager.mock_calls
[call.MockClass1(),
 call.MockClass1().foo(),
 call.MockClass2(),
 call.MockClass2().bar()]
```

If many calls have been made, but you're only interested in a particular sequence of them then an alternative is to use the *assert_has_calls()* method. This takes a list of calls (constructed with the *call* object). If that sequence of calls are in *mock_calls* then the assert succeeds.

```
>>> m = MagicMock()
>>> m().foo().bar().baz()
<MagicMock name='mock().foo().bar().baz()' id='...'>
>>> m.one().two().three()
<MagicMock name='mock.one().two().three()' id='...'>
>>> calls = call.one().two().three().call_list()
>>> m.assert_has_calls(calls)
```

Even though the chained call `m.one().two().three()` aren't the only calls that have been made to the mock, the assert still succeeds.

Sometimes a mock may have several calls made to it, and you are only interested in asserting about *some* of those calls. You may not even care about the order. In this case you can pass `any_order=True` to `assert_has_calls`:

```
>>> m = MagicMock()
>>> m(1), m.two(2, 3), m.seven(7), m.fifty('50')
(...)
>>> calls = [call.fifty('50'), call(1), call.seven(7)]
>>> m.assert_has_calls(calls, any_order=True)
```

More complex argument matching

Using the same basic concept as *ANY* we can implement matchers to do more complex assertions on objects used as arguments to mocks.

Suppose we expect some object to be passed to a mock that by default compares equal based on object identity (which is the Python default for user defined classes). To use *assert_called_with()* we would need to pass in the exact same object. If we are only interested in some of the attributes of this object then we can create a matcher that will check these attributes for us.

You can see in this example how a 'standard' call to `assert_called_with` isn't sufficient:

```
>>> class Foo:
...     def __init__(self, a, b):
...         self.a, self.b = a, b
...
>>> mock = Mock(return_value=None)
>>> mock(Foo(1, 2))
>>> mock.assert_called_with(Foo(1, 2))
```

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```
Traceback (most recent call last):
    ...
AssertionError: Expected: call(<__main__.Foo object at 0x...>)
Actual call: call(<__main__.Foo object at 0x...>)
```

A comparison function for our `Foo` class might look something like this:

```
>>> def compare(self, other):
...     if not type(self) == type(other):
...         return False
...     if self.a != other.a:
...         return False
...     if self.b != other.b:
...         return False
...     return True
...
```

And a matcher object that can use comparison functions like this for its equality operation would look something like this:

```
>>> class Matcher:
...     def __init__(self, compare, some_obj):
...         self.compare = compare
...         self.some_obj = some_obj
...     def __eq__(self, other):
...         return self.compare(self.some_obj, other)
...
```

Putting all this together:

```
>>> match_foo = Matcher(compare, Foo(1, 2))
>>> mock.assert_called_with(match_foo)
```

The `Matcher` is instantiated with our compare function and the `Foo` object we want to compare against. In `assert_called_with` the `Matcher` equality method will be called, which compares the object the mock was called with against the one we created our matcher with. If they match then `assert_called_with` passes, and if they don't an *AssertionError* is raised:

```
>>> match_wrong = Matcher(compare, Foo(3, 4))
>>> mock.assert_called_with(match_wrong)
Traceback (most recent call last):
    ...
AssertionError: Expected: ((<Matcher object at 0x...>,), {})
Called with: ((<Foo object at 0x...>,), {})
```

With a bit of tweaking you could have the comparison function raise the *AssertionError* directly and provide a more useful failure message.

As of version 1.5, the Python testing library PyHamcrest provides similar functionality, that may be useful here, in the form of its equality matcher (hamcrest.library.integration.match_equality).

27.7 2to3 - Automated Python 2 to 3 code translation

2to3 is a Python program that reads Python 2.x source code and applies a series of *fixers* to transform it into valid Python 3.x code. The standard library contains a rich set of fixers that will handle almost all

code. 2to3 supporting library *lib2to3* is, however, a flexible and generic library, so it is possible to write your own fixers for 2to3. *lib2to3* could also be adapted to custom applications in which Python code needs to be edited automatically.

27.7.1 Using 2to3

2to3 will usually be installed with the Python interpreter as a script. It is also located in the `Tools/scripts` directory of the Python root.

2to3's basic arguments are a list of files or directories to transform. The directories are recursively traversed for Python sources.

Here is a sample Python 2.x source file, `example.py`:

```
def greet(name):
    print "Hello, {0}!".format(name)
print "What's your name?"
name = raw_input()
greet(name)
```

It can be converted to Python 3.x code via 2to3 on the command line:

```
$ 2to3 example.py
```

A diff against the original source file is printed. 2to3 can also write the needed modifications right back to the source file. (A backup of the original file is made unless `-n` is also given.) Writing the changes back is enabled with the `-w` flag:

```
$ 2to3 -w example.py
```

After transformation, `example.py` looks like this:

```
def greet(name):
    print("Hello, {0}!".format(name))
print("What's your name?")
name = input()
greet(name)
```

Comments and exact indentation are preserved throughout the translation process.

By default, 2to3 runs a set of *predefined fixers*. The `-l` flag lists all available fixers. An explicit set of fixers to run can be given with `-f`. Likewise the `-x` explicitly disables a fixer. The following example runs only the `imports` and `has_key` fixers:

```
$ 2to3 -f imports -f has_key example.py
```

This command runs every fixer except the `apply` fixer:

```
$ 2to3 -x apply example.py
```

Some fixers are *explicit*, meaning they aren't run by default and must be listed on the command line to be run. Here, in addition to the default fixers, the `idioms` fixer is run:

```
$ 2to3 -f all -f idioms example.py
```

Notice how passing `all` enables all default fixers.

Sometimes 2to3 will find a place in your source code that needs to be changed, but 2to3 cannot fix automatically. In this case, 2to3 will print a warning beneath the diff for a file. You should address the warning in order to have compliant 3.x code.

2to3 can also refactor doctests. To enable this mode, use the `-d` flag. Note that *only* doctests will be refactored. This also doesn't require the module to be valid Python. For example, doctest like examples in a reST document could also be refactored with this option.

The `-v` option enables output of more information on the translation process.

Since some print statements can be parsed as function calls or statements, 2to3 cannot always read files containing the print function. When 2to3 detects the presence of the `from __future__ import print_function` compiler directive, it modifies its internal grammar to interpret *print()* as a function. This change can also be enabled manually with the `-p` flag. Use `-p` to run fixers on code that already has had its print statements converted.

The `-o` or `--output-dir` option allows specification of an alternate directory for processed output files to be written to. The `-n` flag is required when using this as backup files do not make sense when not overwriting the input files.

New in version 3.2.3: The `-o` option was added.

The `-W` or `--write-unchanged-files` flag tells 2to3 to always write output files even if no changes were required to the file. This is most useful with `-o` so that an entire Python source tree is copied with translation from one directory to another. This option implies the `-w` flag as it would not make sense otherwise.

New in version 3.2.3: The `-W` flag was added.

The `--add-suffix` option specifies a string to append to all output filenames. The `-n` flag is required when specifying this as backups are not necessary when writing to different filenames. Example:

```
$ 2to3 -n -W --add-suffix=3 example.py
```

Will cause a converted file named `example.py3` to be written.

New in version 3.2.3: The `--add-suffix` option was added.

To translate an entire project from one directory tree to another use:

```
$ 2to3 --output-dir=python3-version/mycode -W -n python2-version/mycode
```

27.7.2 Fixers

Each step of transforming code is encapsulated in a fixer. The command `2to3 -l` lists them. As *documented above*, each can be turned on and off individually. They are described here in more detail.

apply
: Removes usage of `apply()`. For example `apply(function, *args, **kwargs)` is converted to `function(*args, **kwargs)`.

asserts
: Replaces deprecated *unittest* method names with the correct ones.

From	To
failUnlessEqual(a, b)	*assertEqual(a, b)*
assertEquals(a, b)	*assertEqual(a, b)*
failIfEqual(a, b)	*assertNotEqual(a, b)*
assertNotEquals(a, b)	*assertNotEqual(a, b)*
failUnless(a)	*assertTrue(a)*
assert_(a)	*assertTrue(a)*
failIf(a)	*assertFalse(a)*
failUnlessRaises(exc, cal)	*assertRaises(exc, cal)*
failUnlessAlmostEqual(a, b)	*assertAlmostEqual(a, b)*
assertAlmostEquals(a, b)	*assertAlmostEqual(a, b)*
failIfAlmostEqual(a, b)	*assertNotAlmostEqual(a, b)*
assertNotAlmostEquals(a, b)	*assertNotAlmostEqual(a, b)*

basestring
Converts `basestring` to *str*.

buffer
Converts `buffer` to *memoryview*. This fixer is optional because the *memoryview* API is similar but not exactly the same as that of `buffer`.

dict
Fixes dictionary iteration methods. `dict.iteritems()` is converted to *dict.items()*, `dict.iterkeys()` to *dict.keys()*, and `dict.itervalues()` to *dict.values()*. Similarly, `dict.viewitems()`, `dict.viewkeys()` and `dict.viewvalues()` are converted respectively to *dict.items()*, *dict.keys()* and *dict.values()*. It also wraps existing usages of *dict.items()*, *dict.keys()*, and *dict.values()* in a call to *list*.

except
Converts `except X, T` to `except X as T`.

exec
Converts the `exec` statement to the *exec()* function.

execfile
Removes usage of `execfile()`. The argument to `execfile()` is wrapped in calls to *open()*, *compile()*, and *exec()*.

exitfunc
Changes assignment of `sys.exitfunc` to use of the *atexit* module.

filter
Wraps *filter()* usage in a *list* call.

funcattrs
Fixes function attributes that have been renamed. For example, `my_function.func_closure` is converted to `my_function.__closure__`.

future
Removes `from __future__ import new_feature` statements.

getcwdu
Renames `os.getcwdu()` to *os.getcwd()*.

has_key
Changes `dict.has_key(key)` to `key in dict`.

idioms
This optional fixer performs several transformations that make Python code more idiomatic. Type comparisons like `type(x) is SomeClass` and `type(x) == SomeClass` are converted to `isinstance(x,`

SomeClass). `while 1` becomes `while True`. This fixer also tries to make use of *sorted()* in appropriate places. For example, this block

```
L = list(some_iterable)
L.sort()
```

is changed to

```
L = sorted(some_iterable)
```

import
Detects sibling imports and converts them to relative imports.

imports
Handles module renames in the standard library.

imports2
Handles other modules renames in the standard library. It is separate from the *imports* fixer only because of technical limitations.

input
Converts `input(prompt)` to `eval(input(prompt))`.

intern
Converts `intern()` to *sys.intern()*.

isinstance
Fixes duplicate types in the second argument of *isinstance()*. For example, `isinstance(x, (int, int))` is converted to `isinstance(x, int)` and `isinstance(x, (int, float, int))` is converted to `isinstance(x, (int, float))`.

itertools_imports
Removes imports of `itertools.ifilter()`, `itertools.izip()`, and `itertools.imap()`. Imports of `itertools.ifilterfalse()` are also changed to *itertools.filterfalse()*.

itertools
Changes usage of `itertools.ifilter()`, `itertools.izip()`, and `itertools.imap()` to their built-in equivalents. `itertools.ifilterfalse()` is changed to *itertools.filterfalse()*.

long
Renames `long` to *int*.

map
Wraps *map()* in a *list* call. It also changes `map(None, x)` to `list(x)`. Using `from future_builtins import map` disables this fixer.

metaclass
Converts the old metaclass syntax (`__metaclass__ = Meta` in the class body) to the new (`class X(metaclass=Meta)`).

methodattrs
Fixes old method attribute names. For example, `meth.im_func` is converted to `meth.__func__`.

ne
Converts the old not-equal syntax, `<>`, to `!=`.

next
Converts the use of iterator's `next()` methods to the *next()* function. It also renames *next()* methods to *__next__()*.

nonzero
Renames `__nonzero__()` to `__bool__()`.

numliterals
Converts octal literals into the new syntax.

operator
Converts calls to various functions in the *operator* module to other, but equivalent, function calls. When needed, the appropriate `import` statements are added, e.g. `import collections.abc`. The following mapping are made:

From	To
`operator.isCallable(obj)`	`callable(obj)`
`operator.sequenceIncludes(obj)`	`operator.contains(obj)`
`operator.isSequenceType(obj)`	`isinstance(obj, collections.abc.Sequence)`
`operator.isMappingType(obj)`	`isinstance(obj, collections.abc.Mapping)`
`operator.isNumberType(obj)`	`isinstance(obj, numbers.Number)`
`operator.repeat(obj, n)`	`operator.mul(obj, n)`
`operator.irepeat(obj, n)`	`operator.imul(obj, n)`

paren
Add extra parenthesis where they are required in list comprehensions. For example, `[x for x in 1, 2]` becomes `[x for x in (1, 2)]`.

print
Converts the `print` statement to the *print()* function.

raise
Converts `raise E, V` to `raise E(V)`, and `raise E, V, T` to `raise E(V).with_traceback(T)`. If `E` is a tuple, the translation will be incorrect because substituting tuples for exceptions has been removed in 3.0.

raw_input
Converts `raw_input()` to *input()*.

reduce
Handles the move of `reduce()` to *functools.reduce()*.

reload
Converts `reload()` to *imp.reload()*.

renames
Changes `sys.maxint` to *sys.maxsize*.

repr
Replaces backtick repr with the *repr()* function.

set_literal
Replaces use of the *set* constructor with set literals. This fixer is optional.

standarderror
Renames `StandardError` to *Exception*.

sys_exc
Changes the deprecated `sys.exc_value`, `sys.exc_type`, `sys.exc_traceback` to use *sys.exc_info()*.

throw
Fixes the API change in generator's `throw()` method.

tuple_params
Removes implicit tuple parameter unpacking. This fixer inserts temporary variables.

types
Fixes code broken from the removal of some members in the *types* module.

unicode
Renames `unicode` to *str*.

urllib
Handles the rename of *urllib* and `urllib2` to the *urllib* package.

ws_comma
Removes excess whitespace from comma separated items. This fixer is optional.

xrange
Renames `xrange()` to *range()* and wraps existing *range()* calls with *list*.

xreadlines
Changes `for x in file.xreadlines()` to `for x in file`.

zip
Wraps *zip()* usage in a *list* call. This is disabled when `from future_builtins import zip` appears.

27.7.3 `lib2to3` - 2to3's library

Source code: Lib/lib2to3/

Note: The *lib2to3* API should be considered unstable and may change drastically in the future.

27.8 `test` — Regression tests package for Python

Note: The *test* package is meant for internal use by Python only. It is documented for the benefit of the core developers of Python. Any use of this package outside of Python's standard library is discouraged as code mentioned here can change or be removed without notice between releases of Python.

The *test* package contains all regression tests for Python as well as the modules *test.support* and `test.regrtest`. *test.support* is used to enhance your tests while `test.regrtest` drives the testing suite.

Each module in the *test* package whose name starts with `test_` is a testing suite for a specific module or feature. All new tests should be written using the *unittest* or *doctest* module. Some older tests are written using a "traditional" testing style that compares output printed to `sys.stdout`; this style of test is considered deprecated.

See also:

Module *unittest* Writing PyUnit regression tests.

Module *doctest* Tests embedded in documentation strings.

27.8.1 Writing Unit Tests for the `test` package

It is preferred that tests that use the *unittest* module follow a few guidelines. One is to name the test module by starting it with `test_` and end it with the name of the module being tested. The test methods in the test module should start with `test_` and end with a description of what the method is testing. This is needed so that the methods are recognized by the test driver as test methods. Also, no documentation string for the method should be included. A comment (such as `# Tests function returns only True`

`or False`) should be used to provide documentation for test methods. This is done because documentation strings get printed out if they exist and thus what test is being run is not stated.

A basic boilerplate is often used:

```
import unittest
from test import support

class MyTestCase1(unittest.TestCase):

    # Only use setUp() and tearDown() if necessary

    def setUp(self):
        ... code to execute in preparation for tests ...

    def tearDown(self):
        ... code to execute to clean up after tests ...

    def test_feature_one(self):
        # Test feature one.
        ... testing code ...

    def test_feature_two(self):
        # Test feature two.
        ... testing code ...

    ... more test methods ...

class MyTestCase2(unittest.TestCase):
    ... same structure as MyTestCase1 ...

... more test classes ...

if __name__ == '__main__':
    unittest.main()
```

This code pattern allows the testing suite to be run by `test.regrtest`, on its own as a script that supports the *unittest* CLI, or via the `python -m unittest` CLI.

The goal for regression testing is to try to break code. This leads to a few guidelines to be followed:

- The testing suite should exercise all classes, functions, and constants. This includes not just the external API that is to be presented to the outside world but also "private" code.
- Whitebox testing (examining the code being tested when the tests are being written) is preferred. Blackbox testing (testing only the published user interface) is not complete enough to make sure all boundary and edge cases are tested.
- Make sure all possible values are tested including invalid ones. This makes sure that not only all valid values are acceptable but also that improper values are handled correctly.
- Exhaust as many code paths as possible. Test where branching occurs and thus tailor input to make sure as many different paths through the code are taken.
- Add an explicit test for any bugs discovered for the tested code. This will make sure that the error does not crop up again if the code is changed in the future.
- Make sure to clean up after your tests (such as close and remove all temporary files).
- If a test is dependent on a specific condition of the operating system then verify the condition already exists before attempting the test.

- Import as few modules as possible and do it as soon as possible. This minimizes external dependencies of tests and also minimizes possible anomalous behavior from side-effects of importing a module.
- Try to maximize code reuse. On occasion, tests will vary by something as small as what type of input is used. Minimize code duplication by subclassing a basic test class with a class that specifies the input:

```
class TestFuncAcceptsSequencesMixin:

    func = mySuperWhammyFunction

    def test_func(self):
        self.func(self.arg)

class AcceptLists(TestFuncAcceptsSequencesMixin, unittest.TestCase):
    arg = [1, 2, 3]

class AcceptStrings(TestFuncAcceptsSequencesMixin, unittest.TestCase):
    arg = 'abc'

class AcceptTuples(TestFuncAcceptsSequencesMixin, unittest.TestCase):
    arg = (1, 2, 3)
```

  When using this pattern, remember that all classes that inherit from *unittest.TestCase* are run as tests. The `Mixin` class in the example above does not have any data and so can't be run by itself, thus it does not inherit from *unittest.TestCase*.

See also:

Test Driven Development A book by Kent Beck on writing tests before code.

27.8.2 Running tests using the command-line interface

The *test* package can be run as a script to drive Python's regression test suite, thanks to the `-m` option: **python -m test**. Under the hood, it uses `test.regrtest`; the call **python -m test.regrtest** used in previous Python versions still works. Running the script by itself automatically starts running all regression tests in the *test* package. It does this by finding all modules in the package whose name starts with `test_`, importing them, and executing the function `test_main()` if present or loading the tests via unittest.TestLoader.loadTestsFromModule if `test_main` does not exist. The names of tests to execute may also be passed to the script. Specifying a single regression test (**python -m test test_spam**) will minimize output and only print whether the test passed or failed.

Running *test* directly allows what resources are available for tests to use to be set. You do this by using the `-u` command-line option. Specifying `all` as the value for the `-u` option enables all possible resources: **python -m test -uall**. If all but one resource is desired (a more common case), a comma-separated list of resources that are not desired may be listed after `all`. The command **python -m test -uall,-audio,-largefile** will run *test* with all resources except the `audio` and `largefile` resources. For a list of all resources and more command-line options, run **python -m test -h**.

Some other ways to execute the regression tests depend on what platform the tests are being executed on. On Unix, you can run **make test** at the top-level directory where Python was built. On Windows, executing **rt.bat** from your `PCbuild` directory will run all regression tests.

27.9 `test.support` — Utilities for the Python test suite

The *test.support* module provides support for Python's regression test suite.

Note: *test.support* is not a public module. It is documented here to help Python developers write tests. The API of this module is subject to change without backwards compatibility concerns between releases.

This module defines the following exceptions:

exception test.support.TestFailed
Exception to be raised when a test fails. This is deprecated in favor of *unittest*-based tests and *unittest.TestCase*'s assertion methods.

exception test.support.ResourceDenied
Subclass of *unittest.SkipTest*. Raised when a resource (such as a network connection) is not available. Raised by the *requires()* function.

The *test.support* module defines the following constants:

test.support.verbose
`True` when verbose output is enabled. Should be checked when more detailed information is desired about a running test. *verbose* is set by `test.regrtest`.

test.support.is_jython
`True` if the running interpreter is Jython.

test.support.is_android
`True` if the system is Android.

test.support.unix_shell
Path for shell if not on Windows; otherwise `None`.

test.support.FS_NONASCII
A non-ASCII character encodable by *os.fsencode()*.

test.support.TESTFN
Set to a name that is safe to use as the name of a temporary file. Any temporary file that is created should be closed and unlinked (removed).

test.support.TESTFN_UNICODE
Set to a non-ASCII name for a temporary file.

test.support.TESTFN_ENCODING
Set to *sys.getfilesystemencoding()*.

test.support.TESTFN_UNENCODABLE
Set to a filename (str type) that should not be able to be encoded by file system encoding in strict mode. It may be `None` if it's not possible to generate such a filename.

test.support.TESTFN_UNDECODABLE
Set to a filename (bytes type) that should not be able to be decoded by file system encoding in strict mode. It may be `None` if it's not possible to generate such a filename.

test.support.TESTFN_NONASCII
Set to a filename containing the *FS_NONASCII* character.

test.support.IPV6_ENABLED
Set to `True` if IPV6 is enabled on this host, `False` otherwise.

test.support.SAVEDCWD
Set to *os.getcwd()*.

test.support.PGO
Set when tests can be skipped when they are not useful for PGO.

test.support.PIPE_MAX_SIZE
A constant that is likely larger than the underlying OS pipe buffer size, to make writes blocking.

test.support.SOCK_MAX_SIZE
A constant that is likely larger than the underlying OS socket buffer size, to make writes blocking.

test.support.TEST_SUPPORT_DIR
Set to the top level directory that contains *test.support*.

test.support.TEST_HOME_DIR
Set to the top level directory for the test package.

test.support.TEST_DATA_DIR
Set to the `data` directory within the test package.

test.support.MAX_Py_ssize_t
Set to *sys.maxsize* for big memory tests.

test.support.max_memuse
Set by *set_memlimit()* as the memory limit for big memory tests. Limited by *MAX_Py_ssize_t*.

test.support.real_max_memuse
Set by *set_memlimit()* as the memory limit for big memory tests. Not limited by *MAX_Py_ssize_t*.

test.support.MISSING_C_DOCSTRINGS
Return `True` if running on CPython, not on Windows, and configuration not set with `WITH_DOC_STRINGS`.

test.support.HAVE_DOCSTRINGS
Check for presence of docstrings.

The *test.support* module defines the following functions:

test.support.forget(*module_name*)
Remove the module named *module_name* from `sys.modules` and delete any byte-compiled files of the module.

test.support.unload(*name*)
Delete *name* from `sys.modules`.

test.support.unlink(*filename*)
Call *os.unlink()* on *filename*. On Windows platforms, this is wrapped with a wait loop that checks for the existence fo the file.

test.support.rmdir(*filename*)
Call *os.rmdir()* on *filename*. On Windows platforms, this is wrapped with a wait loop that checks for the existence of the file.

test.support.rmtree(*path*)
Call *shutil.rmtree()* on *path* or call *os.lstat()* and *os.rmdir()* to remove a path and its contents. On Windows platforms, this is wrapped with a wait loop that checks for the existence of the files.

test.support.make_legacy_pyc(*source*)
Move a PEP 3147/488 pyc file to its legacy pyc location and return the file system path to the legacy pyc file. The *source* value is the file system path to the source file. It does not need to exist, however the PEP 3147/488 pyc file must exist.

test.support.is_resource_enabled(*resource*)
Return `True` if *resource* is enabled and available. The list of available resources is only set when `test.regrtest` is executing the tests.

test.support.python_is_optimized()
Return `True` if Python was not built with `-O0` or `-Og`.

test.support.with_pymalloc()
Return `_testcapi.WITH_PYMALLOC`.

test.support.requires(*resource*, *msg=None*)
Raise *ResourceDenied* if *resource* is not available. *msg* is the argument to *ResourceDenied* if it is raised. Always returns `True` if called by a function whose `__name__` is `'__main__'`. Used when tests are executed by `test.regrtest`.

test.support.system_must_validate_cert(*f*)
Raise *unittest.SkipTest* on TLS certification validation failures.

test.support.sortdict(*dict*)
Return a repr of *dict* with keys sorted.

test.support.findfile(*filename*, *subdir=None*)
Return the path to the file named *filename*. If no match is found *filename* is returned. This does not equal a failure since it could be the path to the file.

Setting *subdir* indicates a relative path to use to find the file rather than looking directly in the path directories.

test.support.create_empty_file(*filename*)
Create an empty file with *filename*. If it already exists, truncate it.

test.support.fd_count()
Count the number of open file descriptors.

test.support.match_test(*test*)
Match *test* to patterns set in *set_match_tests()*.

test.support.set_match_tests(*patterns*)
Define match test with regular expression *patterns*.

test.support.run_unittest(**classes*)
Execute *unittest.TestCase* subclasses passed to the function. The function scans the classes for methods starting with the prefix `test_` and executes the tests individually.

It is also legal to pass strings as parameters; these should be keys in `sys.modules`. Each associated module will be scanned by `unittest.TestLoader.loadTestsFromModule()`. This is usually seen in the following `test_main()` function:

```
def test_main():
    support.run_unittest(__name__)
```

This will run all tests defined in the named module.

test.support.run_doctest(*module*, *verbosity=None*, *optionflags=0*)
Run *doctest.testmod()* on the given *module*. Return `(failure_count, test_count)`.

If *verbosity* is `None`, *doctest.testmod()* is run with verbosity set to *verbose*. Otherwise, it is run with verbosity set to `None`. *optionflags* is passed as `optionflags` to *doctest.testmod()*.

test.support.setswitchinterval(*interval*)
Set the *sys.setswitchinterval()* to the given *interval*. Defines a minimum interval for Android systems to prevent the system from hanging.

test.support.check_impl_detail(***guards*)
Use this check to guard CPython's implementation-specific tests or to run them only on the implementations guarded by the arguments:

```
check_impl_detail()               # Only on CPython (default).
check_impl_detail(jython=True)    # Only on Jython.
check_impl_detail(cpython=False)  # Everywhere except CPython.
```

test.support.check_warnings(**filters*, *quiet=True*)
A convenience wrapper for *warnings.catch_warnings()* that makes it easier to test that a warning was

correctly raised. It is approximately equivalent to calling `warnings.catch_warnings(record=True)` with *warnings.simplefilter()* set to `always` and with the option to automatically validate the results that are recorded.

`check_warnings` accepts 2-tuples of the form `("message regexp", WarningCategory)` as positional arguments. If one or more *filters* are provided, or if the optional keyword argument *quiet* is `False`, it checks to make sure the warnings are as expected: each specified filter must match at least one of the warnings raised by the enclosed code or the test fails, and if any warnings are raised that do not match any of the specified filters the test fails. To disable the first of these checks, set *quiet* to `True`.

If no arguments are specified, it defaults to:

```
check_warnings(("", Warning), quiet=True)
```

In this case all warnings are caught and no errors are raised.

On entry to the context manager, a `WarningRecorder` instance is returned. The underlying warnings list from *catch_warnings()* is available via the recorder object's *warnings* attribute. As a convenience, the attributes of the object representing the most recent warning can also be accessed directly through the recorder object (see example below). If no warning has been raised, then any of the attributes that would otherwise be expected on an object representing a warning will return `None`.

The recorder object also has a `reset()` method, which clears the warnings list.

The context manager is designed to be used like this:

```
with check_warnings(("assertion is always true", SyntaxWarning),
                    ("", UserWarning)):
    exec('assert(False, "Hey!")')
    warnings.warn(UserWarning("Hide me!"))
```

In this case if either warning was not raised, or some other warning was raised, *check_warnings()* would raise an error.

When a test needs to look more deeply into the warnings, rather than just checking whether or not they occurred, code like this can be used:

```
with check_warnings(quiet=True) as w:
    warnings.warn("foo")
    assert str(w.args[0]) == "foo"
    warnings.warn("bar")
    assert str(w.args[0]) == "bar"
    assert str(w.warnings[0].args[0]) == "foo"
    assert str(w.warnings[1].args[0]) == "bar"
    w.reset()
    assert len(w.warnings) == 0
```

Here all warnings will be caught, and the test code tests the captured warnings directly.

Changed in version 3.2: New optional arguments *filters* and *quiet*.

`test.support.check_no_resource_warning(`*testcase*`)`
Context manager to check that no *ResourceWarning* was raised. You must remove the object which may emit *ResourceWarning* before the end of the context manager.

`test.support.set_memlimit(`*limit*`)`
Set the values for *max_memuse* and *real_max_memuse* for big memory tests.

`test.support.record_original_stdout(`*stdout*`)`
Store the value from *stdout*. It is meant to hold the stdout at the time the regrtest began.

test.support.**get_original_stdout**()
Return the original stdout set by *record_original_stdout()* or `sys.stdout` if it's not set.

test.support.**strip_python_strerr**(*stderr*)
Strip the *stderr* of a Python process from potential debug output emitted by the interpreter. This will typically be run on the result of *subprocess.Popen.communicate()*.

test.support.**args_from_interpreter_flags**()
Return a list of command line arguments reproducing the current settings in `sys.flags` and `sys.warnoptions`.

test.support.**optim_args_from_interpreter_flags**()
Return a list of command line arguments reproducing the current optimization settings in `sys.flags`.

test.support.**captured_stdin**()
test.support.**captured_stdout**()
test.support.**captured_stderr**()
A context managers that temporarily replaces the named stream with *io.StringIO* object.

Example use with output streams:

```
with captured_stdout() as stdout, captured_stderr() as stderr:
    print("hello")
    print("error", file=sys.stderr)
assert stdout.getvalue() == "hello\n"
assert stderr.getvalue() == "error\n"
```

Example use with input stream:

```
with captured_stdin() as stdin:
    stdin.write('hello\n')
    stdin.seek(0)
    # call test code that consumes from sys.stdin
    captured = input()
self.assertEqual(captured, "hello")
```

test.support.**temp_dir**(*path=None*, *quiet=False*)
A context manager that creates a temporary directory at *path* and yields the directory.

If *path* is `None`, the temporary directory is created using *tempfile.mkdtemp()*. If *quiet* is `False`, the context manager raises an exception on error. Otherwise, if *path* is specified and cannot be created, only a warning is issued.

test.support.**change_cwd**(*path*, *quiet=False*)
A context manager that temporarily changes the current working directory to *path* and yields the directory.

If *quiet* is `False`, the context manager raises an exception on error. Otherwise, it issues only a warning and keeps the current working directory the same.

test.support.**temp_cwd**(*name='tempcwd'*, *quiet=False*)
A context manager that temporarily creates a new directory and changes the current working directory (CWD).

The context manager creates a temporary directory in the current directory with name *name* before temporarily changing the current working directory. If *name* is `None`, the temporary directory is created using *tempfile.mkdtemp()*.

If *quiet* is `False` and it is not possible to create or change the CWD, an error is raised. Otherwise, only a warning is raised and the original CWD is used.

test.support.**temp_umask**(*umask*)
A context manager that temporarily sets the process umask.

test.support.**transient_internet**(*resource_name*, *, *timeout=30.0*, *errnos=()*)
A context manager that raises *ResourceDenied* when various issues with the internet connection manifest themselves as exceptions.

test.support.**disable_faulthandler**()
A context manager that replaces `sys.stderr` with `sys.__stderr__`.

test.support.**gc_collect**()
Force as many objects as possible to be collected. This is needed because timely deallocation is not guaranteed by the garbage collector. This means that `__del__` methods may be called later than expected and weakrefs may remain alive for longer than expected.

test.support.**disable_gc**()
A context manager that disables the garbage collector upon entry and reenables it upon exit.

test.support.**swap_attr**(*obj*, *attr*, *new_val*)
Context manager to swap out an attribute with a new object.

Usage:

```
with swap_attr(obj, "attr", 5):
    ...
```

This will set `obj.attr` to 5 for the duration of the `with` block, restoring the old value at the end of the block. If `attr` doesn't exist on `obj`, it will be created and then deleted at the end of the block.

The old value (or `None` if it doesn't exist) will be assigned to the target of the "as" clause, if there is one.

test.support.**swap_item**(*obj*, *attr*, *new_val*)
Context manager to swap out an item with a new object.

Usage:

```
with swap_item(obj, "item", 5):
    ...
```

This will set `obj["item"]` to 5 for the duration of the `with` block, restoring the old value at the end of the block. If `item` doesn't exist on `obj`, it will be created and then deleted at the end of the block.

The old value (or `None` if it doesn't exist) will be assigned to the target of the "as" clause, if there is one.

test.support.**wait_threads_exit**(*timeout=60.0*)
Context manager to wait until all threads created in the `with` statement exit.

test.support.**start_threads**(*threads*, *unlock=None*)
Context manager to start *threads*. It attempts to join the threads upon exit.

test.support.**calcobjsize**(*fmt*)
Return *struct.calcsize()* for `nP{fmt}0n` or, if `gettotalrefcount` exists, `2PnP{fmt}0P`.

test.support.**calcvobjsize**(*fmt*)
Return *struct.calcsize()* for `nPn{fmt}0n` or, if `gettotalrefcount` exists, `2PnPn{fmt}0P`.

test.support.**checksizeof**(*test*, *o*, *size*)
For testcase *test*, assert that the `sys.getsizeof` for *o* plus the GC header size equals *size*.

test.support.**can_symlink**()
Return `True` if the OS supports symbolic links, `False` otherwise.

test.support.can_xattr()
Return `True` if the OS supports xattr, `False` otherwise.

@test.support.skip_unless_symlink
A decorator for running tests that require support for symbolic links.

@test.support.skip_unless_xattr
A decorator for running tests that require support for xattr.

@test.support.skip_unless_bind_unix_socket
A decorator for running tests that require a functional bind() for Unix sockets.

@test.support.anticipate_failure(*condition*)
A decorator to conditionally mark tests with *unittest.expectedFailure()*. Any use of this decorator should have an associated comment identifying the relevant tracker issue.

@test.support.run_with_locale(*catstr*, **locales*)
A decorator for running a function in a different locale, correctly resetting it after it has finished. *catstr* is the locale category as a string (for example `"LC_ALL"`). The *locales* passed will be tried sequentially, and the first valid locale will be used.

@test.support.run_with_tz(*tz*)
A decorator for running a function in a specific timezone, correctly resetting it after it has finished.

@test.support.requires_freebsd_version(**min_version*)
Decorator for the minimum version when running test on FreeBSD. If the FreeBSD version is less than the minimum, raise *unittest.SkipTest*.

@test.support.requires_linux_version(**min_version*)
Decorator for the minimum version when running test on Linux. If the Linux version is less than the minimum, raise *unittest.SkipTest*.

@test.support.requires_mac_version(**min_version*)
Decorator for the minimum version when running test on Mac OS X. If the MAC OS X version is less than the minimum, raise *unittest.SkipTest*.

@test.support.requires_IEEE_754
Decorator for skipping tests on non-IEEE 754 platforms.

@test.support.requires_zlib
Decorator for skipping tests if *zlib* doesn't exist.

@test.support.requires_gzip
Decorator for skipping tests if *gzip* doesn't exist.

@test.support.requires_bz2
Decorator for skipping tests if *bz2* doesn't exist.

@test.support.requires_lzma
Decorator for skipping tests if *lzma* doesn't exist.

@test.support.requires_resource(*resource*)
Decorator for skipping tests if *resource* is not available.

@test.support.requires_docstrings
Decorator for only running the test if *HAVE_DOCSTRINGS*.

@test.support.cpython_only(*test*)
Decorator for tests only applicable to CPython.

@test.support.impl_detail(*msg=None*, ***guards*)
Decorator for invoking *check_impl_detail()* on *guards*. If that returns `False`, then uses *msg* as the reason for skipping the test.

`@test.support.no_tracing`(*func*)
Decorator to temporarily turn off tracing for the duration of the test.

`@test.support.refcount_test`(*test*)
Decorator for tests which involve reference counting. The decorator does not run the test if it is not run by CPython. Any trace function is unset for the duration of the test to prevent unexpected refcounts caused by the trace function.

`@test.support.reap_threads`(*func*)
Decorator to ensure the threads are cleaned up even if the test fails.

`@test.support.bigmemtest`(*size*, *memuse*, *dry_run=True*)
Decorator for bigmem tests.

size is a requested size for the test (in arbitrary, test-interpreted units.) *memuse* is the number of bytes per unit for the test, or a good estimate of it. For example, a test that needs two byte buffers, of 4 GiB each, could be decorated with `@bigmemtest(size=_4G, memuse=2)`.

The *size* argument is normally passed to the decorated test method as an extra argument. If *dry_run* is `True`, the value passed to the test method may be less than the requested value. If *dry_run* is `False`, it means the test doesn't support dummy runs when `-M` is not specified.

`@test.support.bigaddrspacetest`(*f*)
Decorator for tests that fill the address space. *f* is the function to wrap.

`test.support.make_bad_fd`()
Create an invalid file descriptor by opening and closing a temporary file, and returning its descriptor.

`test.support.check_syntax_error`(*testcase*, *statement*, *errtext=''*, ***, *lineno=None*, *offset=None*)
Test for syntax errors in *statement* by attempting to compile *statement*. *testcase* is the *unittest* instance for the test. *errtext* is the text of the error raised by *SyntaxError*. If *lineno* is not None, compares to the line of the *SyntaxError*. If *offset* is not None, compares to the offset of the *SyntaxError*.

`test.support.open_urlresource`(*url*, **args*, ***kw*)
Open *url*. If open fails, raises *TestFailed*.

`test.support.import_module`(*name*, *deprecated=False*, ***, *required_on()*)
This function imports and returns the named module. Unlike a normal import, this function raises *unittest.SkipTest* if the module cannot be imported.

Module and package deprecation messages are suppressed during this import if *deprecated* is `True`. If a module is required on a platform but optional for others, set *required_on* to an iterable of platform prefixes which will be compared against *sys.platform*.

New in version 3.1.

`test.support.import_fresh_module`(*name*, *fresh=()*, *blocked=()*, *deprecated=False*)
This function imports and returns a fresh copy of the named Python module by removing the named module from `sys.modules` before doing the import. Note that unlike `reload()`, the original module is not affected by this operation.

fresh is an iterable of additional module names that are also removed from the `sys.modules` cache before doing the import.

blocked is an iterable of module names that are replaced with `None` in the module cache during the import to ensure that attempts to import them raise *ImportError*.

The named module and any modules named in the *fresh* and *blocked* parameters are saved before starting the import and then reinserted into `sys.modules` when the fresh import is complete.

Module and package deprecation messages are suppressed during this import if *deprecated* is `True`.

This function will raise *ImportError* if the named module cannot be imported.

Example use:

```
# Get copies of the warnings module for testing without affecting the
# version being used by the rest of the test suite. One copy uses the
# C implementation, the other is forced to use the pure Python fallback
# implementation
py_warnings = import_fresh_module('warnings', blocked=['_warnings'])
c_warnings = import_fresh_module('warnings', fresh=['_warnings'])
```

New in version 3.1.

test.support.modules_setup()
Return a copy of *sys.modules*.

test.support.modules_cleanup(*oldmodules*)
Remove modules except for *oldmodules* and `encodings` in order to preserve internal cache.

test.support.threading_setup()
Return current thread count and copy of dangling threads.

test.support.threading_cleanup(**original_values*)
Cleanup up threads not specified in *original_values*. Designed to emit a warning if a test leaves running threads in the background.

test.support.join_thread(*thread*, *timeout=30.0*)
Join a *thread* within *timeout*. Raise an *AssertionError* if thread is still alive after *timeout* seconds.

test.support.reap_children()
Use this at the end of `test_main` whenever sub-processes are started. This will help ensure that no extra children (zombies) stick around to hog resources and create problems when looking for refleaks.

test.support.get_attribute(*obj*, *name*)
Get an attribute, raising *unittest.SkipTest* if *AttributeError* is raised.

test.support.bind_port(*sock*, *host=HOST*)
Bind the socket to a free port and return the port number. Relies on ephemeral ports in order to ensure we are using an unbound port. This is important as many tests may be running simultaneously, especially in a buildbot environment. This method raises an exception if the `sock.family` is *AF_INET* and `sock.type` is *SOCK_STREAM*, and the socket has `SO_REUSEADDR` or `SO_REUSEPORT` set on it. Tests should never set these socket options for TCP/IP sockets. The only case for setting these options is testing multicasting via multiple UDP sockets.

Additionally, if the `SO_EXCLUSIVEADDRUSE` socket option is available (i.e. on Windows), it will be set on the socket. This will prevent anyone else from binding to our host/port for the duration of the test.

test.support.bind_unix_socket(*sock*, *addr*)
Bind a unix socket, raising *unittest.SkipTest* if *PermissionError* is raised.

test.support.find_unused_port(*family=socket.AF_INET*, *socktype=socket.SOCK_STREAM*)
Returns an unused port that should be suitable for binding. This is achieved by creating a temporary socket with the same family and type as the `sock` parameter (default is *AF_INET*, *SOCK_STREAM*), and binding it to the specified host address (defaults to `0.0.0.0`) with the port set to 0, eliciting an unused ephemeral port from the OS. The temporary socket is then closed and deleted, and the ephemeral port is returned.

Either this method or *bind_port()* should be used for any tests where a server socket needs to be bound to a particular port for the duration of the test. Which one to use depends on whether the calling code is creating a python socket, or if an unused port needs to be provided in a constructor or passed to an external program (i.e. the `-accept` argument to openssl's s_server mode). Always prefer *bind_port()* over *find_unused_port()* where possible. Using a hard coded port is discouraged since it can make multiple instances of the test impossible to run simultaneously, which is a problem for buildbots.

test.support.**load_package_tests**(*pkg_dir*, *loader*, *standard_tests*, *pattern*)
Generic implementation of the *unittest* `load_tests` protocol for use in test packages. *pkg_dir* is the root directory of the package; *loader*, *standard_tests*, and *pattern* are the arguments expected by `load_tests`. In simple cases, the test package's `__init__.py` can be the following:

```
import os
from test.support import load_package_tests

def load_tests(*args):
    return load_package_tests(os.path.dirname(__file__), *args)
```

test.support.**fs_is_case_insensitive**(*directory*)
Return `True` if the file system for *directory* is case-insensitive.

test.support.**detect_api_mismatch**(*ref_api*, *other_api*, *, *ignore=()*)
Returns the set of attributes, functions or methods of *ref_api* not found on *other_api*, except for a defined list of items to be ignored in this check specified in *ignore*.

By default this skips private attributes beginning with '_' but includes all magic methods, i.e. those starting and ending in '___'.

New in version 3.5.

test.support.**patch**(*test_instance*, *object_to_patch*, *attr_name*, *new_value*)
Override *object_to_patch.attr_name* with *new_value*. Also add cleanup procedure to *test_instance* to restore *object_to_patch* for *attr_name*. The *attr_name* should be a valid attribute for *object_to_patch*.

test.support.**run_in_subinterp**(*code*)
Run *code* in subinterpreter. Raise *unittest.SkipTest* if *tracemalloc* is enabled.

test.support.**check_free_after_iterating**(*test*, *iter*, *cls*, *args=()*)
Assert that *iter* is deallocated after iterating.

test.support.**missing_compiler_executable**(*cmd_names=[]*)
Check for the existence of the compiler executables whose names are listed in *cmd_names* or all the compiler executables when *cmd_names* is empty and return the first missing executable or `None` when none is found missing.

test.support.**check__all__**(*test_case*, *module*, *name_of_module=None*, *extra=()*, *blacklist=()*)
Assert that the `__all__` variable of *module* contains all public names.

The module's public names (its API) are detected automatically based on whether they match the public name convention and were defined in *module*.

The *name_of_module* argument can specify (as a string or tuple thereof) what module(s) an API could be defined in order to be detected as a public API. One case for this is when *module* imports part of its public API from other modules, possibly a C backend (like `csv` and its `_csv`).

The *extra* argument can be a set of names that wouldn't otherwise be automatically detected as "public", like objects without a proper `__module__` attribute. If provided, it will be added to the automatically detected ones.

The *blacklist* argument can be a set of names that must not be treated as part of the public API even though their names indicate otherwise.

Example use:

```
import bar
import foo
import unittest
from test import support
```

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```
class MiscTestCase(unittest.TestCase):
    def test__all__(self):
        support.check__all__(self, foo)

class OtherTestCase(unittest.TestCase):
    def test__all__(self):
        extra = {'BAR_CONST', 'FOO_CONST'}
        blacklist = {'baz'}  # Undocumented name.
        # bar imports part of its API from _bar.
        support.check__all__(self, bar, ('bar', '_bar'),
                             extra=extra, blacklist=blacklist)
```

New in version 3.6.

The *test.support* module defines the following classes:

class test.support.TransientResource(*exc*, ***kwargs*)
Instances are a context manager that raises *ResourceDenied* if the specified exception type is raised. Any keyword arguments are treated as attribute/value pairs to be compared against any exception raised within the `with` statement. Only if all pairs match properly against attributes on the exception is *ResourceDenied* raised.

class test.support.EnvironmentVarGuard
Class used to temporarily set or unset environment variables. Instances can be used as a context manager and have a complete dictionary interface for querying/modifying the underlying `os.environ`. After exit from the context manager all changes to environment variables done through this instance will be rolled back.

Changed in version 3.1: Added dictionary interface.

EnvironmentVarGuard.set(*envvar*, *value*)
Temporarily set the environment variable `envvar` to the value of `value`.

EnvironmentVarGuard.unset(*envvar*)
Temporarily unset the environment variable `envvar`.

class test.support.SuppressCrashReport
A context manager used to try to prevent crash dialog popups on tests that are expected to crash a subprocess.

On Windows, it disables Windows Error Reporting dialogs using SetErrorMode.

On UNIX, *resource.setrlimit()* is used to set *resource.RLIMIT_CORE*'s soft limit to 0 to prevent coredump file creation.

On both platforms, the old value is restored by `__exit__()`.

class test.support.CleanImport(**module_names*)
A context manager to force import to return a new module reference. This is useful for testing module-level behaviors, such as the emission of a DeprecationWarning on import. Example usage:

```
with CleanImport('foo'):
    importlib.import_module('foo')  # New reference.
```

class test.support.DirsOnSysPath(**paths*)
A context manager to temporarily add directories to sys.path.

This makes a copy of *sys.path*, appends any directories given as positional arguments, then reverts *sys.path* to the copied settings when the context ends.

Note that *all* *sys.path* modifications in the body of the context manager, including replacement of the object, will be reverted at the end of the block.

class test.support.SaveSignals
Class to save and restore signal handlers registered by the Python signal handler.

class test.support.Matcher

matches(*self*, *d*, ***kwargs*)
Try to match a single dict with the supplied arguments.

match_value(*self*, *k*, *dv*, *v*)
Try to match a single stored value (*dv*) with a supplied value (*v*).

class test.support.WarningsRecorder
Class used to record warnings for unit tests. See documentation of *check_warnings()* above for more details.

class test.support.BasicTestRunner

run(*test*)
Run *test* and return the result.

class test.support.TestHandler(*logging.handlers.BufferingHandler*)
Class for logging support.

class test.support.FakePath(*path*)
Simple *path-like object*. It implements the `__fspath__()` method which just returns the *path* argument. If *path* is an exception, it will be raised in `__fspath__()`.

27.10 test.support.script_helper — Utilities for the Python execution tests

The *test.support.script_helper* module provides support for Python's script execution tests.

test.support.script_helper.interpreter_requires_environment()
Return `True` if `sys.executable interpreter` requires environment variables in order to be able to run at all.

This is designed to be used with `@unittest.skipIf()` to annotate tests that need to use an `assert_python*()` function to launch an isolated mode (`-I`) or no environment mode (`-E`) sub-interpreter process.

A normal build & test does not run into this situation but it can happen when trying to run the standard library test suite from an interpreter that doesn't have an obvious home with Python's current home finding logic.

Setting `PYTHONHOME` is one way to get most of the testsuite to run in that situation. `PYTHONPATH` or `PYTHONUSERSITE` are other common environment variables that might impact whether or not the interpreter can start.

test.support.script_helper.run_python_until_end(**args*, ***env_vars*)
Set up the environment based on *env_vars* for running the interpreter in a subprocess. The values can include `__isolated`, `__cleanenv`, `__cwd`, and `TERM`.

test.support.script_helper.assert_python_ok(**args*, ***env_vars*)
Assert that running the interpreter with *args* and optional environment variables *env_vars* succeeds (`rc == 0`) and return a `(return code, stdout, stderr)` tuple.

If the `__cleanenv` keyword is set, *env_vars* is used as a fresh environment.

Python is started in isolated mode (command line option `-I`), except if the `__isolated` keyword is set to `False`.

`test.support.script_helper.assert_python_failure`(**args*, ***env_vars*)
Assert that running the interpreter with *args* and optional environment variables *env_vars* fails (`rc != 0`) and return a `(return code, stdout, stderr)` tuple.

See *assert_python_ok()* for more options.

`test.support.script_helper.spawn_python`(**args*, *stdout=subprocess.PIPE*, *stderr=subprocess.STDOUT*, ***kw*)
Run a Python subprocess with the given arguments.

kw is extra keyword args to pass to *subprocess.Popen()*. Returns a *subprocess.Popen* object.

`test.support.script_helper.kill_python`(*p*)
Run the given *subprocess.Popen* process until completion and return stdout.

`test.support.script_helper.make_script`(*script_dir*, *script_basename*, *source*, *omit_suffix=False*)
Create script containing *source* in path *script_dir* and *script_basename*. If *omit_suffix* is `False`, append `.py` to the name. Return the full script path.

`test.support.script_helper.make_zip_script`(*zip_dir*, *zip_basename*, *script_name*, *name_in_zip=None*)
Create zip file at *zip_dir* and *zip_basename* with extension `zip` which contains the files in *script_name*. *name_in_zip* is the archive name. Return a tuple containing `(full path, full path of archive name)`.

`test.support.script_helper.make_pkg`(*pkg_dir*, *init_source=''*)
Create a directory named *pkg_dir* containing an `__init__` file with *init_source* as its contents.

`test.support.script_helper.make_zip_pkg`(*zip_dir*, *zip_basename*, *pkg_name*, *script_basename*, *source*, *depth=1*, *compiled=False*)
Create a zip package directory with a path of *zip_dir* and *zip_basename* containing an empty `__init__` file and a file *script_basename* containing the *source*. If *compiled* is `True`, both source files will be compiled and added to the zip package. Return a tuple of the full zip path and the archive name for the zip file.

See also the Python development mode: the `-X dev` option and `PYTHONDEVMODE` environment variable.

CHAPTER

TWENTYEIGHT

DEBUGGING AND PROFILING

These libraries help you with Python development: the debugger enables you to step through code, analyze stack frames and set breakpoints etc., and the profilers run code and give you a detailed breakdown of execution times, allowing you to identify bottlenecks in your programs.

28.1 bdb — Debugger framework

Source code: Lib/bdb.py

The *bdb* module handles basic debugger functions, like setting breakpoints or managing execution via the debugger.

The following exception is defined:

exception bdb.BdbQuit
Exception raised by the *Bdb* class for quitting the debugger.

The *bdb* module also defines two classes:

class bdb.Breakpoint(*self*, *file*, *line*, *temporary=0*, *cond=None*, *funcname=None*)
This class implements temporary breakpoints, ignore counts, disabling and (re-)enabling, and conditionals.

Breakpoints are indexed by number through a list called `bpbynumber` and by `(file, line)` pairs through `bplist`. The former points to a single instance of class *Breakpoint*. The latter points to a list of such instances since there may be more than one breakpoint per line.

When creating a breakpoint, its associated filename should be in canonical form. If a *funcname* is defined, a breakpoint hit will be counted when the first line of that function is executed. A conditional breakpoint always counts a hit.

Breakpoint instances have the following methods:

deleteMe()
Delete the breakpoint from the list associated to a file/line. If it is the last breakpoint in that position, it also deletes the entry for the file/line.

enable()
Mark the breakpoint as enabled.

disable()
Mark the breakpoint as disabled.

bpformat()
Return a string with all the information about the breakpoint, nicely formatted:

- The breakpoint number.

- If it is temporary or not.
- Its file,line position.
- The condition that causes a break.
- If it must be ignored the next N times.
- The breakpoint hit count.

New in version 3.2.

bpprint(*out=None*)
Print the output of *bpformat()* to the file *out*, or if it is `None`, to standard output.

class bdb.**Bdb**(*skip=None*)
The *Bdb* class acts as a generic Python debugger base class.

This class takes care of the details of the trace facility; a derived class should implement user interaction. The standard debugger class (*pdb.Pdb*) is an example.

The *skip* argument, if given, must be an iterable of glob-style module name patterns. The debugger will not step into frames that originate in a module that matches one of these patterns. Whether a frame is considered to originate in a certain module is determined by the `__name__` in the frame globals.

New in version 3.1: The *skip* argument.

The following methods of *Bdb* normally don't need to be overridden.

canonic(*filename*)
Auxiliary method for getting a filename in a canonical form, that is, as a case-normalized (on case-insensitive filesystems) absolute path, stripped of surrounding angle brackets.

reset()
Set the `botframe`, `stopframe`, `returnframe` and `quitting` attributes with values ready to start debugging.

trace_dispatch(*frame*, *event*, *arg*)
This function is installed as the trace function of debugged frames. Its return value is the new trace function (in most cases, that is, itself).

The default implementation decides how to dispatch a frame, depending on the type of event (passed as a string) that is about to be executed. *event* can be one of the following:

- `"line"`: A new line of code is going to be executed.
- `"call"`: A function is about to be called, or another code block entered.
- `"return"`: A function or other code block is about to return.
- `"exception"`: An exception has occurred.
- `"c_call"`: A C function is about to be called.
- `"c_return"`: A C function has returned.
- `"c_exception"`: A C function has raised an exception.

For the Python events, specialized functions (see below) are called. For the C events, no action is taken.

The *arg* parameter depends on the previous event.

See the documentation for *sys.settrace()* for more information on the trace function. For more information on code and frame objects, refer to types.

dispatch_line(*frame*)
If the debugger should stop on the current line, invoke the *user_line()* method (which should be overridden in subclasses). Raise a *BdbQuit* exception if the `Bdb.quitting` flag is set (which

can be set from *user_line()*). Return a reference to the *trace_dispatch()* method for further tracing in that scope.

dispatch_call(*frame*, *arg*)
If the debugger should stop on this function call, invoke the *user_call()* method (which should be overridden in subclasses). Raise a *BdbQuit* exception if the `Bdb.quitting` flag is set (which can be set from *user_call()*). Return a reference to the *trace_dispatch()* method for further tracing in that scope.

dispatch_return(*frame*, *arg*)
If the debugger should stop on this function return, invoke the *user_return()* method (which should be overridden in subclasses). Raise a *BdbQuit* exception if the `Bdb.quitting` flag is set (which can be set from *user_return()*). Return a reference to the *trace_dispatch()* method for further tracing in that scope.

dispatch_exception(*frame*, *arg*)
If the debugger should stop at this exception, invokes the *user_exception()* method (which should be overridden in subclasses). Raise a *BdbQuit* exception if the `Bdb.quitting` flag is set (which can be set from *user_exception()*). Return a reference to the *trace_dispatch()* method for further tracing in that scope.

Normally derived classes don't override the following methods, but they may if they want to redefine the definition of stopping and breakpoints.

stop_here(*frame*)
This method checks if the *frame* is somewhere below `botframe` in the call stack. `botframe` is the frame in which debugging started.

break_here(*frame*)
This method checks if there is a breakpoint in the filename and line belonging to *frame* or, at least, in the current function. If the breakpoint is a temporary one, this method deletes it.

break_anywhere(*frame*)
This method checks if there is a breakpoint in the filename of the current frame.

Derived classes should override these methods to gain control over debugger operation.

user_call(*frame*, *argument_list*)
This method is called from *dispatch_call()* when there is the possibility that a break might be necessary anywhere inside the called function.

user_line(*frame*)
This method is called from *dispatch_line()* when either *stop_here()* or *break_here()* yields `True`.

user_return(*frame*, *return_value*)
This method is called from *dispatch_return()* when *stop_here()* yields `True`.

user_exception(*frame*, *exc_info*)
This method is called from *dispatch_exception()* when *stop_here()* yields `True`.

do_clear(*arg*)
Handle how a breakpoint must be removed when it is a temporary one.

This method must be implemented by derived classes.

Derived classes and clients can call the following methods to affect the stepping state.

set_step()
Stop after one line of code.

set_next(*frame*)
Stop on the next line in or below the given frame.

set_return(*frame*)
Stop when returning from the given frame.

set_until(*frame*)
Stop when the line with the line no greater than the current one is reached or when returning from current frame.

set_trace([*frame*])
Start debugging from *frame*. If *frame* is not specified, debugging starts from caller's frame.

set_continue()
Stop only at breakpoints or when finished. If there are no breakpoints, set the system trace function to `None`.

set_quit()
Set the `quitting` attribute to `True`. This raises *BdbQuit* in the next call to one of the `dispatch_*()` methods.

Derived classes and clients can call the following methods to manipulate breakpoints. These methods return a string containing an error message if something went wrong, or `None` if all is well.

set_break(*filename*, *lineno*, *temporary=0*, *cond*, *funcname*)
Set a new breakpoint. If the *lineno* line doesn't exist for the *filename* passed as argument, return an error message. The *filename* should be in canonical form, as described in the *canonic()* method.

clear_break(*filename*, *lineno*)
Delete the breakpoints in *filename* and *lineno*. If none were set, an error message is returned.

clear_bpbynumber(*arg*)
Delete the breakpoint which has the index *arg* in the `Breakpoint.bpbynumber`. If *arg* is not numeric or out of range, return an error message.

clear_all_file_breaks(*filename*)
Delete all breakpoints in *filename*. If none were set, an error message is returned.

clear_all_breaks()
Delete all existing breakpoints.

get_bpbynumber(*arg*)
Return a breakpoint specified by the given number. If *arg* is a string, it will be converted to a number. If *arg* is a non-numeric string, if the given breakpoint never existed or has been deleted, a *ValueError* is raised.

New in version 3.2.

get_break(*filename*, *lineno*)
Check if there is a breakpoint for *lineno* of *filename*.

get_breaks(*filename*, *lineno*)
Return all breakpoints for *lineno* in *filename*, or an empty list if none are set.

get_file_breaks(*filename*)
Return all breakpoints in *filename*, or an empty list if none are set.

get_all_breaks()
Return all breakpoints that are set.

Derived classes and clients can call the following methods to get a data structure representing a stack trace.

get_stack(*f*, *t*)
Get a list of records for a frame and all higher (calling) and lower frames, and the size of the higher part.

format_stack_entry(*frame_lineno*, *lprefix=': '*)
Return a string with information about a stack entry, identified by a `(frame, lineno)` tuple:

- The canonical form of the filename which contains the frame.
- The function name, or `"<lambda>"`.
- The input arguments.
- The return value.
- The line of code (if it exists).

The following two methods can be called by clients to use a debugger to debug a *statement*, given as a string.

run(*cmd*, *globals=None*, *locals=None*)
Debug a statement executed via the *exec()* function. *globals* defaults to `__main__.__dict__`, *locals* defaults to *globals*.

runeval(*expr*, *globals=None*, *locals=None*)
Debug an expression executed via the *eval()* function. *globals* and *locals* have the same meaning as in *run()*.

runctx(*cmd*, *globals*, *locals*)
For backwards compatibility. Calls the *run()* method.

runcall(*func*, **args*, ***kwds*)
Debug a single function call, and return its result.

Finally, the module defines the following functions:

bdb.**checkfuncname**(*b*, *frame*)
Check whether we should break here, depending on the way the breakpoint *b* was set.

If it was set via line number, it checks if `b.line` is the same as the one in the frame also passed as argument. If the breakpoint was set via function name, we have to check we are in the right frame (the right function) and if we are in its first executable line.

bdb.**effective**(*file*, *line*, *frame*)
Determine if there is an effective (active) breakpoint at this line of code. Return a tuple of the breakpoint and a boolean that indicates if it is ok to delete a temporary breakpoint. Return `(None, None)` if there is no matching breakpoint.

bdb.**set_trace**()
Start debugging with a *Bdb* instance from caller's frame.

28.2 faulthandler — Dump the Python traceback

New in version 3.3.

This module contains functions to dump Python tracebacks explicitly, on a fault, after a timeout, or on a user signal. Call *faulthandler.enable()* to install fault handlers for the `SIGSEGV`, `SIGFPE`, `SIGABRT`, `SIGBUS`, and `SIGILL` signals. You can also enable them at startup by setting the `PYTHONFAULTHANDLER` environment variable or by using the `-X faulthandler` command line option.

The fault handler is compatible with system fault handlers like Apport or the Windows fault handler. The module uses an alternative stack for signal handlers if the `sigaltstack()` function is available. This allows it to dump the traceback even on a stack overflow.

The fault handler is called on catastrophic cases and therefore can only use signal-safe functions (e.g. it cannot allocate memory on the heap). Because of this limitation traceback dumping is minimal compared to normal Python tracebacks:

- Only ASCII is supported. The `backslashreplace` error handler is used on encoding.
- Each string is limited to 500 characters.
- Only the filename, the function name and the line number are displayed. (no source code)
- It is limited to 100 frames and 100 threads.
- The order is reversed: the most recent call is shown first.

By default, the Python traceback is written to *sys.stderr*. To see tracebacks, applications must be run in the terminal. A log file can alternatively be passed to *faulthandler.enable()*.

The module is implemented in C, so tracebacks can be dumped on a crash or when Python is deadlocked.

28.2.1 Dumping the traceback

faulthandler.dump_traceback(*file=sys.stderr*, *all_threads=True*)
Dump the tracebacks of all threads into *file*. If *all_threads* is `False`, dump only the current thread.

Changed in version 3.5: Added support for passing file descriptor to this function.

28.2.2 Fault handler state

faulthandler.enable(*file=sys.stderr*, *all_threads=True*)
Enable the fault handler: install handlers for the `SIGSEGV`, `SIGFPE`, `SIGABRT`, `SIGBUS` and `SIGILL` signals to dump the Python traceback. If *all_threads* is `True`, produce tracebacks for every running thread. Otherwise, dump only the current thread.

The *file* must be kept open until the fault handler is disabled: see *issue with file descriptors*.

Changed in version 3.5: Added support for passing file descriptor to this function.

Changed in version 3.6: On Windows, a handler for Windows exception is also installed.

faulthandler.disable()
Disable the fault handler: uninstall the signal handlers installed by *enable()*.

faulthandler.is_enabled()
Check if the fault handler is enabled.

28.2.3 Dumping the tracebacks after a timeout

faulthandler.dump_traceback_later(*timeout*, *repeat=False*, *file=sys.stderr*, *exit=False*)
Dump the tracebacks of all threads, after a timeout of *timeout* seconds, or every *timeout* seconds if *repeat* is `True`. If *exit* is `True`, call `_exit()` with status=1 after dumping the tracebacks. (Note `_exit()` exits the process immediately, which means it doesn't do any cleanup like flushing file buffers.) If the function is called twice, the new call replaces previous parameters and resets the timeout. The timer has a sub-second resolution.

The *file* must be kept open until the traceback is dumped or *cancel_dump_traceback_later()* is called: see *issue with file descriptors*.

This function is implemented using a watchdog thread and therefore is not available if Python is compiled with threads disabled.

Changed in version 3.5: Added support for passing file descriptor to this function.

faulthandler.cancel_dump_traceback_later()
Cancel the last call to *dump_traceback_later()*.

28.2.4 Dumping the traceback on a user signal

faulthandler.register(*signum*, *file=sys.stderr*, *all_threads=True*, *chain=False*)
Register a user signal: install a handler for the *signum* signal to dump the traceback of all threads, or of the current thread if *all_threads* is `False`, into *file*. Call the previous handler if chain is `True`.

The *file* must be kept open until the signal is unregistered by *unregister()*: see *issue with file descriptors*.

Not available on Windows.

Changed in version 3.5: Added support for passing file descriptor to this function.

faulthandler.unregister(*signum*)
Unregister a user signal: uninstall the handler of the *signum* signal installed by *register()*. Return `True` if the signal was registered, `False` otherwise.

Not available on Windows.

28.2.5 Issue with file descriptors

enable(), *dump_traceback_later()* and *register()* keep the file descriptor of their *file* argument. If the file is closed and its file descriptor is reused by a new file, or if *os.dup2()* is used to replace the file descriptor, the traceback will be written into a different file. Call these functions again each time that the file is replaced.

28.2.6 Example

Example of a segmentation fault on Linux with and without enabling the fault handler:

```
$ python3 -c "import ctypes; ctypes.string_at(0)"
Segmentation fault

$ python3 -q -X faulthandler
>>> import ctypes
>>> ctypes.string_at(0)
Fatal Python error: Segmentation fault

Current thread 0x00007fb899f39700 (most recent call first):
  File "/home/python/cpython/Lib/ctypes/__init__.py", line 486 in string_at
  File "<stdin>", line 1 in <module>
Segmentation fault
```

28.3 pdb — The Python Debugger

Source code: Lib/pdb.py

The module *pdb* defines an interactive source code debugger for Python programs. It supports setting (conditional) breakpoints and single stepping at the source line level, inspection of stack frames, source code listing, and evaluation of arbitrary Python code in the context of any stack frame. It also supports post-mortem debugging and can be called under program control.

The debugger is extensible – it is actually defined as the class *Pdb*. This is currently undocumented but easily understood by reading the source. The extension interface uses the modules *bdb* and *cmd*.

The debugger's prompt is `(Pdb)`. Typical usage to run a program under control of the debugger is:

```
>>> import pdb
>>> import mymodule
>>> pdb.run('mymodule.test()')
> <string>(0)?()
(Pdb) continue
> <string>(1)?()
(Pdb) continue
NameError: 'spam'
> <string>(1)?()
(Pdb)
```

Changed in version 3.3: Tab-completion via the *readline* module is available for commands and command arguments, e.g. the current global and local names are offered as arguments of the `p` command.

`pdb.py` can also be invoked as a script to debug other scripts. For example:

```
python3 -m pdb myscript.py
```

When invoked as a script, pdb will automatically enter post-mortem debugging if the program being debugged exits abnormally. After post-mortem debugging (or after normal exit of the program), pdb will restart the program. Automatic restarting preserves pdb's state (such as breakpoints) and in most cases is more useful than quitting the debugger upon program's exit.

New in version 3.2: `pdb.py` now accepts a `-c` option that executes commands as if given in a `.pdbrc` file, see *Debugger Commands*.

New in version 3.7: `pdb.py` now accepts a `-m` option that execute modules similar to the way `python3 -m` does. As with a script, the debugger will pause execution just before the first line of the module.

The typical usage to break into the debugger from a running program is to insert

```
import pdb; pdb.set_trace()
```

at the location you want to break into the debugger. You can then step through the code following this statement, and continue running without the debugger using the *continue* command.

The typical usage to inspect a crashed program is:

```
>>> import pdb
>>> import mymodule
>>> mymodule.test()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "./mymodule.py", line 4, in test
    test2()
  File "./mymodule.py", line 3, in test2
    print(spam)
NameError: spam
>>> pdb.pm()
> ./mymodule.py(3)test2()
-> print(spam)
(Pdb)
```

The module defines the following functions; each enters the debugger in a slightly different way:

pdb.run(*statement*, *globals=None*, *locals=None*)
Execute the *statement* (given as a string or a code object) under debugger control. The debugger prompt appears before any code is executed; you can set breakpoints and type *continue*, or you can step through the statement using *step* or *next* (all these commands are explained below). The optional *globals* and *locals* arguments specify the environment in which the code is executed; by default the dictionary of the module *__main__* is used. (See the explanation of the built-in *exec()* or *eval()* functions.)

pdb.runeval(*expression*, *globals=None*, *locals=None*)
Evaluate the *expression* (given as a string or a code object) under debugger control. When *runeval()* returns, it returns the value of the expression. Otherwise this function is similar to *run()*.

pdb.runcall(*function*, **args*, ***kwds*)
Call the *function* (a function or method object, not a string) with the given arguments. When *runcall()* returns, it returns whatever the function call returned. The debugger prompt appears as soon as the function is entered.

pdb.set_trace(***, *header=None*)
Enter the debugger at the calling stack frame. This is useful to hard-code a breakpoint at a given point in a program, even if the code is not otherwise being debugged (e.g. when an assertion fails). If given, *header* is printed to the console just before debugging begins.

Changed in version 3.7: The keyword-only argument *header*.

pdb.post_mortem(*traceback=None*)
Enter post-mortem debugging of the given *traceback* object. If no *traceback* is given, it uses the one of the exception that is currently being handled (an exception must be being handled if the default is to be used).

pdb.pm()
Enter post-mortem debugging of the traceback found in *sys.last_traceback*.

The `run*` functions and *set_trace()* are aliases for instantiating the *Pdb* class and calling the method of the same name. If you want to access further features, you have to do this yourself:

class pdb.Pdb(*completekey='tab'*, *stdin=None*, *stdout=None*, *skip=None*, *nosigint=False*, *readrc=True*)
Pdb is the debugger class.

The *completekey*, *stdin* and *stdout* arguments are passed to the underlying *cmd.Cmd* class; see the description there.

The *skip* argument, if given, must be an iterable of glob-style module name patterns. The debugger will not step into frames that originate in a module that matches one of these patterns.[1]

By default, Pdb sets a handler for the SIGINT signal (which is sent when the user presses `Ctrl-C` on the console) when you give a `continue` command. This allows you to break into the debugger again by pressing `Ctrl-C`. If you want Pdb not to touch the SIGINT handler, set *nosigint* to true.

The *readrc* argument defaults to true and controls whether Pdb will load .pdbrc files from the filesystem.

Example call to enable tracing with *skip*:

```
import pdb; pdb.Pdb(skip=['django.*']).set_trace()
```

New in version 3.1: The *skip* argument.

New in version 3.2: The *nosigint* argument. Previously, a SIGINT handler was never set by Pdb.

Changed in version 3.6: The *readrc* argument.

run(*statement*, *globals=None*, *locals=None*)

[1] Whether a frame is considered to originate in a certain module is determined by the `__name__` in the frame globals.

runeval(*expression*, *globals=None*, *locals=None*)
runcall(*function*, **args*, ***kwds*)
set_trace()
See the documentation for the functions explained above.

28.3.1 Debugger Commands

The commands recognized by the debugger are listed below. Most commands can be abbreviated to one or two letters as indicated; e.g. `h(elp)` means that either `h` or `help` can be used to enter the help command (but not `he` or `hel`, nor `H` or `Help` or `HELP`). Arguments to commands must be separated by whitespace (spaces or tabs). Optional arguments are enclosed in square brackets (`[]`) in the command syntax; the square brackets must not be typed. Alternatives in the command syntax are separated by a vertical bar (`|`).

Entering a blank line repeats the last command entered. Exception: if the last command was a *list* command, the next 11 lines are listed.

Commands that the debugger doesn't recognize are assumed to be Python statements and are executed in the context of the program being debugged. Python statements can also be prefixed with an exclamation point (`!`). This is a powerful way to inspect the program being debugged; it is even possible to change a variable or call a function. When an exception occurs in such a statement, the exception name is printed but the debugger's state is not changed.

The debugger supports *aliases*. Aliases can have parameters which allows one a certain level of adaptability to the context under examination.

Multiple commands may be entered on a single line, separated by `;;`. (A single `;` is not used as it is the separator for multiple commands in a line that is passed to the Python parser.) No intelligence is applied to separating the commands; the input is split at the first `;;` pair, even if it is in the middle of a quoted string.

If a file `.pdbrc` exists in the user's home directory or in the current directory, it is read in and executed as if it had been typed at the debugger prompt. This is particularly useful for aliases. If both files exist, the one in the home directory is read first and aliases defined there can be overridden by the local file.

Changed in version 3.2: `.pdbrc` can now contain commands that continue debugging, such as *continue* or *next*. Previously, these commands had no effect.

h(elp) [command]
Without argument, print the list of available commands. With a *command* as argument, print help about that command. `help pdb` displays the full documentation (the docstring of the *pdb* module). Since the *command* argument must be an identifier, `help exec` must be entered to get help on the `!` command.

w(here)
Print a stack trace, with the most recent frame at the bottom. An arrow indicates the current frame, which determines the context of most commands.

d(own) [count]
Move the current frame *count* (default one) levels down in the stack trace (to a newer frame).

u(p) [count]
Move the current frame *count* (default one) levels up in the stack trace (to an older frame).

b(reak) [([filename:]lineno | function) [, condition]]
With a *lineno* argument, set a break there in the current file. With a *function* argument, set a break at the first executable statement within that function. The line number may be prefixed with a filename and a colon, to specify a breakpoint in another file (probably one that hasn't been loaded yet). The file is searched on *sys.path*. Note that each breakpoint is assigned a number to which all the other breakpoint commands refer.

If a second argument is present, it is an expression which must evaluate to true before the breakpoint is honored.

Without argument, list all breaks, including for each breakpoint, the number of times that breakpoint has been hit, the current ignore count, and the associated condition if any.

tbreak [([filename:]lineno | function) [, condition]]
Temporary breakpoint, which is removed automatically when it is first hit. The arguments are the same as for *break*.

cl(ear) [filename:lineno | bpnumber [bpnumber ...]]
With a *filename:lineno* argument, clear all the breakpoints at this line. With a space separated list of breakpoint numbers, clear those breakpoints. Without argument, clear all breaks (but first ask confirmation).

disable [bpnumber [bpnumber ...]]
Disable the breakpoints given as a space separated list of breakpoint numbers. Disabling a breakpoint means it cannot cause the program to stop execution, but unlike clearing a breakpoint, it remains in the list of breakpoints and can be (re-)enabled.

enable [bpnumber [bpnumber ...]]
Enable the breakpoints specified.

ignore bpnumber [count]
Set the ignore count for the given breakpoint number. If count is omitted, the ignore count is set to 0. A breakpoint becomes active when the ignore count is zero. When non-zero, the count is decremented each time the breakpoint is reached and the breakpoint is not disabled and any associated condition evaluates to true.

condition bpnumber [condition]
Set a new *condition* for the breakpoint, an expression which must evaluate to true before the breakpoint is honored. If *condition* is absent, any existing condition is removed; i.e., the breakpoint is made unconditional.

commands [bpnumber]
Specify a list of commands for breakpoint number *bpnumber*. The commands themselves appear on the following lines. Type a line containing just **end** to terminate the commands. An example:

```
(Pdb) commands 1
(com) p some_variable
(com) end
(Pdb)
```

To remove all commands from a breakpoint, type **commands** and follow it immediately with **end**; that is, give no commands.

With no *bpnumber* argument, **commands** refers to the last breakpoint set.

You can use breakpoint commands to start your program up again. Simply use the *continue* command, or *step*, or any other command that resumes execution.

Specifying any command resuming execution (currently *continue*, *step*, *next*, *return*, *jump*, *quit* and their abbreviations) terminates the command list (as if that command was immediately followed by end). This is because any time you resume execution (even with a simple next or step), you may encounter another breakpoint—which could have its own command list, leading to ambiguities about which list to execute.

If you use the 'silent' command in the command list, the usual message about stopping at a breakpoint is not printed. This may be desirable for breakpoints that are to print a specific message and then continue. If none of the other commands print anything, you see no sign that the breakpoint was reached.

s(tep)
Execute the current line, stop at the first possible occasion (either in a function that is called or on the next line in the current function).

n(ext)
Continue execution until the next line in the current function is reached or it returns. (The difference between *next* and *step* is that *step* stops inside a called function, while *next* executes called functions at (nearly) full speed, only stopping at the next line in the current function.)

unt(il) [lineno]
Without argument, continue execution until the line with a number greater than the current one is reached.

With a line number, continue execution until a line with a number greater or equal to that is reached. In both cases, also stop when the current frame returns.

Changed in version 3.2: Allow giving an explicit line number.

r(eturn)
Continue execution until the current function returns.

c(ont(inue))
Continue execution, only stop when a breakpoint is encountered.

j(ump) lineno
Set the next line that will be executed. Only available in the bottom-most frame. This lets you jump back and execute code again, or jump forward to skip code that you don't want to run.

It should be noted that not all jumps are allowed – for instance it is not possible to jump into the middle of a `for` loop or out of a `finally` clause.

l(ist) [first[, last]]
List source code for the current file. Without arguments, list 11 lines around the current line or continue the previous listing. With `.` as argument, list 11 lines around the current line. With one argument, list 11 lines around at that line. With two arguments, list the given range; if the second argument is less than the first, it is interpreted as a count.

The current line in the current frame is indicated by `->`. If an exception is being debugged, the line where the exception was originally raised or propagated is indicated by `>>`, if it differs from the current line.

New in version 3.2: The `>>` marker.

ll | longlist
List all source code for the current function or frame. Interesting lines are marked as for *list*.

New in version 3.2.

a(rgs)
Print the argument list of the current function.

p expression
Evaluate the *expression* in the current context and print its value.

Note: `print()` can also be used, but is not a debugger command — this executes the Python *print()* function.

---

pp expression
Like the *p* command, except the value of the expression is pretty-printed using the *pprint* module.

whatis expression
Print the type of the *expression*.

source expression
Try to get source code for the given object and display it.

New in version 3.2.

display [expression]
Display the value of the expression if it changed, each time execution stops in the current frame.

Without expression, list all display expressions for the current frame.

New in version 3.2.

undisplay [expression]
Do not display the expression any more in the current frame. Without expression, clear all display expressions for the current frame.

New in version 3.2.

interact
Start an interactive interpreter (using the *code* module) whose global namespace contains all the (global and local) names found in the current scope.

New in version 3.2.

alias [name [command]]
Create an alias called *name* that executes *command*. The command must *not* be enclosed in quotes. Replaceable parameters can be indicated by %1, %2, and so on, while %* is replaced by all the parameters. If no command is given, the current alias for *name* is shown. If no arguments are given, all aliases are listed.

Aliases may be nested and can contain anything that can be legally typed at the pdb prompt. Note that internal pdb commands *can* be overridden by aliases. Such a command is then hidden until the alias is removed. Aliasing is recursively applied to the first word of the command line; all other words in the line are left alone.

As an example, here are two useful aliases (especially when placed in the .pdbrc file):

```
# Print instance variables (usage "pi classInst")
alias pi for k in %1.__dict__.keys(): print("%1.",k,"=",%1.__dict__[k])
# Print instance variables in self
alias ps pi self
```

unalias name
Delete the specified alias.

! statement
Execute the (one-line) *statement* in the context of the current stack frame. The exclamation point can be omitted unless the first word of the statement resembles a debugger command. To set a global variable, you can prefix the assignment command with a global statement on the same line, e.g.:

```
(Pdb) global list_options; list_options = ['-l']
(Pdb)
```

run [args ...]
restart [args ...]
Restart the debugged Python program. If an argument is supplied, it is split with *shlex* and the result is used as the new *sys.argv*. History, breakpoints, actions and debugger options are preserved. *restart* is an alias for *run*.

q(uit)
Quit from the debugger. The program being executed is aborted.

28.4 The Python Profilers

Source code: Lib/profile.py and Lib/pstats.py

28.4.1 Introduction to the profilers

cProfile and *profile* provide *deterministic profiling* of Python programs. A *profile* is a set of statistics that describes how often and for how long various parts of the program executed. These statistics can be formatted into reports via the *pstats* module.

The Python standard library provides two different implementations of the same profiling interface:

1. *cProfile* is recommended for most users; it's a C extension with reasonable overhead that makes it suitable for profiling long-running programs. Based on `lsprof`, contributed by Brett Rosen and Ted Czotter.
2. *profile*, a pure Python module whose interface is imitated by *cProfile*, but which adds significant overhead to profiled programs. If you're trying to extend the profiler in some way, the task might be easier with this module. Originally designed and written by Jim Roskind.

Note: The profiler modules are designed to provide an execution profile for a given program, not for benchmarking purposes (for that, there is *timeit* for reasonably accurate results). This particularly applies to benchmarking Python code against C code: the profilers introduce overhead for Python code, but not for C-level functions, and so the C code would seem faster than any Python one.

28.4.2 Instant User's Manual

This section is provided for users that "don't want to read the manual." It provides a very brief overview, and allows a user to rapidly perform profiling on an existing application.

To profile a function that takes a single argument, you can do:

```
import cProfile
import re
cProfile.run('re.compile("foo|bar")')
```

(Use *profile* instead of *cProfile* if the latter is not available on your system.)

The above action would run *re.compile()* and print profile results like the following:

```
      197 function calls (192 primitive calls) in 0.002 seconds

Ordered by: standard name

ncalls  tottime  percall  cumtime  percall filename:lineno(function)
     1    0.000    0.000    0.001    0.001 <string>:1(<module>)
     1    0.000    0.000    0.001    0.001 re.py:212(compile)
     1    0.000    0.000    0.001    0.001 re.py:268(_compile)
     1    0.000    0.000    0.000    0.000 sre_compile.py:172(_compile_charset)
     1    0.000    0.000    0.000    0.000 sre_compile.py:201(_optimize_charset)
     4    0.000    0.000    0.000    0.000 sre_compile.py:25(_identityfunction)
   3/1    0.000    0.000    0.000    0.000 sre_compile.py:33(_compile)
```

The first line indicates that 197 calls were monitored. Of those calls, 192 were *primitive*, meaning that the call was not induced via recursion. The next line: `Ordered by: standard name`, indicates that the text string in the far right column was used to sort the output. The column headings include:

ncalls for the number of calls.

tottime for the total time spent in the given function (and excluding time made in calls to sub-functions)

percall is the quotient of `tottime` divided by `ncalls`

cumtime is the cumulative time spent in this and all subfunctions (from invocation till exit). This figure is accurate *even* for recursive functions.

percall is the quotient of `cumtime` divided by primitive calls

filename:lineno(function) provides the respective data of each function

When there are two numbers in the first column (for example `3/1`), it means that the function recursed. The second value is the number of primitive calls and the former is the total number of calls. Note that when the function does not recurse, these two values are the same, and only the single figure is printed.

Instead of printing the output at the end of the profile run, you can save the results to a file by specifying a filename to the `run()` function:

```
import cProfile
import re
cProfile.run('re.compile("foo|bar")', 'restats')
```

The *pstats.Stats* class reads profile results from a file and formats them in various ways.

The file *cProfile* can also be invoked as a script to profile another script. For example:

```
python -m cProfile [-o output_file] [-s sort_order] (-m module | myscript.py)
```

`-o` writes the profile results to a file instead of to stdout

`-s` specifies one of the *sort_stats()* sort values to sort the output by. This only applies when `-o` is not supplied.

`-m` specifies that a module is being profiled instead of a script.

New in version 3.7: Added the `-m` option.

The *pstats* module's *Stats* class has a variety of methods for manipulating and printing the data saved into a profile results file:

```
import pstats
from pstats import SortKey
p = pstats.Stats('restats')
p.strip_dirs().sort_stats(-1).print_stats()
```

The *strip_dirs()* method removed the extraneous path from all the module names. The *sort_stats()* method sorted all the entries according to the standard module/line/name string that is printed. The *print_stats()* method printed out all the statistics. You might try the following sort calls:

```
p.sort_stats(SortKey.NAME)
p.print_stats()
```

The first call will actually sort the list by function name, and the second call will print out the statistics. The following are some interesting calls to experiment with:

```
p.sort_stats(SortKey.CUMULATIVE).print_stats(10)
```

This sorts the profile by cumulative time in a function, and then only prints the ten most significant lines. If you want to understand what algorithms are taking time, the above line is what you would use.

If you were looking to see what functions were looping a lot, and taking a lot of time, you would do:

```
p.sort_stats(SortKey.TIME).print_stats(10)
```

to sort according to time spent within each function, and then print the statistics for the top ten functions.

You might also try:

```
p.sort_stats(SortKey.FILENAME).print_stats('__init__')
```

This will sort all the statistics by file name, and then print out statistics for only the class init methods (since they are spelled with `__init__` in them). As one final example, you could try:

```
p.sort_stats(SortKey.TIME, SortKey.CUMULATIVE).print_stats(.5, 'init')
```

This line sorts statistics with a primary key of time, and a secondary key of cumulative time, and then prints out some of the statistics. To be specific, the list is first culled down to 50% (re: `.5`) of its original size, then only lines containing `init` are maintained, and that sub-sub-list is printed.

If you wondered what functions called the above functions, you could now (`p` is still sorted according to the last criteria) do:

```
p.print_callers(.5, 'init')
```

and you would get a list of callers for each of the listed functions.

If you want more functionality, you're going to have to read the manual, or guess what the following functions do:

```
p.print_callees()
p.add('restats')
```

Invoked as a script, the *pstats* module is a statistics browser for reading and examining profile dumps. It has a simple line-oriented interface (implemented using *cmd*) and interactive help.

28.4.3 `profile` and `cProfile` Module Reference

Both the *profile* and *cProfile* modules provide the following functions:

profile.run(*command*, *filename=None*, *sort=-1*)

This function takes a single argument that can be passed to the *exec()* function, and an optional file name. In all cases this routine executes:

```
exec(command, __main__.__dict__, __main__.__dict__)
```

and gathers profiling statistics from the execution. If no file name is present, then this function automatically creates a *Stats* instance and prints a simple profiling report. If the sort value is specified, it is passed to this *Stats* instance to control how the results are sorted.

profile.runctx(*command*, *globals*, *locals*, *filename=None*, *sort=-1*)

This function is similar to *run()*, with added arguments to supply the globals and locals dictionaries for the *command* string. This routine executes:

```
exec(command, globals, locals)
```

and gathers profiling statistics as in the *run()* function above.

class profile.Profile(*timer=None*, *timeunit=0.0*, *subcalls=True*, *builtins=True*)

This class is normally only used if more precise control over profiling is needed than what the `cProfile.run()` function provides.

A custom timer can be supplied for measuring how long code takes to run via the *timer* argument. This must be a function that returns a single number representing the current time. If the number is an integer, the *timeunit* specifies a multiplier that specifies the duration of each unit of time. For example, if the timer returns times measured in thousands of seconds, the time unit would be `.001`.

Directly using the *Profile* class allows formatting profile results without writing the profile data to a file:

```
import cProfile, pstats, io
from pstats import SortKey
pr = cProfile.Profile()
pr.enable()
# ... do something ...
pr.disable()
s = io.StringIO()
sortby = SortKey.CUMULATIVE
ps = pstats.Stats(pr, stream=s).sort_stats(sortby)
ps.print_stats()
print(s.getvalue())
```

enable()

Start collecting profiling data.

disable()

Stop collecting profiling data.

create_stats()

Stop collecting profiling data and record the results internally as the current profile.

print_stats(*sort=-1*)

Create a *Stats* object based on the current profile and print the results to stdout.

dump_stats(*filename*)

Write the results of the current profile to *filename*.

run(*cmd*)

Profile the cmd via *exec()*.

runctx(*cmd*, *globals*, *locals*)

Profile the cmd via *exec()* with the specified global and local environment.

runcall(*func*, **args*, ***kwargs*)

Profile `func(*args, **kwargs)`

28.4.4 The `Stats` Class

Analysis of the profiler data is done using the *Stats* class.

class pstats.Stats(**filenames or profile*, *stream=sys.stdout*)

This class constructor creates an instance of a "statistics object" from a *filename* (or list of filenames) or from a `Profile` instance. Output will be printed to the stream specified by *stream*.

The file selected by the above constructor must have been created by the corresponding version of *profile* or *cProfile*. To be specific, there is *no* file compatibility guaranteed with future versions of this profiler, and there is no compatibility with files produced by other profilers, or the same profiler run on a different operating system. If several files are provided, all the statistics for identical functions will be coalesced, so that an overall view of several processes can be considered in a single report. If

additional files need to be combined with data in an existing *Stats* object, the *add()* method can be used.

Instead of reading the profile data from a file, a `cProfile.Profile` or *profile.Profile* object can be used as the profile data source.

Stats objects have the following methods:

strip_dirs()
This method for the *Stats* class removes all leading path information from file names. It is very useful in reducing the size of the printout to fit within (close to) 80 columns. This method modifies the object, and the stripped information is lost. After performing a strip operation, the object is considered to have its entries in a "random" order, as it was just after object initialization and loading. If *strip_dirs()* causes two function names to be indistinguishable (they are on the same line of the same filename, and have the same function name), then the statistics for these two entries are accumulated into a single entry.

add(**filenames***)**
This method of the *Stats* class accumulates additional profiling information into the current profiling object. Its arguments should refer to filenames created by the corresponding version of *profile.run()* or `cProfile.run()`. Statistics for identically named (re: file, line, name) functions are automatically accumulated into single function statistics.

dump_stats(*filename***)**
Save the data loaded into the *Stats* object to a file named *filename*. The file is created if it does not exist, and is overwritten if it already exists. This is equivalent to the method of the same name on the *profile.Profile* and `cProfile.Profile` classes.

sort_stats(**keys***)**
This method modifies the *Stats* object by sorting it according to the supplied criteria. The argument can be either a string or a SortKey enum identifying the basis of a sort (example: `'time'`, `'name'`, `SortKey.TIME` or `SortKey.NAME`). The SortKey enums argument have advantage over the string argument in that it is more robust and less error prone.

When more than one key is provided, then additional keys are used as secondary criteria when there is equality in all keys selected before them. For example, `sort_stats(SortKey.NAME, SortKey.FILE)` will sort all the entries according to their function name, and resolve all ties (identical function names) by sorting by file name.

For the string argument, abbreviations can be used for any key names, as long as the abbreviation is unambiguous.

The following are the valid string and SortKey:

Valid String Arg	Valid enum Arg	Meaning
`'calls'`	SortKey.CALLS	call count
`'cumulative'`	SortKey.CUMULATIVE	cumulative time
`'cumtime'`	N/A	cumulative time
`'file'`	N/A	file name
`'filename'`	SortKey.FILENAME	file name
`'module'`	N/A	file name
`'ncalls'`	N/A	call count
`'pcalls'`	SortKey.PCALLS	primitive call count
`'line'`	SortKey.LINE	line number
`'name'`	SortKey.NAME	function name
`'nfl'`	SortKey.NFL	name/file/line
`'stdname'`	SortKey.STDNAME	standard name
`'time'`	SortKey.TIME	internal time
`'tottime'`	N/A	internal time

Note that all sorts on statistics are in descending order (placing most time consuming items first), where as name, file, and line number searches are in ascending order (alphabetical). The subtle distinction between `SortKey.NFL` and `SortKey.STDNAME` is that the standard name is a sort of the name as printed, which means that the embedded line numbers get compared in an odd way. For example, lines 3, 20, and 40 would (if the file names were the same) appear in the string order 20, 3 and 40. In contrast, `SortKey.NFL` does a numeric compare of the line numbers. In fact, `sort_stats(SortKey.NFL)` is the same as `sort_stats(SortKey.NAME, SortKey.FILENAME, SortKey.LINE)`.

For backward-compatibility reasons, the numeric arguments `-1`, `0`, `1`, and `2` are permitted. They are interpreted as `'stdname'`, `'calls'`, `'time'`, and `'cumulative'` respectively. If this old style format (numeric) is used, only one sort key (the numeric key) will be used, and additional arguments will be silently ignored.

New in version 3.7: Added the SortKey enum.

reverse_order()

This method for the *Stats* class reverses the ordering of the basic list within the object. Note that by default ascending vs descending order is properly selected based on the sort key of choice.

print_stats(**restrictions*)

This method for the *Stats* class prints out a report as described in the *profile.run()* definition.

The order of the printing is based on the last *sort_stats()* operation done on the object (subject to caveats in *add()* and *strip_dirs()*).

The arguments provided (if any) can be used to limit the list down to the significant entries. Initially, the list is taken to be the complete set of profiled functions. Each restriction is either an integer (to select a count of lines), or a decimal fraction between 0.0 and 1.0 inclusive (to select a percentage of lines), or a string that will interpreted as a regular expression (to pattern match the standard name that is printed). If several restrictions are provided, then they are applied sequentially. For example:

```
print_stats(.1, 'foo:')
```

would first limit the printing to first 10% of list, and then only print functions that were part of filename `.*foo:`. In contrast, the command:

```
print_stats('foo:', .1)
```

would limit the list to all functions having file names `.*foo:`, and then proceed to only print the first 10% of them.

print_callers(**restrictions*)

This method for the *Stats* class prints a list of all functions that called each function in the profiled database. The ordering is identical to that provided by *print_stats()*, and the definition of the restricting argument is also identical. Each caller is reported on its own line. The format differs slightly depending on the profiler that produced the stats:

- With *profile*, a number is shown in parentheses after each caller to show how many times this specific call was made. For convenience, a second non-parenthesized number repeats the cumulative time spent in the function at the right.
- With *cProfile*, each caller is preceded by three numbers: the number of times this specific call was made, and the total and cumulative times spent in the current function while it was invoked by this specific caller.

print_callees(**restrictions*)

This method for the *Stats* class prints a list of all function that were called by the indicated function. Aside from this reversal of direction of calls (re: called vs was called by), the arguments and ordering are identical to the *print_callers()* method.

28.4.5 What Is Deterministic Profiling?

Deterministic profiling is meant to reflect the fact that all *function call*, *function return*, and *exception* events are monitored, and precise timings are made for the intervals between these events (during which time the user's code is executing). In contrast, *statistical profiling* (which is not done by this module) randomly samples the effective instruction pointer, and deduces where time is being spent. The latter technique traditionally involves less overhead (as the code does not need to be instrumented), but provides only relative indications of where time is being spent.

In Python, since there is an interpreter active during execution, the presence of instrumented code is not required to do deterministic profiling. Python automatically provides a *hook* (optional callback) for each event. In addition, the interpreted nature of Python tends to add so much overhead to execution, that deterministic profiling tends to only add small processing overhead in typical applications. The result is that deterministic profiling is not that expensive, yet provides extensive run time statistics about the execution of a Python program.

Call count statistics can be used to identify bugs in code (surprising counts), and to identify possible inline-expansion points (high call counts). Internal time statistics can be used to identify "hot loops" that should be carefully optimized. Cumulative time statistics should be used to identify high level errors in the selection of algorithms. Note that the unusual handling of cumulative times in this profiler allows statistics for recursive implementations of algorithms to be directly compared to iterative implementations.

28.4.6 Limitations

One limitation has to do with accuracy of timing information. There is a fundamental problem with deterministic profilers involving accuracy. The most obvious restriction is that the underlying "clock" is only ticking at a rate (typically) of about .001 seconds. Hence no measurements will be more accurate than the underlying clock. If enough measurements are taken, then the "error" will tend to average out. Unfortunately, removing this first error induces a second source of error.

The second problem is that it "takes a while" from when an event is dispatched until the profiler's call to get the time actually *gets* the state of the clock. Similarly, there is a certain lag when exiting the profiler event handler from the time that the clock's value was obtained (and then squirreled away), until the user's code is once again executing. As a result, functions that are called many times, or call many functions, will typically accumulate this error. The error that accumulates in this fashion is typically less than the accuracy of the clock (less than one clock tick), but it *can* accumulate and become very significant.

The problem is more important with *profile* than with the lower-overhead *cProfile*. For this reason, *profile* provides a means of calibrating itself for a given platform so that this error can be probabilistically (on the average) removed. After the profiler is calibrated, it will be more accurate (in a least square sense), but it will sometimes produce negative numbers (when call counts are exceptionally low, and the gods of probability work against you :-).) Do *not* be alarmed by negative numbers in the profile. They should *only* appear if you have calibrated your profiler, and the results are actually better than without calibration.

28.4.7 Calibration

The profiler of the *profile* module subtracts a constant from each event handling time to compensate for the overhead of calling the time function, and socking away the results. By default, the constant is 0. The following procedure can be used to obtain a better constant for a given platform (see *Limitations*).

```
import profile
pr = profile.Profile()
for i in range(5):
    print(pr.calibrate(10000))
```

The method executes the number of Python calls given by the argument, directly and again under the profiler, measuring the time for both. It then computes the hidden overhead per profiler event, and returns that as a float. For example, on a 1.8Ghz Intel Core i5 running Mac OS X, and using Python's time.process_time() as the timer, the magical number is about 4.04e-6.

The object of this exercise is to get a fairly consistent result. If your computer is *very* fast, or your timer function has poor resolution, you might have to pass 100000, or even 1000000, to get consistent results.

When you have a consistent answer, there are three ways you can use it:

```
import profile

# 1. Apply computed bias to all Profile instances created hereafter.
profile.Profile.bias = your_computed_bias

# 2. Apply computed bias to a specific Profile instance.
pr = profile.Profile()
pr.bias = your_computed_bias

# 3. Specify computed bias in instance constructor.
pr = profile.Profile(bias=your_computed_bias)
```

If you have a choice, you are better off choosing a smaller constant, and then your results will "less often" show up as negative in profile statistics.

28.4.8 Using a custom timer

If you want to change how current time is determined (for example, to force use of wall-clock time or elapsed process time), pass the timing function you want to the `Profile` class constructor:

```
pr = profile.Profile(your_time_func)
```

The resulting profiler will then call `your_time_func`. Depending on whether you are using *profile.Profile* or `cProfile.Profile`, `your_time_func`'s return value will be interpreted differently:

profile.Profile `your_time_func` should return a single number, or a list of numbers whose sum is the current time (like what *os.times()* returns). If the function returns a single time number, or the list of returned numbers has length 2, then you will get an especially fast version of the dispatch routine.

Be warned that you should calibrate the profiler class for the timer function that you choose (see *Calibration*). For most machines, a timer that returns a lone integer value will provide the best results in terms of low overhead during profiling. (*os.times()* is *pretty* bad, as it returns a tuple of floating point values). If you want to substitute a better timer in the cleanest fashion, derive a class and hardwire a replacement dispatch method that best handles your timer call, along with the appropriate calibration constant.

`cProfile.Profile` `your_time_func` should return a single number. If it returns integers, you can also invoke the class constructor with a second argument specifying the real duration of one unit of time. For example, if `your_integer_time_func` returns times measured in thousands of seconds, you would construct the `Profile` instance as follows:

```
pr = cProfile.Profile(your_integer_time_func, 0.001)
```

As the `cProfile.Profile` class cannot be calibrated, custom timer functions should be used with care and should be as fast as possible. For the best results with a custom timer, it might be necessary to hard-code it in the C source of the internal `_lsprof` module.

Python 3.3 adds several new functions in *time* that can be used to make precise measurements of process or wall-clock time. For example, see *time.perf_counter()*.

28.5 timeit — Measure execution time of small code snippets

Source code: Lib/timeit.py

This module provides a simple way to time small bits of Python code. It has both a *Command-Line Interface* as well as a *callable* one. It avoids a number of common traps for measuring execution times. See also Tim Peters' introduction to the "Algorithms" chapter in the *Python Cookbook*, published by O'Reilly.

28.5.1 Basic Examples

The following example shows how the *Command-Line Interface* can be used to compare three different expressions:

```
$ python3 -m timeit '"-".join(str(n) for n in range(100))'
10000 loops, best of 5: 30.2 usec per loop
$ python3 -m timeit '"-".join([str(n) for n in range(100)])'
10000 loops, best of 5: 27.5 usec per loop
$ python3 -m timeit '"-".join(map(str, range(100)))'
10000 loops, best of 5: 23.2 usec per loop
```

This can be achieved from the *Python Interface* with:

```
>>> import timeit
>>> timeit.timeit('"-".join(str(n) for n in range(100))', number=10000)
0.3018611848820001
>>> timeit.timeit('"-".join([str(n) for n in range(100)])', number=10000)
0.2727368790656328
>>> timeit.timeit('"-".join(map(str, range(100)))', number=10000)
0.23702679807320237
```

Note however that *timeit* will automatically determine the number of repetitions only when the command-line interface is used. In the *Examples* section you can find more advanced examples.

28.5.2 Python Interface

The module defines three convenience functions and a public class:

timeit.timeit(*stmt='pass'*, *setup='pass'*, *timer=<default timer>*, *number=1000000*, *globals=None*)

Create a *Timer* instance with the given statement, *setup* code and *timer* function and run its *timeit()* method with *number* executions. The optional *globals* argument specifies a namespace in which to execute the code.

Changed in version 3.5: The optional *globals* parameter was added.

timeit.repeat(*stmt='pass'*, *setup='pass'*, *timer=<default timer>*, *repeat=5*, *number=1000000*, *globals=None*)

Create a *Timer* instance with the given statement, *setup* code and *timer* function and run its *repeat()* method with the given *repeat* count and *number* executions. The optional *globals* argument specifies a namespace in which to execute the code.

Changed in version 3.5: The optional *globals* parameter was added.

Changed in version 3.7: Default value of *repeat* changed from 3 to 5.

timeit.default_timer()
The default timer, which is always *time.perf_counter()*.

Changed in version 3.3: *time.perf_counter()* is now the default timer.

class timeit.Timer(*stmt='pass'*, *setup='pass'*, *timer=<timer function>*, *globals=None*)
Class for timing execution speed of small code snippets.

The constructor takes a statement to be timed, an additional statement used for setup, and a timer function. Both statements default to `'pass'`; the timer function is platform-dependent (see the module doc string). *stmt* and *setup* may also contain multiple statements separated by `;` or newlines, as long as they don't contain multi-line string literals. The statement will by default be executed within timeit's namespace; this behavior can be controlled by passing a namespace to *globals*.

To measure the execution time of the first statement, use the *timeit()* method. The *repeat()* and *autorange()* methods are convenience methods to call *timeit()* multiple times.

The execution time of *setup* is excluded from the overall timed execution run.

The *stmt* and *setup* parameters can also take objects that are callable without arguments. This will embed calls to them in a timer function that will then be executed by *timeit()*. Note that the timing overhead is a little larger in this case because of the extra function calls.

Changed in version 3.5: The optional *globals* parameter was added.

timeit(*number=1000000*)
Time *number* executions of the main statement. This executes the setup statement once, and then returns the time it takes to execute the main statement a number of times, measured in seconds as a float. The argument is the number of times through the loop, defaulting to one million. The main statement, the setup statement and the timer function to be used are passed to the constructor.

Note: By default, *timeit()* temporarily turns off *garbage collection* during the timing. The advantage of this approach is that it makes independent timings more comparable. This disadvantage is that GC may be an important component of the performance of the function being measured. If so, GC can be re-enabled as the first statement in the *setup* string. For example:

```
timeit.Timer('for i in range(10): oct(i)', 'gc.enable()').timeit()
```

---

autorange(*callback=None*)
Automatically determine how many times to call *timeit()*.

This is a convenience function that calls *timeit()* repeatedly so that the total time >= 0.2 second, returning the eventual (number of loops, time taken for that number of loops). It calls *timeit()* with increasing numbers from the sequence 1, 2, 5, 10, 20, 50, … until the time taken is at least 0.2 second.

If *callback* is given and is not `None`, it will be called after each trial with two arguments: `callback(number, time_taken)`.

New in version 3.6.

repeat(*repeat=5*, *number=1000000*)
Call *timeit()* a few times.

This is a convenience function that calls the *timeit()* repeatedly, returning a list of results. The first argument specifies how many times to call *timeit()*. The second argument specifies the *number* argument for *timeit()*.

Note: It's tempting to calculate mean and standard deviation from the result vector and report these. However, this is not very useful. In a typical case, the lowest value gives a lower bound for how fast your machine can run the given code snippet; higher values in the result vector are typically not caused by variability in Python's speed, but by other processes interfering with your timing accuracy. So the *min()* of the result is probably the only number you should be interested in. After that, you should look at the entire vector and apply common sense rather than statistics.

Changed in version 3.7: Default value of *repeat* changed from 3 to 5.

print_exc(*file=None*)

Helper to print a traceback from the timed code.

Typical use:

```
t = Timer(...)       # outside the try/except
try:
    t.timeit(...)    # or t.repeat(...)
except Exception:
    t.print_exc()
```

The advantage over the standard traceback is that source lines in the compiled template will be displayed. The optional *file* argument directs where the traceback is sent; it defaults to *sys.stderr*.

28.5.3 Command-Line Interface

When called as a program from the command line, the following form is used:

```
python -m timeit [-n N] [-r N] [-u U] [-s S] [-h] [statement ...]
```

Where the following options are understood:

-n N, --number=N
how many times to execute 'statement'

-r N, --repeat=N
how many times to repeat the timer (default 5)

-s S, --setup=S
statement to be executed once initially (default `pass`)

-p, --process
measure process time, not wallclock time, using *time.process_time()* instead of *time.perf_counter()*, which is the default

New in version 3.3.

-u, --unit=U

specify a time unit for timer output; can select nsec, usec, msec, or sec

New in version 3.5.

-v, --verbose
print raw timing results; repeat for more digits precision

-h, --help
print a short usage message and exit

A multi-line statement may be given by specifying each line as a separate statement argument; indented lines are possible by enclosing an argument in quotes and using leading spaces. Multiple *-s* options are treated similarly.

If *-n* is not given, a suitable number of loops is calculated by trying successive powers of 10 until the total time is at least 0.2 seconds.

default_timer() measurements can be affected by other programs running on the same machine, so the best thing to do when accurate timing is necessary is to repeat the timing a few times and use the best time. The *-r* option is good for this; the default of 5 repetitions is probably enough in most cases. You can use *time.process_time()* to measure CPU time.

Note: There is a certain baseline overhead associated with executing a pass statement. The code here doesn't try to hide it, but you should be aware of it. The baseline overhead can be measured by invoking the program without arguments, and it might differ between Python versions.

28.5.4 Examples

It is possible to provide a setup statement that is executed only once at the beginning:

```
$ python -m timeit -s 'text = "sample string"; char = "g"'  'char in text'
5000000 loops, best of 5: 0.0877 usec per loop
$ python -m timeit -s 'text = "sample string"; char = "g"'  'text.find(char)'
1000000 loops, best of 5: 0.342 usec per loop
```

```
>>> import timeit
>>> timeit.timeit('char in text', setup='text = "sample string"; char = "g"')
0.41440500499993504
>>> timeit.timeit('text.find(char)', setup='text = "sample string"; char = "g"')
1.7246671520006203
```

The same can be done using the *Timer* class and its methods:

```
>>> import timeit
>>> t = timeit.Timer('char in text', setup='text = "sample string"; char = "g"')
>>> t.timeit()
0.3955516149999312
>>> t.repeat()
[0.40193588800002544, 0.3960157959998014, 0.39594301399984033]
```

The following examples show how to time expressions that contain multiple lines. Here we compare the cost of using *hasattr()* vs. `try`/`except` to test for missing and present object attributes:

```
$ python -m timeit 'try:' '  str.__bool__' 'except AttributeError:' '  pass'
20000 loops, best of 5: 15.7 usec per loop
$ python -m timeit 'if hasattr(str, "__bool__"): pass'
50000 loops, best of 5: 4.26 usec per loop

$ python -m timeit 'try:' '  int.__bool__' 'except AttributeError:' '  pass'
200000 loops, best of 5: 1.43 usec per loop
$ python -m timeit 'if hasattr(int, "__bool__"): pass'
100000 loops, best of 5: 2.23 usec per loop
```

```
>>> import timeit
>>> # attribute is missing
>>> s = """\
... try:
...     str.__bool__
... except AttributeError:
...     pass
... """
>>> timeit.timeit(stmt=s, number=100000)
0.9138244460009446
>>> s = "if hasattr(str, '__bool__'): pass"
>>> timeit.timeit(stmt=s, number=100000)
0.5829014980008651
>>>
>>> # attribute is present
>>> s = """\
... try:
...     int.__bool__
... except AttributeError:
...     pass
... """
>>> timeit.timeit(stmt=s, number=100000)
0.04215312199994514
>>> s = "if hasattr(int, '__bool__'): pass"
>>> timeit.timeit(stmt=s, number=100000)
0.08588060699912603
```

To give the *timeit* module access to functions you define, you can pass a *setup* parameter which contains an import statement:

```
def test():
    """Stupid test function"""
    L = [i for i in range(100)]

if __name__ == '__main__':
    import timeit
    print(timeit.timeit("test()", setup="from __main__ import test"))
```

Another option is to pass *globals()* to the *globals* parameter, which will cause the code to be executed within your current global namespace. This can be more convenient than individually specifying imports:

```
def f(x):
    return x**2
def g(x):
    return x**4
def h(x):
    return x**8

import timeit
print(timeit.timeit('[func(42) for func in (f,g,h)]', globals=globals()))
```

28.6 `trace` — Trace or track Python statement execution

Source code: Lib/trace.py

The *trace* module allows you to trace program execution, generate annotated statement coverage listings, print caller/callee relationships and list functions executed during a program run. It can be used in another program or from the command line.

See also:

Coverage.py A popular third-party coverage tool that provides HTML output along with advanced features such as branch coverage.

28.6.1 Command-Line Usage

The *trace* module can be invoked from the command line. It can be as simple as

```
python -m trace --count -C . somefile.py ...
```

The above will execute `somefile.py` and generate annotated listings of all Python modules imported during the execution into the current directory.

--help
Display usage and exit.

--version
Display the version of the module and exit.

Main options

At least one of the following options must be specified when invoking *trace*. The *--listfuncs* option is mutually exclusive with the *--trace* and *--count* options. When *--listfuncs* is provided, neither *--count* nor *--trace* are accepted, and vice versa.

-c, --count
Produce a set of annotated listing files upon program completion that shows how many times each statement was executed. See also *--coverdir*, *--file* and *--no-report* below.

-t, --trace
Display lines as they are executed.

-l, --listfuncs
Display the functions executed by running the program.

-r, --report
Produce an annotated list from an earlier program run that used the *--count* and *--file* option. This does not execute any code.

-T, --trackcalls
Display the calling relationships exposed by running the program.

Modifiers

-f, --file=<file>
Name of a file to accumulate counts over several tracing runs. Should be used with the *--count* option.

-C, --coverdir=<dir>
Directory where the report files go. The coverage report for `package.module` is written to file *dir/package/module*`.cover`.

-m, --missing
When generating annotated listings, mark lines which were not executed with `>>>>>>`.

-s, --summary
When using *--count* or *--report*, write a brief summary to stdout for each file processed.

-R, --no-report
Do not generate annotated listings. This is useful if you intend to make several runs with *--count*, and then produce a single set of annotated listings at the end.

-g, --timing
Prefix each line with the time since the program started. Only used while tracing.

Filters

These options may be repeated multiple times.

--ignore-module=<mod>
Ignore each of the given module names and its submodules (if it is a package). The argument can be a list of names separated by a comma.

--ignore-dir=<dir>
Ignore all modules and packages in the named directory and subdirectories. The argument can be a list of directories separated by *os.pathsep*.

28.6.2 Programmatic Interface

class trace.Trace(*count=1*, *trace=1*, *countfuncs=0*, *countcallers=0*, *ignoremods=()*, *ignoredirs=()*, *infile=None*, *outfile=None*, *timing=False*)
Create an object to trace execution of a single statement or expression. All parameters are optional. *count* enables counting of line numbers. *trace* enables line execution tracing. *countfuncs* enables listing of the functions called during the run. *countcallers* enables call relationship tracking. *ignoremods* is a list of modules or packages to ignore. *ignoredirs* is a list of directories whose modules or packages should be ignored. *infile* is the name of the file from which to read stored count information. *outfile* is the name of the file in which to write updated count information. *timing* enables a timestamp relative to when tracing was started to be displayed.

run(*cmd*)
Execute the command and gather statistics from the execution with the current tracing parameters. *cmd* must be a string or code object, suitable for passing into *exec()*.

runctx(*cmd*, *globals=None*, *locals=None*)
Execute the command and gather statistics from the execution with the current tracing parameters, in the defined global and local environments. If not defined, *globals* and *locals* default to empty dictionaries.

runfunc(*func*, **args*, ***kwds*)
Call *func* with the given arguments under control of the *Trace* object with the current tracing parameters.

results()
Return a *CoverageResults* object that contains the cumulative results of all previous calls to **run**, **runctx** and **runfunc** for the given *Trace* instance. Does not reset the accumulated trace results.

class trace.CoverageResults
A container for coverage results, created by *Trace.results()*. Should not be created directly by the user.

update(*other*)
Merge in data from another *CoverageResults* object.

write_results(*show_missing=True*, *summary=False*, *coverdir=None*)
Write coverage results. Set *show_missing* to show lines that had no hits. Set *summary* to include in the output the coverage summary per module. *coverdir* specifies the directory into which the coverage result files will be output. If `None`, the results for each source file are placed in its directory.

A simple example demonstrating the use of the programmatic interface:

```
import sys
import trace

# create a Trace object, telling it what to ignore, and whether to
# do tracing or line-counting or both.
tracer = trace.Trace(
    ignoredirs=[sys.prefix, sys.exec_prefix],
    trace=0,
    count=1)

# run the new command using the given tracer
tracer.run('main()')

# make a report, placing output in the current directory
r = tracer.results()
r.write_results(show_missing=True, coverdir=".")
```

28.7 tracemalloc — Trace memory allocations

New in version 3.4.

Source code: Lib/tracemalloc.py

The tracemalloc module is a debug tool to trace memory blocks allocated by Python. It provides the following information:

- Traceback where an object was allocated
- Statistics on allocated memory blocks per filename and per line number: total size, number and average size of allocated memory blocks
- Compute the differences between two snapshots to detect memory leaks

To trace most memory blocks allocated by Python, the module should be started as early as possible by setting the `PYTHONTRACEMALLOC` environment variable to `1`, or by using `-X tracemalloc` command line option. The *tracemalloc.start()* function can be called at runtime to start tracing Python memory allocations.

By default, a trace of an allocated memory block only stores the most recent frame (1 frame). To store 25 frames at startup: set the `PYTHONTRACEMALLOC` environment variable to `25`, or use the `-X tracemalloc=25` command line option.

28.7.1 Examples

Display the top 10

Display the 10 files allocating the most memory:

```
import tracemalloc

tracemalloc.start()

# ... run your application ...

snapshot = tracemalloc.take_snapshot()
top_stats = snapshot.statistics('lineno')

print("[ Top 10 ]")
for stat in top_stats[:10]:
    print(stat)
```

Example of output of the Python test suite:

```
[ Top 10 ]
<frozen importlib._bootstrap>:716: size=4855 KiB, count=39328, average=126 B
<frozen importlib._bootstrap>:284: size=521 KiB, count=3199, average=167 B
/usr/lib/python3.4/collections/__init__.py:368: size=244 KiB, count=2315, average=108 B
/usr/lib/python3.4/unittest/case.py:381: size=185 KiB, count=779, average=243 B
/usr/lib/python3.4/unittest/case.py:402: size=154 KiB, count=378, average=416 B
/usr/lib/python3.4/abc.py:133: size=88.7 KiB, count=347, average=262 B
<frozen importlib._bootstrap>:1446: size=70.4 KiB, count=911, average=79 B
<frozen importlib._bootstrap>:1454: size=52.0 KiB, count=25, average=2131 B
<string>:5: size=49.7 KiB, count=148, average=344 B
/usr/lib/python3.4/sysconfig.py:411: size=48.0 KiB, count=1, average=48.0 KiB
```

We can see that Python loaded `4855 KiB` data (bytecode and constants) from modules and that the *collections* module allocated `244 KiB` to build *namedtuple* types.

See *Snapshot.statistics()* for more options.

Compute differences

Take two snapshots and display the differences:

```
import tracemalloc
tracemalloc.start()
# ... start your application ...

snapshot1 = tracemalloc.take_snapshot()
# ... call the function leaking memory ...
snapshot2 = tracemalloc.take_snapshot()

top_stats = snapshot2.compare_to(snapshot1, 'lineno')

print("[ Top 10 differences ]")
for stat in top_stats[:10]:
    print(stat)
```

Example of output before/after running some tests of the Python test suite:

```
[ Top 10 differences ]
<frozen importlib._bootstrap>:716: size=8173 KiB (+4428 KiB), count=71332 (+39369), average=117 B
/usr/lib/python3.4/linecache.py:127: size=940 KiB (+940 KiB), count=8106 (+8106), average=119 B
/usr/lib/python3.4/unittest/case.py:571: size=298 KiB (+298 KiB), count=589 (+589), average=519 B
<frozen importlib._bootstrap>:284: size=1005 KiB (+166 KiB), count=7423 (+1526), average=139 B
```

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```
/usr/lib/python3.4/mimetypes.py:217: size=112 KiB (+112 KiB), count=1334 (+1334), average=86 B
/usr/lib/python3.4/http/server.py:848: size=96.0 KiB (+96.0 KiB), count=1 (+1), average=96.0 KiB
/usr/lib/python3.4/inspect.py:1465: size=83.5 KiB (+83.5 KiB), count=109 (+109), average=784 B
/usr/lib/python3.4/unittest/mock.py:491: size=77.7 KiB (+77.7 KiB), count=143 (+143), average=557 B
/usr/lib/python3.4/urllib/parse.py:476: size=71.8 KiB (+71.8 KiB), count=969 (+969), average=76 B
/usr/lib/python3.4/contextlib.py:38: size=67.2 KiB (+67.2 KiB), count=126 (+126), average=546 B
```

We can see that Python has loaded `8173 KiB` of module data (bytecode and constants), and that this is `4428 KiB` more than had been loaded before the tests, when the previous snapshot was taken. Similarly, the *linecache* module has cached `940 KiB` of Python source code to format tracebacks, all of it since the previous snapshot.

If the system has little free memory, snapshots can be written on disk using the *Snapshot.dump()* method to analyze the snapshot offline. Then use the *Snapshot.load()* method reload the snapshot.

Get the traceback of a memory block

Code to display the traceback of the biggest memory block:

```
import tracemalloc

# Store 25 frames
tracemalloc.start(25)

# ... run your application ...

snapshot = tracemalloc.take_snapshot()
top_stats = snapshot.statistics('traceback')

# pick the biggest memory block
stat = top_stats[0]
print("%s memory blocks: %.1f KiB" % (stat.count, stat.size / 1024))
for line in stat.traceback.format():
    print(line)
```

Example of output of the Python test suite (traceback limited to 25 frames):

```
903 memory blocks: 870.1 KiB
  File "<frozen importlib._bootstrap>", line 716
  File "<frozen importlib._bootstrap>", line 1036
  File "<frozen importlib._bootstrap>", line 934
  File "<frozen importlib._bootstrap>", line 1068
  File "<frozen importlib._bootstrap>", line 619
  File "<frozen importlib._bootstrap>", line 1581
  File "<frozen importlib._bootstrap>", line 1614
  File "/usr/lib/python3.4/doctest.py", line 101
    import pdb
  File "<frozen importlib._bootstrap>", line 284
  File "<frozen importlib._bootstrap>", line 938
  File "<frozen importlib._bootstrap>", line 1068
  File "<frozen importlib._bootstrap>", line 619
  File "<frozen importlib._bootstrap>", line 1581
  File "<frozen importlib._bootstrap>", line 1614
  File "/usr/lib/python3.4/test/support/__init__.py", line 1728
    import doctest
  File "/usr/lib/python3.4/test/test_pickletools.py", line 21
```

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```
    support.run_doctest(pickletools)
  File "/usr/lib/python3.4/test/regrtest.py", line 1276
    test_runner()
  File "/usr/lib/python3.4/test/regrtest.py", line 976
    display_failure=not verbose)
  File "/usr/lib/python3.4/test/regrtest.py", line 761
    match_tests=ns.match_tests)
  File "/usr/lib/python3.4/test/regrtest.py", line 1563
    main()
  File "/usr/lib/python3.4/test/__main__.py", line 3
    regrtest.main_in_temp_cwd()
  File "/usr/lib/python3.4/runpy.py", line 73
    exec(code, run_globals)
  File "/usr/lib/python3.4/runpy.py", line 160
    "__main__", fname, loader, pkg_name)
```

We can see that the most memory was allocated in the *importlib* module to load data (bytecode and constants) from modules: `870.1 KiB`. The traceback is where the *importlib* loaded data most recently: on the `import pdb` line of the *doctest* module. The traceback may change if a new module is loaded.

Pretty top

Code to display the 10 lines allocating the most memory with a pretty output, ignoring `<frozen importlib._bootstrap>` and `<unknown>` files:

```
import linecache
import os
import tracemalloc

def display_top(snapshot, key_type='lineno', limit=10):
    snapshot = snapshot.filter_traces((
        tracemalloc.Filter(False, "<frozen importlib._bootstrap>"),
        tracemalloc.Filter(False, "<unknown>"),
    ))
    top_stats = snapshot.statistics(key_type)

    print("Top %s lines" % limit)
    for index, stat in enumerate(top_stats[:limit], 1):
        frame = stat.traceback[0]
        # replace "/path/to/module/file.py" with "module/file.py"
        filename = os.sep.join(frame.filename.split(os.sep)[-2:])
        print("#%s: %s:%s: %.1f KiB"
              % (index, filename, frame.lineno, stat.size / 1024))
        line = linecache.getline(frame.filename, frame.lineno).strip()
        if line:
            print('    %s' % line)

    other = top_stats[limit:]
    if other:
        size = sum(stat.size for stat in other)
        print("%s other: %.1f KiB" % (len(other), size / 1024))
    total = sum(stat.size for stat in top_stats)
    print("Total allocated size: %.1f KiB" % (total / 1024))

tracemalloc.start()
```

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```
# ... run your application ...

snapshot = tracemalloc.take_snapshot()
display_top(snapshot)
```

Example of output of the Python test suite:

```
Top 10 lines
#1: Lib/base64.py:414: 419.8 KiB
    _b85chars2 = [(a + b) for a in _b85chars for b in _b85chars]
#2: Lib/base64.py:306: 419.8 KiB
    _a85chars2 = [(a + b) for a in _a85chars for b in _a85chars]
#3: collections/__init__.py:368: 293.6 KiB
    exec(class_definition, namespace)
#4: Lib/abc.py:133: 115.2 KiB
    cls = super().__new__(mcls, name, bases, namespace)
#5: unittest/case.py:574: 103.1 KiB
    testMethod()
#6: Lib/linecache.py:127: 95.4 KiB
    lines = fp.readlines()
#7: urllib/parse.py:476: 71.8 KiB
    for a in _hexdig for b in _hexdig}
#8: <string>:5: 62.0 KiB
#9: Lib/_weakrefset.py:37: 60.0 KiB
    self.data = set()
#10: Lib/base64.py:142: 59.8 KiB
    _b32tab2 = [a + b for a in _b32tab for b in _b32tab]
6220 other: 3602.8 KiB
Total allocated size: 5303.1 KiB
```

See *Snapshot.statistics()* for more options.

28.7.2 API

Functions

tracemalloc.clear_traces()

Clear traces of memory blocks allocated by Python.

See also *stop()*.

tracemalloc.get_object_traceback(*obj*)

Get the traceback where the Python object *obj* was allocated. Return a *Traceback* instance, or `None` if the *tracemalloc* module is not tracing memory allocations or did not trace the allocation of the object.

See also *gc.get_referrers()* and *sys.getsizeof()* functions.

tracemalloc.get_traceback_limit()

Get the maximum number of frames stored in the traceback of a trace.

The *tracemalloc* module must be tracing memory allocations to get the limit, otherwise an exception is raised.

The limit is set by the *start()* function.

tracemalloc.**get_traced_memory**()
Get the current size and peak size of memory blocks traced by the *tracemalloc* module as a tuple: `(current: int, peak: int)`.

tracemalloc.**get_tracemalloc_memory**()
Get the memory usage in bytes of the *tracemalloc* module used to store traces of memory blocks. Return an *int*.

tracemalloc.**is_tracing**()
`True` if the *tracemalloc* module is tracing Python memory allocations, `False` otherwise.

See also *start()* and *stop()* functions.

tracemalloc.**start**(*nframe: int=1*)
Start tracing Python memory allocations: install hooks on Python memory allocators. Collected tracebacks of traces will be limited to *nframe* frames. By default, a trace of a memory block only stores the most recent frame: the limit is `1`. *nframe* must be greater or equal to `1`.

Storing more than `1` frame is only useful to compute statistics grouped by `'traceback'` or to compute cumulative statistics: see the *Snapshot.compare_to()* and *Snapshot.statistics()* methods.

Storing more frames increases the memory and CPU overhead of the *tracemalloc* module. Use the *get_tracemalloc_memory()* function to measure how much memory is used by the *tracemalloc* module.

The `PYTHONTRACEMALLOC` environment variable (`PYTHONTRACEMALLOC=NFRAME`) and the `-X tracemalloc=NFRAME` command line option can be used to start tracing at startup.

See also *stop()*, *is_tracing()* and *get_traceback_limit()* functions.

tracemalloc.**stop**()
Stop tracing Python memory allocations: uninstall hooks on Python memory allocators. Also clears all previously collected traces of memory blocks allocated by Python.

Call *take_snapshot()* function to take a snapshot of traces before clearing them.

See also *start()*, *is_tracing()* and *clear_traces()* functions.

tracemalloc.**take_snapshot**()
Take a snapshot of traces of memory blocks allocated by Python. Return a new *Snapshot* instance.

The snapshot does not include memory blocks allocated before the *tracemalloc* module started to trace memory allocations.

Tracebacks of traces are limited to *get_traceback_limit()* frames. Use the *nframe* parameter of the *start()* function to store more frames.

The *tracemalloc* module must be tracing memory allocations to take a snapshot, see the *start()* function.

See also the *get_object_traceback()* function.

DomainFilter

class tracemalloc.**DomainFilter**(*inclusive: bool*, *domain: int*)
Filter traces of memory blocks by their address space (domain).

New in version 3.6.

inclusive
If *inclusive* is `True` (include), match memory blocks allocated in the address space *domain*.

If *inclusive* is `False` (exclude), match memory blocks not allocated in the address space *domain*.

domain
Address space of a memory block (`int`). Read-only property.

Filter

class tracemalloc.Filter(*inclusive: bool*, *filename_pattern: str*, *lineno: int=None*, *all_frames: bool=False*, *domain: int=None*)
Filter on traces of memory blocks.

See the *fnmatch.fnmatch()* function for the syntax of *filename_pattern*. The `'.pyc'` file extension is replaced with `'.py'`.

Examples:

- `Filter(True, subprocess.__file__)` only includes traces of the *subprocess* module
- `Filter(False, tracemalloc.__file__)` excludes traces of the *tracemalloc* module
- `Filter(False, "<unknown>")` excludes empty tracebacks

Changed in version 3.5: The `'.pyo'` file extension is no longer replaced with `'.py'`.

Changed in version 3.6: Added the *domain* attribute.

domain
Address space of a memory block (`int` or `None`).

tracemalloc uses the domain `0` to trace memory allocations made by Python. C extensions can use other domains to trace other resources.

inclusive
If *inclusive* is `True` (include), only match memory blocks allocated in a file with a name matching *filename_pattern* at line number *lineno*.

If *inclusive* is `False` (exclude), ignore memory blocks allocated in a file with a name matching *filename_pattern* at line number *lineno*.

lineno
Line number (`int`) of the filter. If *lineno* is `None`, the filter matches any line number.

filename_pattern
Filename pattern of the filter (`str`). Read-only property.

all_frames
If *all_frames* is `True`, all frames of the traceback are checked. If *all_frames* is `False`, only the most recent frame is checked.

This attribute has no effect if the traceback limit is `1`. See the *get_traceback_limit()* function and *Snapshot.traceback_limit* attribute.

Frame

class tracemalloc.Frame
Frame of a traceback.

The *Traceback* class is a sequence of *Frame* instances.

filename
Filename (`str`).

lineno
Line number (`int`).

Snapshot

class tracemalloc.Snapshot

Snapshot of traces of memory blocks allocated by Python.

The *take_snapshot()* function creates a snapshot instance.

compare_to(*old_snapshot: Snapshot*, *key_type: str*, *cumulative: bool=False*)

Compute the differences with an old snapshot. Get statistics as a sorted list of *StatisticDiff* instances grouped by *key_type*.

See the *Snapshot.statistics()* method for *key_type* and *cumulative* parameters.

The result is sorted from the biggest to the smallest by: absolute value of *StatisticDiff.size_diff*, *StatisticDiff.size*, absolute value of *StatisticDiff.count_diff*, *Statistic.count* and then by *StatisticDiff.traceback*.

dump(*filename*)

Write the snapshot into a file.

Use *load()* to reload the snapshot.

filter_traces(*filters*)

Create a new *Snapshot* instance with a filtered *traces* sequence, *filters* is a list of *DomainFilter* and *Filter* instances. If *filters* is an empty list, return a new *Snapshot* instance with a copy of the traces.

All inclusive filters are applied at once, a trace is ignored if no inclusive filters match it. A trace is ignored if at least one exclusive filter matches it.

Changed in version 3.6: *DomainFilter* instances are now also accepted in *filters*.

classmethod load(*filename*)

Load a snapshot from a file.

See also *dump()*.

statistics(*key_type: str*, *cumulative: bool=False*)

Get statistics as a sorted list of *Statistic* instances grouped by *key_type*:

key_type	description
`'filename'`	filename
`'lineno'`	filename and line number
`'traceback'`	traceback

If *cumulative* is `True`, cumulate size and count of memory blocks of all frames of the traceback of a trace, not only the most recent frame. The cumulative mode can only be used with *key_type* equals to `'filename'` and `'lineno'`.

The result is sorted from the biggest to the smallest by: *Statistic.size*, *Statistic.count* and then by *Statistic.traceback*.

traceback_limit

Maximum number of frames stored in the traceback of *traces*: result of the *get_traceback_limit()* when the snapshot was taken.

traces

Traces of all memory blocks allocated by Python: sequence of *Trace* instances.

The sequence has an undefined order. Use the *Snapshot.statistics()* method to get a sorted list of statistics.

Statistic

class tracemalloc.Statistic
Statistic on memory allocations.

Snapshot.statistics() returns a list of *Statistic* instances.

See also the *StatisticDiff* class.

count
Number of memory blocks (`int`).

size
Total size of memory blocks in bytes (`int`).

traceback
Traceback where the memory block was allocated, *Traceback* instance.

StatisticDiff

class tracemalloc.StatisticDiff
Statistic difference on memory allocations between an old and a new *Snapshot* instance.

Snapshot.compare_to() returns a list of *StatisticDiff* instances. See also the *Statistic* class.

count
Number of memory blocks in the new snapshot (`int`): `0` if the memory blocks have been released in the new snapshot.

count_diff
Difference of number of memory blocks between the old and the new snapshots (`int`): `0` if the memory blocks have been allocated in the new snapshot.

size
Total size of memory blocks in bytes in the new snapshot (`int`): `0` if the memory blocks have been released in the new snapshot.

size_diff
Difference of total size of memory blocks in bytes between the old and the new snapshots (`int`): `0` if the memory blocks have been allocated in the new snapshot.

traceback
Traceback where the memory blocks were allocated, *Traceback* instance.

Trace

class tracemalloc.Trace
Trace of a memory block.

The *Snapshot.traces* attribute is a sequence of *Trace* instances.

Changed in version 3.6: Added the *domain* attribute.

domain
Address space of a memory block (`int`). Read-only property.

tracemalloc uses the domain `0` to trace memory allocations made by Python. C extensions can use other domains to trace other resources.

size
Size of the memory block in bytes (`int`).

traceback
Traceback where the memory block was allocated, *Traceback* instance.

Traceback

class tracemalloc.Traceback
Sequence of *Frame* instances sorted from the oldest frame to the most recent frame.

A traceback contains at least `1` frame. If the `tracemalloc` module failed to get a frame, the filename `"<unknown>"` at line number `0` is used.

When a snapshot is taken, tracebacks of traces are limited to *get_traceback_limit()* frames. See the *take_snapshot()* function.

The *Trace.traceback* attribute is an instance of *Traceback* instance.

Changed in version 3.7: Frames are now sorted from the oldest to the most recent, instead of most recent to oldest.

format(*limit=None*, *most_recent_first=False*)
Format the traceback as a list of lines with newlines. Use the *linecache* module to retrieve lines from the source code. If *limit* is set, format the *limit* most recent frames if *limit* is positive. Otherwise, format the `abs(limit)` oldest frames. If *most_recent_first* is `True`, the order of the formatted frames is reversed, returning the most recent frame first instead of last.

Similar to the *traceback.format_tb()* function, except that *format()* does not include newlines.

Example:

```
print("Traceback (most recent call first):")
for line in traceback:
    print(line)
```

Output:

```
Traceback (most recent call first):
  File "test.py", line 9
    obj = Object()
  File "test.py", line 12
    tb = tracemalloc.get_object_traceback(f())
```

CHAPTER

TWENTYNINE

SOFTWARE PACKAGING AND DISTRIBUTION

These libraries help you with publishing and installing Python software. While these modules are designed to work in conjunction with the Python Package Index, they can also be used with a local index server, or without any index server at all.

29.1 `distutils` — Building and installing Python modules

The *`distutils`* package provides support for building and installing additional modules into a Python installation. The new modules may be either 100%-pure Python, or may be extension modules written in C, or may be collections of Python packages which include modules coded in both Python and C.

Most Python users will *not* want to use this module directly, but instead use the cross-version tools maintained by the Python Packaging Authority. In particular, setuptools is an enhanced alternative to *`distutils`* that provides:

- support for declaring project dependencies
- additional mechanisms for configuring which files to include in source releases (including plugins for integration with version control systems)
- the ability to declare project "entry points", which can be used as the basis for application plugin systems
- the ability to automatically generate Windows command line executables at installation time rather than needing to prebuild them
- consistent behaviour across all supported Python versions

The recommended pip installer runs all `setup.py` scripts with `setuptools`, even if the script itself only imports `distutils`. Refer to the Python Packaging User Guide for more information.

For the benefits of packaging tool authors and users seeking a deeper understanding of the details of the current packaging and distribution system, the legacy *`distutils`* based user documentation and API reference remain available:

- install-index
- distutils-index

29.2 `ensurepip` — Bootstrapping the `pip` installer

New in version 3.4.

The *ensurepip* package provides support for bootstrapping the `pip` installer into an existing Python installation or virtual environment. This bootstrapping approach reflects the fact that `pip` is an independent project with its own release cycle, and the latest available stable version is bundled with maintenance and feature releases of the CPython reference interpreter.

In most cases, end users of Python shouldn't need to invoke this module directly (as `pip` should be bootstrapped by default), but it may be needed if installing `pip` was skipped when installing Python (or when creating a virtual environment) or after explicitly uninstalling `pip`.

Note: This module *does not* access the internet. All of the components needed to bootstrap `pip` are included as internal parts of the package.

See also:

installing-index The end user guide for installing Python packages

PEP 453: Explicit bootstrapping of pip in Python installations The original rationale and specification for this module.

29.2.1 Command line interface

The command line interface is invoked using the interpreter's `-m` switch.

The simplest possible invocation is:

```
python -m ensurepip
```

This invocation will install `pip` if it is not already installed, but otherwise does nothing. To ensure the installed version of `pip` is at least as recent as the one bundled with `ensurepip`, pass the `--upgrade` option:

```
python -m ensurepip --upgrade
```

By default, `pip` is installed into the current virtual environment (if one is active) or into the system site packages (if there is no active virtual environment). The installation location can be controlled through two additional command line options:

- `--root <dir>`: Installs `pip` relative to the given root directory rather than the root of the currently active virtual environment (if any) or the default root for the current Python installation.
- `--user`: Installs `pip` into the user site packages directory rather than globally for the current Python installation (this option is not permitted inside an active virtual environment).

By default, the scripts `pipX` and `pipX.Y` will be installed (where X.Y stands for the version of Python used to invoke `ensurepip`). The scripts installed can be controlled through two additional command line options:

- `--altinstall`: if an alternate installation is requested, the `pipX` script will *not* be installed.
- `--default-pip`: if a "default pip" installation is requested, the `pip` script will be installed in addition to the two regular scripts.

Providing both of the script selection options will trigger an exception.

29.2.2 Module API

ensurepip exposes two functions for programmatic use:

`ensurepip.version()`
Returns a string specifying the bundled version of pip that will be installed when bootstrapping an environment.

ensurepip.bootstrap(*root=None*, *upgrade=False*, *user=False*, *altinstall=False*, *default_pip=False*, *verbosity=0*)

Bootstraps `pip` into the current or designated environment.

root specifies an alternative root directory to install relative to. If *root* is `None`, then installation uses the default install location for the current environment.

upgrade indicates whether or not to upgrade an existing installation of an earlier version of `pip` to the bundled version.

user indicates whether to use the user scheme rather than installing globally.

By default, the scripts `pipX` and `pipX.Y` will be installed (where X.Y stands for the current version of Python).

If *altinstall* is set, then `pipX` will *not* be installed.

If *default_pip* is set, then `pip` will be installed in addition to the two regular scripts.

Setting both *altinstall* and *default_pip* will trigger *ValueError*.

verbosity controls the level of output to *sys.stdout* from the bootstrapping operation.

Note: The bootstrapping process has side effects on both `sys.path` and `os.environ`. Invoking the command line interface in a subprocess instead allows these side effects to be avoided.

Note: The bootstrapping process may install additional modules required by `pip`, but other software should not assume those dependencies will always be present by default (as the dependencies may be removed in a future version of `pip`).

29.3 venv — Creation of virtual environments

New in version 3.3.

Source code: Lib/venv/

The *venv* module provides support for creating lightweight "virtual environments" with their own site directories, optionally isolated from system site directories. Each virtual environment has its own Python binary (allowing creation of environments with various Python versions) and can have its own independent set of installed Python packages in its site directories.

See **PEP 405** for more information about Python virtual environments.

Note: The `pyvenv` script has been deprecated as of Python 3.6 in favor of using `python3 -m venv` to help prevent any potential confusion as to which Python interpreter a virtual environment will be based on.

29.3.1 Creating virtual environments

Creation of *virtual environments* is done by executing the command `venv`:

```
python3 -m venv /path/to/new/virtual/environment
```

Running this command creates the target directory (creating any parent directories that don't exist already) and places a `pyvenv.cfg` file in it with a `home` key pointing to the Python installation from which the command was run. It also creates a `bin` (or `Scripts` on Windows) subdirectory containing a copy of the `python` binary (or binaries, in the case of Windows). It also creates an (initially empty) `lib/pythonX.Y/site-packages` subdirectory (on Windows, this is `Lib\site-packages`). If an existing directory is specified, it will be re-used.

Deprecated since version 3.6: `pyvenv` was the recommended tool for creating virtual environments for Python 3.3 and 3.4, and is deprecated in Python 3.6.

Changed in version 3.5: The use of `venv` is now recommended for creating virtual environments.

See also:

Python Packaging User Guide: Creating and using virtual environments

On Windows, invoke the `venv` command as follows:

```
c:\>c:\Python35\python -m venv c:\path\to\myenv
```

Alternatively, if you configured the `PATH` and `PATHEXT` variables for your Python installation:

```
c:\>python -m venv c:\path\to\myenv
```

The command, if run with `-h`, will show the available options:

```
usage: venv [-h] [--system-site-packages] [--symlinks | --copies] [--clear]
            [--upgrade] [--without-pip]
            ENV_DIR [ENV_DIR ...]

Creates virtual Python environments in one or more target directories.

positional arguments:
  ENV_DIR               A directory to create the environment in.

optional arguments:
  -h, --help            show this help message and exit
  --system-site-packages
                        Give the virtual environment access to the system
                        site-packages dir.
  --symlinks            Try to use symlinks rather than copies, when symlinks
                        are not the default for the platform.
  --copies              Try to use copies rather than symlinks, even when
                        symlinks are the default for the platform.
  --clear               Delete the contents of the environment directory if it
                        already exists, before environment creation.
  --upgrade             Upgrade the environment directory to use this version
                        of Python, assuming Python has been upgraded in-place.
  --without-pip         Skips installing or upgrading pip in the virtual
                        environment (pip is bootstrapped by default)

Once an environment has been created, you may wish to activate it, e.g. by
sourcing an activate script in its bin directory.
```

Changed in version 3.4: Installs pip by default, added the `--without-pip` and `--copies` options

Changed in version 3.4: In earlier versions, if the target directory already existed, an error was raised, unless the `--clear` or `--upgrade` option was provided.

The created `pyvenv.cfg` file also includes the `include-system-site-packages` key, set to `true` if `venv` is run with the `--system-site-packages` option, `false` otherwise.

Unless the `--without-pip` option is given, *ensurepip* will be invoked to bootstrap `pip` into the virtual environment.

Multiple paths can be given to `venv`, in which case an identical virtual environment will be created, according to the given options, at each provided path.

Once a virtual environment has been created, it can be "activated" using a script in the virtual environment's binary directory. The invocation of the script is platform-specific:

Platform	Shell	Command to activate virtual environment
Posix	bash/zsh	$ source <venv>/bin/activate
	fish	$. <venv>/bin/activate.fish
	csh/tcsh	$ source <venv>/bin/activate.csh
Windows	cmd.exe	C:\> <venv>\Scripts\activate.bat
	PowerShell	PS C:\> <venv>\Scripts\Activate.ps1

You don't specifically *need* to activate an environment; activation just prepends the virtual environment's binary directory to your path, so that "python" invokes the virtual environment's Python interpreter and you can run installed scripts without having to use their full path. However, all scripts installed in a virtual environment should be runnable without activating it, and run with the virtual environment's Python automatically.

You can deactivate a virtual environment by typing "deactivate" in your shell. The exact mechanism is platform-specific: for example, the Bash activation script defines a "deactivate" function, whereas on Windows there are separate scripts called `deactivate.bat` and `Deactivate.ps1` which are installed when the virtual environment is created.

New in version 3.4: `fish` and `csh` activation scripts.

Note: A virtual environment is a Python environment such that the Python interpreter, libraries and scripts installed into it are isolated from those installed in other virtual environments, and (by default) any libraries installed in a "system" Python, i.e., one which is installed as part of your operating system.

A virtual environment is a directory tree which contains Python executable files and other files which indicate that it is a virtual environment.

Common installation tools such as `Setuptools` and `pip` work as expected with virtual environments. In other words, when a virtual environment is active, they install Python packages into the virtual environment without needing to be told to do so explicitly.

When a virtual environment is active (i.e., the virtual environment's Python interpreter is running), the attributes *sys.prefix* and *sys.exec_prefix* point to the base directory of the virtual environment, whereas *sys.base_prefix* and *sys.base_exec_prefix* point to the non-virtual environment Python installation which was used to create the virtual environment. If a virtual environment is not active, then *sys.prefix* is the same as *sys.base_prefix* and *sys.exec_prefix* is the same as *sys.base_exec_prefix* (they all point to a non-virtual environment Python installation).

When a virtual environment is active, any options that change the installation path will be ignored from all distutils configuration files to prevent projects being inadvertently installed outside of the virtual environment.

When working in a command shell, users can make a virtual environment active by running an `activate` script in the virtual environment's executables directory (the precise filename is shell-dependent), which prepends the virtual environment's directory for executables to the `PATH` environment variable for the running shell. There should be no need in other circumstances to activate a virtual environment—scripts installed into virtual environments have a "shebang" line which points to the virtual environment's Python interpreter. This means that the script will run with that interpreter regardless of the value of `PATH`. On Windows, "shebang" line processing is supported if you have the Python Launcher for Windows installed (this was

added to Python in 3.3 - see **PEP 397** for more details). Thus, double-clicking an installed script in a Windows Explorer window should run the script with the correct interpreter without there needing to be any reference to its virtual environment in `PATH`.

29.3.2 API

The high-level method described above makes use of a simple API which provides mechanisms for third-party virtual environment creators to customize environment creation according to their needs, the *EnvBuilder* class.

class venv.EnvBuilder(*system_site_packages=False*, *clear=False*, *symlinks=False*, *upgrade=False*, *with_pip=False*, *prompt=None*)

The *EnvBuilder* class accepts the following keyword arguments on instantiation:

- `system_site_packages` – a Boolean value indicating that the system Python site-packages should be available to the environment (defaults to `False`).
- `clear` – a Boolean value which, if true, will delete the contents of any existing target directory, before creating the environment.
- `symlinks` – a Boolean value indicating whether to attempt to symlink the Python binary (and any necessary DLLs or other binaries, e.g. `pythonw.exe`), rather than copying.
- `upgrade` – a Boolean value which, if true, will upgrade an existing environment with the running Python - for use when that Python has been upgraded in-place (defaults to `False`).
- `with_pip` – a Boolean value which, if true, ensures pip is installed in the virtual environment. This uses *ensurepip* with the `--default-pip` option.
- `prompt` – a String to be used after virtual environment is activated (defaults to `None` which means directory name of the environment would be used).

Changed in version 3.4: Added the `with_pip` parameter

New in version 3.6: Added the `prompt` parameter

Creators of third-party virtual environment tools will be free to use the provided `EnvBuilder` class as a base class.

The returned env-builder is an object which has a method, `create`:

create(*env_dir*)

This method takes as required argument the path (absolute or relative to the current directory) of the target directory which is to contain the virtual environment. The `create` method will either create the environment in the specified directory, or raise an appropriate exception.

The `create` method of the `EnvBuilder` class illustrates the hooks available for subclass customization:

```
def create(self, env_dir):
    """
    Create a virtualized Python environment in a directory.
    env_dir is the target directory to create an environment in.
    """
    env_dir = os.path.abspath(env_dir)
    context = self.ensure_directories(env_dir)
    self.create_configuration(context)
    self.setup_python(context)
    self.setup_scripts(context)
    self.post_setup(context)
```

Each of the methods *ensure_directories()*, *create_configuration()*, *setup_python()*, *setup_scripts()* and *post_setup()* can be overridden.

ensure_directories(*env_dir*)
Creates the environment directory and all necessary directories, and returns a context object. This is just a holder for attributes (such as paths), for use by the other methods. The directories are allowed to exist already, as long as either `clear` or `upgrade` were specified to allow operating on an existing environment directory.

create_configuration(*context*)
Creates the `pyvenv.cfg` configuration file in the environment.

setup_python(*context*)
Creates a copy of the Python executable (and, under Windows, DLLs) in the environment. On a POSIX system, if a specific executable `python3.x` was used, symlinks to `python` and `python3` will be created pointing to that executable, unless files with those names already exist.

setup_scripts(*context*)
Installs activation scripts appropriate to the platform into the virtual environment.

post_setup(*context*)
A placeholder method which can be overridden in third party implementations to pre-install packages in the virtual environment or perform other post-creation steps.

In addition, *EnvBuilder* provides this utility method that can be called from *setup_scripts()* or *post_setup()* in subclasses to assist in installing custom scripts into the virtual environment.

install_scripts(*context*, *path*)
path is the path to a directory that should contain subdirectories "common", "posix", "nt", each containing scripts destined for the bin directory in the environment. The contents of "common" and the directory corresponding to *os.name* are copied after some text replacement of placeholders:

- `__VENV_DIR__` is replaced with the absolute path of the environment directory.
- `__VENV_NAME__` is replaced with the environment name (final path segment of environment directory).
- `__VENV_PROMPT__` is replaced with the prompt (the environment name surrounded by parentheses and with a following space)
- `__VENV_BIN_NAME__` is replaced with the name of the bin directory (either `bin` or `Scripts`).
- `__VENV_PYTHON__` is replaced with the absolute path of the environment's executable.

The directories are allowed to exist (for when an existing environment is being upgraded).

There is also a module-level convenience function:

venv.create(*env_dir*, *system_site_packages=False*, *clear=False*, *symlinks=False*, *with_pip=False*)
Create an *EnvBuilder* with the given keyword arguments, and call its *create()* method with the *env_dir* argument.

Changed in version 3.4: Added the `with_pip` parameter

29.3.3 An example of extending `EnvBuilder`

The following script shows how to extend *EnvBuilder* by implementing a subclass which installs setuptools and pip into a created virtual environment:

```
import os
import os.path
from subprocess import Popen, PIPE
```

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```
import sys
from threading import Thread
from urllib.parse import urlparse
from urllib.request import urlretrieve
import venv

class ExtendedEnvBuilder(venv.EnvBuilder):
    """
    This builder installs setuptools and pip so that you can pip or
    easy_install other packages into the created virtual environment.

    :param nodist: If True, setuptools and pip are not installed into the
                   created virtual environment.
    :param nopip: If True, pip is not installed into the created
                  virtual environment.
    :param progress: If setuptools or pip are installed, the progress of the
                     installation can be monitored by passing a progress
                     callable. If specified, it is called with two
                     arguments: a string indicating some progress, and a
                     context indicating where the string is coming from.
                     The context argument can have one of three values:
                     'main', indicating that it is called from virtualize()
                     itself, and 'stdout' and 'stderr', which are obtained
                     by reading lines from the output streams of a subprocess
                     which is used to install the app.

                     If a callable is not specified, default progress
                     information is output to sys.stderr.
    """

    def __init__(self, *args, **kwargs):
        self.nodist = kwargs.pop('nodist', False)
        self.nopip = kwargs.pop('nopip', False)
        self.progress = kwargs.pop('progress', None)
        self.verbose = kwargs.pop('verbose', False)
        super().__init__(*args, **kwargs)

    def post_setup(self, context):
        """
        Set up any packages which need to be pre-installed into the
        virtual environment being created.

        :param context: The information for the virtual environment
                        creation request being processed.
        """
        os.environ['VIRTUAL_ENV'] = context.env_dir
        if not self.nodist:
            self.install_setuptools(context)
        # Can't install pip without setuptools
        if not self.nopip and not self.nodist:
            self.install_pip(context)

    def reader(self, stream, context):
        """
        Read lines from a subprocess' output stream and either pass to a progress
        callable (if specified) or write progress information to sys.stderr.
```

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```
        """
        progress = self.progress
        while True:
            s = stream.readline()
            if not s:
                break
            if progress is not None:
                progress(s, context)
            else:
                if not self.verbose:
                    sys.stderr.write('.')
                else:
                    sys.stderr.write(s.decode('utf-8'))
                sys.stderr.flush()
        stream.close()

    def install_script(self, context, name, url):
        _, _, path, _, _, _ = urlparse(url)
        fn = os.path.split(path)[-1]
        binpath = context.bin_path
        distpath = os.path.join(binpath, fn)
        # Download script into the virtual environment's binaries folder
        urlretrieve(url, distpath)
        progress = self.progress
        if self.verbose:
            term = '\n'
        else:
            term = ''
        if progress is not None:
            progress('Installing %s ...%s' % (name, term), 'main')
        else:
            sys.stderr.write('Installing %s ...%s' % (name, term))
            sys.stderr.flush()
        # Install in the virtual environment
        args = [context.env_exe, fn]
        p = Popen(args, stdout=PIPE, stderr=PIPE, cwd=binpath)
        t1 = Thread(target=self.reader, args=(p.stdout, 'stdout'))
        t1.start()
        t2 = Thread(target=self.reader, args=(p.stderr, 'stderr'))
        t2.start()
        p.wait()
        t1.join()
        t2.join()
        if progress is not None:
            progress('done.', 'main')
        else:
            sys.stderr.write('done.\n')
        # Clean up - no longer needed
        os.unlink(distpath)

    def install_setuptools(self, context):
        """
        Install setuptools in the virtual environment.

        :param context: The information for the virtual environment
                        creation request being processed.
```

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```
        """
        url = 'https://bitbucket.org/pypa/setuptools/downloads/ez_setup.py'
        self.install_script(context, 'setuptools', url)
        # clear up the setuptools archive which gets downloaded
        pred = lambda o: o.startswith('setuptools-') and o.endswith('.tar.gz')
        files = filter(pred, os.listdir(context.bin_path))
        for f in files:
            f = os.path.join(context.bin_path, f)
            os.unlink(f)

    def install_pip(self, context):
        """
        Install pip in the virtual environment.

        :param context: The information for the virtual environment
                        creation request being processed.
        """
        url = 'https://raw.github.com/pypa/pip/master/contrib/get-pip.py'
        self.install_script(context, 'pip', url)

def main(args=None):
    compatible = True
    if sys.version_info < (3, 3):
        compatible = False
    elif not hasattr(sys, 'base_prefix'):
        compatible = False
    if not compatible:
        raise ValueError('This script is only for use with '
                         'Python 3.3 or later')
    else:
        import argparse

        parser = argparse.ArgumentParser(prog=__name__,
                                         description='Creates virtual Python '
                                                     'environments in one or '
                                                     'more target '
                                                     'directories.')
        parser.add_argument('dirs', metavar='ENV_DIR', nargs='+',
                            help='A directory in which to create the
                                 'virtual environment.')
        parser.add_argument('--no-setuptools', default=False,
                            action='store_true', dest='nodist',
                            help="Don't install setuptools or pip in the "
                                 "virtual environment.")
        parser.add_argument('--no-pip', default=False,
                            action='store_true', dest='nopip',
                            help="Don't install pip in the virtual "
                                 "environment.")
        parser.add_argument('--system-site-packages', default=False,
                            action='store_true', dest='system_site',
                            help='Give the virtual environment access to the '
                                 'system site-packages dir.')
        if os.name == 'nt':
            use_symlinks = False
        else:
            use_symlinks = True
```

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```
        parser.add_argument('--symlinks', default=use_symlinks,
                            action='store_true', dest='symlinks',
                            help='Try to use symlinks rather than copies, '
                                 'when symlinks are not the default for '
                                 'the platform.')
        parser.add_argument('--clear', default=False, action='store_true',
                            dest='clear', help='Delete the contents of the '
                                               'virtual environment '
                                               'directory if it already '
                                               'exists, before virtual '
                                               'environment creation.')
        parser.add_argument('--upgrade', default=False, action='store_true',
                            dest='upgrade', help='Upgrade the virtual '
                                                 'environment directory to '
                                                 'use this version of '
                                                 'Python, assuming Python '
                                                 'has been upgraded '
                                                 'in-place.')
        parser.add_argument('--verbose', default=False, action='store_true',
                            dest='verbose', help='Display the output '
                                               'from the scripts which '
                                               'install setuptools and pip.')
        options = parser.parse_args(args)
        if options.upgrade and options.clear:
            raise ValueError('you cannot supply --upgrade and --clear together.')
        builder = ExtendedEnvBuilder(system_site_packages=options.system_site,
                                     clear=options.clear,
                                     symlinks=options.symlinks,
                                     upgrade=options.upgrade,
                                     nodist=options.nodist,
                                     nopip=options.nopip,
                                     verbose=options.verbose)
        for d in options.dirs:
            builder.create(d)

if __name__ == '__main__':
    rc = 1
    try:
        main()
        rc = 0
    except Exception as e:
        print('Error: %s' % e, file=sys.stderr)
    sys.exit(rc)
```

This script is also available for download online.

29.4 zipapp — Manage executable python zip archives

New in version 3.5.

Source code: Lib/zipapp.py

This module provides tools to manage the creation of zip files containing Python code, which can be executed directly by the Python interpreter. The module provides both a *Command-Line Interface* and a *Python API*.

29.4.1 Basic Example

The following example shows how the *Command-Line Interface* can be used to create an executable archive from a directory containing Python code. When run, the archive will execute the `main` function from the module `myapp` in the archive.

```
$ python -m zipapp myapp -m "myapp:main"
$ python myapp.pyz
<output from myapp>
```

29.4.2 Command-Line Interface

When called as a program from the command line, the following form is used:

```
$ python -m zipapp source [options]
```

If *source* is a directory, this will create an archive from the contents of *source*. If *source* is a file, it should be an archive, and it will be copied to the target archive (or the contents of its shebang line will be displayed if the –info option is specified).

The following options are understood:

-o <output>, --output=<output>
: Write the output to a file named *output*. If this option is not specified, the output filename will be the same as the input *source*, with the extension `.pyz` added. If an explicit filename is given, it is used as is (so a `.pyz` extension should be included if required).

  An output filename must be specified if the *source* is an archive (and in that case, *output* must not be the same as *source*).

-p <interpreter>, --python=<interpreter>
: Add a `#!` line to the archive specifying *interpreter* as the command to run. Also, on POSIX, make the archive executable. The default is to write no `#!` line, and not make the file executable.

-m <mainfn>, --main=<mainfn>
: Write a `__main__.py` file to the archive that executes *mainfn*. The *mainfn* argument should have the form "pkg.mod:fn", where "pkg.mod" is a package/module in the archive, and "fn" is a callable in the given module. The `__main__.py` file will execute that callable.

  --main cannot be specified when copying an archive.

-c, --compress
: Compress files with the deflate method, reducing the size of the output file. By default, files are stored uncompressed in the archive.

  --compress has no effect when copying an archive.

  New in version 3.7.

--info
: Display the interpreter embedded in the archive, for diagnostic purposes. In this case, any other options are ignored and SOURCE must be an archive, not a directory.

-h, --help
: Print a short usage message and exit.

29.4.3 Python API

The module defines two convenience functions:

zipapp.create_archive(*source*, *target=None*, *interpreter=None*, *main=None*, *filter=None*, *compressed=False*)

Create an application archive from *source*. The source can be any of the following:

- The name of a directory, or a *path-like object* referring to a directory, in which case a new application archive will be created from the content of that directory.
- The name of an existing application archive file, or a *path-like object* referring to such a file, in which case the file is copied to the target (modifying it to reflect the value given for the *interpreter* argument). The file name should include the `.pyz` extension, if required.
- A file object open for reading in bytes mode. The content of the file should be an application archive, and the file object is assumed to be positioned at the start of the archive.

The *target* argument determines where the resulting archive will be written:

- If it is the name of a file, or a *path-like object*, the archive will be written to that file.
- If it is an open file object, the archive will be written to that file object, which must be open for writing in bytes mode.
- If the target is omitted (or `None`), the source must be a directory and the target will be a file with the same name as the source, with a `.pyz` extension added.

The *interpreter* argument specifies the name of the Python interpreter with which the archive will be executed. It is written as a "shebang" line at the start of the archive. On POSIX, this will be interpreted by the OS, and on Windows it will be handled by the Python launcher. Omitting the *interpreter* results in no shebang line being written. If an interpreter is specified, and the target is a filename, the executable bit of the target file will be set.

The *main* argument specifies the name of a callable which will be used as the main program for the archive. It can only be specified if the source is a directory, and the source does not already contain a `__main__.py` file. The *main* argument should take the form "pkg.module:callable" and the archive will be run by importing "pkg.module" and executing the given callable with no arguments. It is an error to omit *main* if the source is a directory and does not contain a `__main__.py` file, as otherwise the resulting archive would not be executable.

The optional *filter* argument specifies a callback function that is passed a Path object representing the path to the file being added (relative to the source directory). It should return `True` if the file is to be added.

The optional *compressed* argument determines whether files are compressed. If set to `True`, files in the archive are compressed with the deflate method; otherwise, files are stored uncompressed. This argument has no effect when copying an existing archive.

If a file object is specified for *source* or *target*, it is the caller's responsibility to close it after calling create_archive.

When copying an existing archive, file objects supplied only need `read` and `readline`, or `write` methods. When creating an archive from a directory, if the target is a file object it will be passed to the `zipfile.ZipFile` class, and must supply the methods needed by that class.

New in version 3.7: Added the *filter* and *compressed* arguments.

zipapp.get_interpreter(*archive*)

Return the interpreter specified in the `#!` line at the start of the archive. If there is no `#!` line, return *None*. The *archive* argument can be a filename or a file-like object open for reading in bytes mode. It is assumed to be at the start of the archive.

29.4.4 Examples

Pack up a directory into an archive, and run it.

```
$ python -m zipapp myapp
$ python myapp.pyz
<output from myapp>
```

The same can be done using the *create_archive()* functon:

```
>>> import zipapp
>>> zipapp.create_archive('myapp.pyz', 'myapp')
```

To make the application directly executable on POSIX, specify an interpreter to use.

```
$ python -m zipapp myapp -p "/usr/bin/env python"
$ ./myapp.pyz
<output from myapp>
```

To replace the shebang line on an existing archive, create a modified archive using the *create_archive()* function:

```
>>> import zipapp
>>> zipapp.create_archive('old_archive.pyz', 'new_archive.pyz', '/usr/bin/python3')
```

To update the file in place, do the replacement in memory using a `BytesIO` object, and then overwrite the source afterwards. Note that there is a risk when overwriting a file in place that an error will result in the loss of the original file. This code does not protect against such errors, but production code should do so. Also, this method will only work if the archive fits in memory:

```
>>> import zipapp
>>> import io
>>> temp = io.BytesIO()
>>> zipapp.create_archive('myapp.pyz', temp, '/usr/bin/python2')
>>> with open('myapp.pyz', 'wb') as f:
>>>     f.write(temp.getvalue())
```

29.4.5 Specifying the Interpreter

Note that if you specify an interpreter and then distribute your application archive, you need to ensure that the interpreter used is portable. The Python launcher for Windows supports most common forms of POSIX `#!` line, but there are other issues to consider:

- If you use "/usr/bin/env python" (or other forms of the "python" command, such as "/usr/bin/python"), you need to consider that your users may have either Python 2 or Python 3 as their default, and write your code to work under both versions.
- If you use an explicit version, for example "/usr/bin/env python3" your application will not work for users who do not have that version. (This may be what you want if you have not made your code Python 2 compatible).
- There is no way to say "python X.Y or later", so be careful of using an exact version like "/usr/bin/env python3.4" as you will need to change your shebang line for users of Python 3.5, for example.

Typically, you should use an "/usr/bin/env python2" or "/usr/bin/env python3", depending on whether your code is written for Python 2 or 3.

29.4.6 Creating Standalone Applications with zipapp

Using the *zipapp* module, it is possible to create self-contained Python programs, which can be distributed to end users who only need to have a suitable version of Python installed on their system. The key to doing

this is to bundle all of the application's dependencies into the archive, along with the application code.

The steps to create a standalone archive are as follows:

1. Create your application in a directory as normal, so you have a `myapp` directory containing a `__main__.py` file, and any supporting application code.
2. Install all of your application's dependencies into the `myapp` directory, using pip:

   ```
   $ python -m pip install -r requirements.txt --target myapp
   ```

   (this assumes you have your project requirements in a `requirements.txt` file - if not, you can just list the dependencies manually on the pip command line).
3. Optionally, delete the `.dist-info` directories created by pip in the `myapp` directory. These hold metadata for pip to manage the packages, and as you won't be making any further use of pip they aren't required - although it won't do any harm if you leave them.
4. Package the application using:

   ```
   $ python -m zipapp -p "interpreter" myapp
   ```

This will produce a standalone executable, which can be run on any machine with the appropriate interpreter available. See *Specifying the Interpreter* for details. It can be shipped to users as a single file.

On Unix, the `myapp.pyz` file is executable as it stands. You can rename the file to remove the `.pyz` extension if you prefer a "plain" command name. On Windows, the `myapp.pyz[w]` file is executable by virtue of the fact that the Python interpreter registers the `.pyz` and `.pyzw` file extensions when installed.

Making a Windows executable

On Windows, registration of the `.pyz` extension is optional, and furthermore, there are certain places that don't recognise registered extensions "transparently" (the simplest example is that `subprocess.run(['myapp'])` won't find your application - you need to explicitly specify the extension).

On Windows, therefore, it is often preferable to create an executable from the zipapp. This is relatively easy, although it does require a C compiler. The basic approach relies on the fact that zipfiles can have arbitrary data prepended, and Windows exe files can have arbitrary data appended. So by creating a suitable launcher and tacking the `.pyz` file onto the end of it, you end up with a single-file executable that runs your application.

A suitable launcher can be as simple as the following:

```
#define Py_LIMITED_API 1
#include "Python.h"

#define WIN32_LEAN_AND_MEAN
#include <windows.h>

#ifdef WINDOWS
int WINAPI wWinMain(
    HINSTANCE hInstance,      /* handle to current instance */
    HINSTANCE hPrevInstance,  /* handle to previous instance */
    LPWSTR lpCmdLine,         /* pointer to command line */
    int nCmdShow              /* show state of window */
)
#else
int wmain()
#endif
```

(continues on next page)

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```
{
    wchar_t **myargv = _alloca((__argc + 1) * sizeof(wchar_t*));
    myargv[0] = __wargv[0];
    memcpy(myargv + 1, __wargv, __argc * sizeof(wchar_t *));
    return Py_Main(__argc+1, myargv);
}
```

If you define the `WINDOWS` preprocessor symbol, this will generate a GUI executable, and without it, a console executable.

To compile the executable, you can either just use the standard MSVC command line tools, or you can take advantage of the fact that distutils knows how to compile Python source:

```
>>> from distutils.ccompiler import new_compiler
>>> import distutils.sysconfig
>>> import sys
>>> import os
>>> from pathlib import Path

>>> def compile(src):
>>>     src = Path(src)
>>>     cc = new_compiler()
>>>     exe = src.stem
>>>     cc.add_include_dir(distutils.sysconfig.get_python_inc())
>>>     cc.add_library_dir(os.path.join(sys.base_exec_prefix, 'libs'))
>>>     # First the CLI executable
>>>     objs = cc.compile([str(src)])
>>>     cc.link_executable(objs, exe)
>>>     # Now the GUI executable
>>>     cc.define_macro('WINDOWS')
>>>     objs = cc.compile([str(src)])
>>>     cc.link_executable(objs, exe + 'w')

>>> if __name__ == "__main__":
>>>     compile("zastub.c")
```

The resulting launcher uses the "Limited ABI", so it will run unchanged with any version of Python 3.x. All it needs is for Python (`python3.dll`) to be on the user's `PATH`.

For a fully standalone distribution, you can distribute the launcher with your application appended, bundled with the Python "embedded" distribution. This will run on any PC with the appropriate architecture (32 bit or 64 bit).

Caveats

There are some limitations to the process of bundling your application into a single file. In most, if not all, cases they can be addressed without needing major changes to your application.

1. If your application depends on a package that includes a C extension, that package cannot be run from a zip file (this is an OS limitation, as executable code must be present in the filesystem for the OS loader to load it). In this case, you can exclude that dependency from the zipfile, and either require your users to have it installed, or ship it alongside your zipfile and add code to your `__main__.py` to include the directory containing the unzipped module in `sys.path`. In this case, you will need to make sure to ship appropriate binaries for your target architecture(s) (and potentially pick the correct version to add to `sys.path` at runtime, based on the user's machine).

2. If you are shipping a Windows executable as described above, you either need to ensure that your users have `python3.dll` on their PATH (which is not the default behaviour of the installer) or you should bundle your application with the embedded distribution.
3. The suggested launcher above uses the Python embedding API. This means that in your application, `sys.executable` will be your application, and *not* a conventional Python interpreter. Your code and its dependencies need to be prepared for this possibility. For example, if your application uses the *multiprocessing* module, it will need to call *multiprocessing.set_executable()* to let the module know where to find the standard Python interpreter.

29.4.7 The Python Zip Application Archive Format

Python has been able to execute zip files which contain a `__main__.py` file since version 2.6. In order to be executed by Python, an application archive simply has to be a standard zip file containing a `__main__.py` file which will be run as the entry point for the application. As usual for any Python script, the parent of the script (in this case the zip file) will be placed on *sys.path* and thus further modules can be imported from the zip file.

The zip file format allows arbitrary data to be prepended to a zip file. The zip application format uses this ability to prepend a standard POSIX "shebang" line to the file (`#!/path/to/interpreter`).

Formally, the Python zip application format is therefore:

1. An optional shebang line, containing the characters `b'#!'` followed by an interpreter name, and then a newline (`b'\n'`) character. The interpreter name can be anything acceptable to the OS "shebang" processing, or the Python launcher on Windows. The interpreter should be encoded in UTF-8 on Windows, and in *sys.getfilesystemencoding()* on POSIX.
2. Standard zipfile data, as generated by the *zipfile* module. The zipfile content *must* include a file called `__main__.py` (which must be in the "root" of the zipfile - i.e., it cannot be in a subdirectory). The zipfile data can be compressed or uncompressed.

If an application archive has a shebang line, it may have the executable bit set on POSIX systems, to allow it to be executed directly.

There is no requirement that the tools in this module are used to create application archives - the module is a convenience, but archives in the above format created by any means are acceptable to Python.

CHAPTER

THIRTY

PYTHON RUNTIME SERVICES

The modules described in this chapter provide a wide range of services related to the Python interpreter and its interaction with its environment. Here's an overview:

30.1 sys — System-specific parameters and functions

This module provides access to some variables used or maintained by the interpreter and to functions that interact strongly with the interpreter. It is always available.

sys.abiflags
On POSIX systems where Python was built with the standard `configure` script, this contains the ABI flags as specified by **PEP 3149**.

New in version 3.2.

sys.argv
The list of command line arguments passed to a Python script. `argv[0]` is the script name (it is operating system dependent whether this is a full pathname or not). If the command was executed using the `-c` command line option to the interpreter, `argv[0]` is set to the string `'-c'`. If no script name was passed to the Python interpreter, `argv[0]` is the empty string.

To loop over the standard input, or the list of files given on the command line, see the *fileinput* module.

sys.base_exec_prefix
Set during Python startup, before `site.py` is run, to the same value as *exec_prefix*. If not running in a *virtual environment*, the values will stay the same; if `site.py` finds that a virtual environment is in use, the values of *prefix* and *exec_prefix* will be changed to point to the virtual environment, whereas *base_prefix* and *base_exec_prefix* will remain pointing to the base Python installation (the one which the virtual environment was created from).

New in version 3.3.

sys.base_prefix
Set during Python startup, before `site.py` is run, to the same value as *prefix*. If not running in a *virtual environment*, the values will stay the same; if `site.py` finds that a virtual environment is in use, the values of *prefix* and *exec_prefix* will be changed to point to the virtual environment, whereas *base_prefix* and *base_exec_prefix* will remain pointing to the base Python installation (the one which the virtual environment was created from).

New in version 3.3.

sys.byteorder
An indicator of the native byte order. This will have the value `'big'` on big-endian (most-significant byte first) platforms, and `'little'` on little-endian (least-significant byte first) platforms.

sys.builtin_module_names
: A tuple of strings giving the names of all modules that are compiled into this Python interpreter. (This information is not available in any other way — `modules.keys()` only lists the imported modules.)

sys.call_tracing(*func*, *args*)
: Call `func(*args)`, while tracing is enabled. The tracing state is saved, and restored afterwards. This is intended to be called from a debugger from a checkpoint, to recursively debug some other code.

sys.copyright
: A string containing the copyright pertaining to the Python interpreter.

sys._clear_type_cache()
: Clear the internal type cache. The type cache is used to speed up attribute and method lookups. Use the function *only* to drop unnecessary references during reference leak debugging.

  This function should be used for internal and specialized purposes only.

sys._current_frames()
: Return a dictionary mapping each thread's identifier to the topmost stack frame currently active in that thread at the time the function is called. Note that functions in the *traceback* module can build the call stack given such a frame.

  This is most useful for debugging deadlock: this function does not require the deadlocked threads' cooperation, and such threads' call stacks are frozen for as long as they remain deadlocked. The frame returned for a non-deadlocked thread may bear no relationship to that thread's current activity by the time calling code examines the frame.

  This function should be used for internal and specialized purposes only.

sys.breakpointhook()
: This hook function is called by built-in *breakpoint()*. By default, it drops you into the *pdb* debugger, but it can be set to any other function so that you can choose which debugger gets used.

  The signature of this function is dependent on what it calls. For example, the default binding (e.g. `pdb.set_trace()`) expects no arguments, but you might bind it to a function that expects additional arguments (positional and/or keyword). The built-in `breakpoint()` function passes its `*args` and `**kws` straight through. Whatever `breakpointhooks()` returns is returned from `breakpoint()`.

  The default implementation first consults the environment variable `PYTHONBREAKPOINT`. If that is set to `"0"` then this function returns immediately; i.e. it is a no-op. If the environment variable is not set, or is set to the empty string, `pdb.set_trace()` is called. Otherwise this variable should name a function to run, using Python's dotted-import nomenclature, e.g. `package.subpackage.module.function`. In this case, `package.subpackage.module` would be imported and the resulting module must have a callable named `function()`. This is run, passing in `*args` and `**kws`, and whatever `function()` returns, `sys.breakpointhook()` returns to the built-in *breakpoint()* function.

  Note that if anything goes wrong while importing the callable named by `PYTHONBREAKPOINT`, a *RuntimeWarning* is reported and the breakpoint is ignored.

  Also note that if `sys.breakpointhook()` is overridden programmatically, `PYTHONBREAKPOINT` is *not* consulted.

  New in version 3.7.

sys._debugmallocstats()
: Print low-level information to stderr about the state of CPython's memory allocator.

  If Python is configured –with-pydebug, it also performs some expensive internal consistency checks.

  New in version 3.3.

  CPython implementation detail: This function is specific to CPython. The exact output format is not defined here, and may change.

sys.dllhandle
: Integer specifying the handle of the Python DLL. Availability: Windows.

sys.displayhook(*value*)
: If *value* is not `None`, this function prints `repr(value)` to `sys.stdout`, and saves *value* in `builtins._`. If `repr(value)` is not encodable to `sys.stdout.encoding` with `sys.stdout.errors` error handler (which is probably `'strict'`), encode it to `sys.stdout.encoding` with `'backslashreplace'` error handler.

  `sys.displayhook` is called on the result of evaluating an *expression* entered in an interactive Python session. The display of these values can be customized by assigning another one-argument function to `sys.displayhook`.

  Pseudo-code:

```
def displayhook(value):
    if value is None:
        return
    # Set '_' to None to avoid recursion
    builtins._ = None
    text = repr(value)
    try:
        sys.stdout.write(text)
    except UnicodeEncodeError:
        bytes = text.encode(sys.stdout.encoding, 'backslashreplace')
        if hasattr(sys.stdout, 'buffer'):
            sys.stdout.buffer.write(bytes)
        else:
            text = bytes.decode(sys.stdout.encoding, 'strict')
            sys.stdout.write(text)
    sys.stdout.write("\n")
    builtins._ = value
```

  Changed in version 3.2: Use `'backslashreplace'` error handler on *UnicodeEncodeError*.

sys.dont_write_bytecode
: If this is true, Python won't try to write `.pyc` files on the import of source modules. This value is initially set to `True` or `False` depending on the `-B` command line option and the `PYTHONDONTWRITEBYTECODE` environment variable, but you can set it yourself to control bytecode file generation.

sys.excepthook(*type*, *value*, *traceback*)
: This function prints out a given traceback and exception to `sys.stderr`.

  When an exception is raised and uncaught, the interpreter calls `sys.excepthook` with three arguments, the exception class, exception instance, and a traceback object. In an interactive session this happens just before control is returned to the prompt; in a Python program this happens just before the program exits. The handling of such top-level exceptions can be customized by assigning another three-argument function to `sys.excepthook`.

sys.__breakpointhook__
sys.__displayhook__
sys.__excepthook__
: These objects contain the original values of `breakpointhook`, `displayhook`, and `excepthook` at the start of the program. They are saved so that `breakpointhook`, `displayhook` and `excepthook` can be restored in case they happen to get replaced with broken or alternative objects.

  New in version 3.7: ___breakpointhook___

sys.exc_info()
: This function returns a tuple of three values that give information about the exception that is currently

being handled. The information returned is specific both to the current thread and to the current stack frame. If the current stack frame is not handling an exception, the information is taken from the calling stack frame, or its caller, and so on until a stack frame is found that is handling an exception. Here, "handling an exception" is defined as "executing an except clause." For any stack frame, only information about the exception being currently handled is accessible.

If no exception is being handled anywhere on the stack, a tuple containing three `None` values is returned. Otherwise, the values returned are `(type, value, traceback)`. Their meaning is: *type* gets the type of the exception being handled (a subclass of *BaseException*); *value* gets the exception instance (an instance of the exception type); *traceback* gets a traceback object (see the Reference Manual) which encapsulates the call stack at the point where the exception originally occurred.

`sys.exec_prefix`
A string giving the site-specific directory prefix where the platform-dependent Python files are installed; by default, this is also `'/usr/local'`. This can be set at build time with the `--exec-prefix` argument to the `configure` script. Specifically, all configuration files (e.g. the `pyconfig.h` header file) are installed in the directory *exec_prefix*`/lib/python`*X.Y*`/config`, and shared library modules are installed in *exec_prefix*`/lib/python`*X.Y*`/lib-dynload`, where *X.Y* is the version number of Python, for example `3.2`.

Note: If a *virtual environment* is in effect, this value will be changed in `site.py` to point to the virtual environment. The value for the Python installation will still be available, via *base_exec_prefix*.

`sys.executable`
A string giving the absolute path of the executable binary for the Python interpreter, on systems where this makes sense. If Python is unable to retrieve the real path to its executable, *sys.executable* will be an empty string or `None`.

`sys.exit(`[*arg*]`)`
Exit from Python. This is implemented by raising the *SystemExit* exception, so cleanup actions specified by finally clauses of `try` statements are honored, and it is possible to intercept the exit attempt at an outer level.

The optional argument *arg* can be an integer giving the exit status (defaulting to zero), or another type of object. If it is an integer, zero is considered "successful termination" and any nonzero value is considered "abnormal termination" by shells and the like. Most systems require it to be in the range 0–127, and produce undefined results otherwise. Some systems have a convention for assigning specific meanings to specific exit codes, but these are generally underdeveloped; Unix programs generally use 2 for command line syntax errors and 1 for all other kind of errors. If another type of object is passed, `None` is equivalent to passing zero, and any other object is printed to *stderr* and results in an exit code of 1. In particular, `sys.exit("some error message")` is a quick way to exit a program when an error occurs.

Since *exit()* ultimately "only" raises an exception, it will only exit the process when called from the main thread, and the exception is not intercepted.

Changed in version 3.6: If an error occurs in the cleanup after the Python interpreter has caught *SystemExit* (such as an error flushing buffered data in the standard streams), the exit status is changed to 120.

Changed in version 3.7: Added `utf8_mode` attribute for the new `-X utf8` flag.

`sys.flags`
The *struct sequence* *flags* exposes the status of command line flags. The attributes are read only.

attribute	flag
debug	-d
inspect	-i
interactive	-i
optimize	-O or -OO
dont_write_bytecode	-B
no_user_site	-s
no_site	-S
ignore_environment	-E
verbose	-v
bytes_warning	-b
quiet	-q
hash_randomization	-R
dev_mode	-X dev
utf8_mode	-X utf8

Changed in version 3.2: Added `quiet` attribute for the new `-q` flag.

New in version 3.2.3: The `hash_randomization` attribute.

Changed in version 3.3: Removed obsolete `division_warning` attribute.

Changed in version 3.7: Added `dev_mode` attribute for the new `-X dev` flag and `utf8_mode` attribute for the new `-X utf8` flag.

`sys.float_info`

A *struct sequence* holding information about the float type. It contains low level information about the precision and internal representation. The values correspond to the various floating-point constants defined in the standard header file `float.h` for the 'C' programming language; see section 5.2.4.2.2 of the 1999 ISO/IEC C standard *[C99]*, 'Characteristics of floating types', for details.

attribute	float.h macro	explanation
epsilon	DBL_EPSILON	difference between 1 and the least value greater than 1 that is representable as a float
dig	DBL_DIG	maximum number of decimal digits that can be faithfully represented in a float; see below
mant_dig	DBL_MANT_DIG	float precision: the number of base-`radix` digits in the significand of a float
max	DBL_MAX	maximum representable finite float
max_exp	DBL_MAX_EXP	maximum integer e such that `radix**(e-1)` is a representable finite float
max_10_exp	DBL_MAX_10_EXP	maximum integer e such that `10**e` is in the range of representable finite floats
min	DBL_MIN	minimum positive normalized float
min_exp	DBL_MIN_EXP	minimum integer e such that `radix**(e-1)` is a normalized float
min_10_exp	DBL_MIN_10_EXP	minimum integer e such that `10**e` is a normalized float
radix	FLT_RADIX	radix of exponent representation
rounds	FLT_ROUNDS	integer constant representing the rounding mode used for arithmetic operations. This reflects the value of the system FLT_ROUNDS macro at interpreter startup time. See section 5.2.4.2.2 of the C99 standard for an explanation of the possible values and their meanings.

The attribute `sys.float_info.dig` needs further explanation. If `s` is any string representing a decimal number with at most `sys.float_info.dig` significant digits, then converting `s` to a float and back again will recover a string representing the same decimal value:

```
>>> import sys
>>> sys.float_info.dig
15
>>> s = '3.14159265358979'    # decimal string with 15 significant digits
>>> format(float(s), '.15g')  # convert to float and back -> same value
'3.14159265358979'
```

But for strings with more than `sys.float_info.dig` significant digits, this isn't always true:

```
>>> s = '9876543211234567'    # 16 significant digits is too many!
>>> format(float(s), '.16g')  # conversion changes value
'9876543211234568'
```

sys.float_repr_style

A string indicating how the *repr()* function behaves for floats. If the string has value `'short'` then for a finite float `x`, `repr(x)` aims to produce a short string with the property that `float(repr(x)) == x`. This is the usual behaviour in Python 3.1 and later. Otherwise, `float_repr_style` has value `'legacy'` and `repr(x)` behaves in the same way as it did in versions of Python prior to 3.1.

New in version 3.1.

sys.getallocatedblocks()

Return the number of memory blocks currently allocated by the interpreter, regardless of their size. This function is mainly useful for tracking and debugging memory leaks. Because of the interpreter's internal caches, the result can vary from call to call; you may have to call *_clear_type_cache()* and *gc.collect()* to get more predictable results.

If a Python build or implementation cannot reasonably compute this information, *getallocatedblocks()* is allowed to return 0 instead.

New in version 3.4.

sys.getandroidapilevel()

Return the build time API version of Android as an integer.

Availability: Android.

New in version 3.7.

sys.getcheckinterval()

Return the interpreter's "check interval"; see *setcheckinterval()*.

Deprecated since version 3.2: Use *getswitchinterval()* instead.

sys.getdefaultencoding()

Return the name of the current default string encoding used by the Unicode implementation.

sys.getdlopenflags()

Return the current value of the flags that are used for `dlopen()` calls. Symbolic names for the flag values can be found in the *os* module (`RTLD_xxx` constants, e.g. *os.RTLD_LAZY*). Availability: Unix.

sys.getfilesystemencoding()

Return the name of the encoding used to convert between Unicode filenames and bytes filenames. For best compatibility, str should be used for filenames in all cases, although representing filenames as bytes is also supported. Functions accepting or returning filenames should support either str or bytes and internally convert to the system's preferred representation.

This encoding is always ASCII-compatible.

os.fsencode() and *os.fsdecode()* should be used to ensure that the correct encoding and errors mode are used.

- In the UTF-8 mode, the encoding is `utf-8` on any platform.
- On Mac OS X, the encoding is `'utf-8'`.
- On Unix, the encoding is the locale encoding.
- On Windows, the encoding may be `'utf-8'` or `'mbcs'`, depending on user configuration.

Changed in version 3.2: *getfilesystemencoding()* result cannot be `None` anymore.

Changed in version 3.6: Windows is no longer guaranteed to return `'mbcs'`. See **PEP 529** and *_enablelegacywindowsfsencoding()* for more information.

Changed in version 3.7: Return 'utf-8' in the UTF-8 mode.

`sys.getfilesystemencodeerrors()`
Return the name of the error mode used to convert between Unicode filenames and bytes filenames. The encoding name is returned from *getfilesystemencoding()*.

os.fsencode() and *os.fsdecode()* should be used to ensure that the correct encoding and errors mode are used.

New in version 3.6.

`sys.getrefcount(`*object*`)`
Return the reference count of the *object*. The count returned is generally one higher than you might expect, because it includes the (temporary) reference as an argument to *getrefcount()*.

`sys.getrecursionlimit()`
Return the current value of the recursion limit, the maximum depth of the Python interpreter stack. This limit prevents infinite recursion from causing an overflow of the C stack and crashing Python. It can be set by *setrecursionlimit()*.

`sys.getsizeof(`*object*[, *default*]`)`
Return the size of an object in bytes. The object can be any type of object. All built-in objects will return correct results, but this does not have to hold true for third-party extensions as it is implementation specific.

Only the memory consumption directly attributed to the object is accounted for, not the memory consumption of objects it refers to.

If given, *default* will be returned if the object does not provide means to retrieve the size. Otherwise a *TypeError* will be raised.

getsizeof() calls the object's `__sizeof__` method and adds an additional garbage collector overhead if the object is managed by the garbage collector.

See recursive sizeof recipe for an example of using *getsizeof()* recursively to find the size of containers and all their contents.

`sys.getswitchinterval()`
Return the interpreter's "thread switch interval"; see *setswitchinterval()*.

New in version 3.2.

`sys._getframe(`[*depth*]`)`
Return a frame object from the call stack. If optional integer *depth* is given, return the frame object that many calls below the top of the stack. If that is deeper than the call stack, *ValueError* is raised. The default for *depth* is zero, returning the frame at the top of the call stack.

CPython implementation detail: This function should be used for internal and specialized purposes only. It is not guaranteed to exist in all implementations of Python.

sys.getprofile()
Get the profiler function as set by *setprofile()*.

sys.gettrace()
Get the trace function as set by *settrace()*.

CPython implementation detail: The *gettrace()* function is intended only for implementing debuggers, profilers, coverage tools and the like. Its behavior is part of the implementation platform, rather than part of the language definition, and thus may not be available in all Python implementations.

sys.getwindowsversion()
Return a named tuple describing the Windows version currently running. The named elements are *major*, *minor*, *build*, *platform*, *service_pack*, *service_pack_minor*, *service_pack_major*, *suite_mask*, *product_type* and *platform_version*. *service_pack* contains a string, *platform_version* a 3-tuple and all other values are integers. The components can also be accessed by name, so `sys.getwindowsversion()[0]` is equivalent to `sys.getwindowsversion().major`. For compatibility with prior versions, only the first 5 elements are retrievable by indexing.

platform will be `2 (VER_PLATFORM_WIN32_NT)`.

product_type may be one of the following values:

Constant	Meaning
`1 (VER_NT_WORKSTATION)`	The system is a workstation.
`2 (VER_NT_DOMAIN_CONTROLLER)`	The system is a domain controller.
`3 (VER_NT_SERVER)`	The system is a server, but not a domain controller.

This function wraps the Win32 `GetVersionEx()` function; see the Microsoft documentation on `OSVERSIONINFOEX()` for more information about these fields.

platform_version returns the accurate major version, minor version and build number of the current operating system, rather than the version that is being emulated for the process. It is intended for use in logging rather than for feature detection.

Availability: Windows.

Changed in version 3.2: Changed to a named tuple and added *service_pack_minor*, *service_pack_major*, *suite_mask*, and *product_type*.

Changed in version 3.6: Added *platform_version*

sys.get_asyncgen_hooks()
Returns an *asyncgen_hooks* object, which is similar to a *namedtuple* of the form *(firstiter, finalizer)*, where *firstiter* and *finalizer* are expected to be either `None` or functions which take an *asynchronous generator iterator* as an argument, and are used to schedule finalization of an asynchronous generator by an event loop.

New in version 3.6: See **PEP 525** for more details.

Note: This function has been added on a provisional basis (see **PEP 411** for details.)

sys.get_coroutine_origin_tracking_depth()
Get the current coroutine origin tracking depth, as set by func:*set_coroutine_origin_tracking_depth*.

New in version 3.7.

Note: This function has been added on a provisional basis (see **PEP 411** for details.) Use it only for debugging purposes.

sys.**get_coroutine_wrapper**()
Returns None, or a wrapper set by *set_coroutine_wrapper()*.

New in version 3.5: See **PEP 492** for more details.

Note: This function has been added on a provisional basis (see **PEP 411** for details.) Use it only for debugging purposes.

Deprecated since version 3.7: The coroutine wrapper functionality has been deprecated, and will be removed in 3.8. See bpo-32591 for details.

sys.**hash_info**
A *struct sequence* giving parameters of the numeric hash implementation. For more details about hashing of numeric types, see *Hashing of numeric types*.

attribute	explanation
width	width in bits used for hash values
modulus	prime modulus P used for numeric hash scheme
inf	hash value returned for a positive infinity
nan	hash value returned for a nan
imag	multiplier used for the imaginary part of a complex number
algorithm	name of the algorithm for hashing of str, bytes, and memoryview
hash_bits	internal output size of the hash algorithm
seed_bits	size of the seed key of the hash algorithm

New in version 3.2.

Changed in version 3.4: Added *algorithm*, *hash_bits* and *seed_bits*

sys.**hexversion**
The version number encoded as a single integer. This is guaranteed to increase with each version, including proper support for non-production releases. For example, to test that the Python interpreter is at least version 1.5.2, use:

```
if sys.hexversion >= 0x010502F0:
    # use some advanced feature
    ...
else:
    # use an alternative implementation or warn the user
    ...
```

This is called **hexversion** since it only really looks meaningful when viewed as the result of passing it to the built-in *hex()* function. The *struct sequence* *sys.version_info* may be used for a more human-friendly encoding of the same information.

More details of **hexversion** can be found at apiabiversion.

sys.**implementation**
An object containing information about the implementation of the currently running Python interpreter. The following attributes are required to exist in all Python implementations.

name is the implementation's identifier, e.g. 'cpython'. The actual string is defined by the Python implementation, but it is guaranteed to be lower case.

version is a named tuple, in the same format as *sys.version_info*. It represents the version of the Python *implementation*. This has a distinct meaning from the specific version of the Python *language* to which the currently running interpreter conforms, which `sys.version_info` represents. For example, for PyPy 1.8 `sys.implementation.version` might be `sys.version_info(1, 8, 0, 'final', 0)`, whereas `sys.version_info` would be `sys.version_info(2, 7, 2, 'final', 0)`. For CPython they are the same value, since it is the reference implementation.

hexversion is the implementation version in hexadecimal format, like *sys.hexversion*.

cache_tag is the tag used by the import machinery in the filenames of cached modules. By convention, it would be a composite of the implementation's name and version, like `'cpython-33'`. However, a Python implementation may use some other value if appropriate. If `cache_tag` is set to `None`, it indicates that module caching should be disabled.

sys.implementation may contain additional attributes specific to the Python implementation. These non-standard attributes must start with an underscore, and are not described here. Regardless of its contents, *sys.implementation* will not change during a run of the interpreter, nor between implementation versions. (It may change between Python language versions, however.) See **PEP 421** for more information.

New in version 3.3.

sys.int_info

A *struct sequence* that holds information about Python's internal representation of integers. The attributes are read only.

Attribute	Explanation
`bits_per_digit`	number of bits held in each digit. Python integers are stored internally in base `2**int_info.bits_per_digit`
`sizeof_digit`	size in bytes of the C type used to represent a digit

New in version 3.1.

sys.__interactivehook__

When this attribute exists, its value is automatically called (with no arguments) when the interpreter is launched in interactive mode. This is done after the `PYTHONSTARTUP` file is read, so that you can set this hook there. The *site* module *sets this*.

New in version 3.4.

sys.intern(*string*)

Enter *string* in the table of "interned" strings and return the interned string – which is *string* itself or a copy. Interning strings is useful to gain a little performance on dictionary lookup – if the keys in a dictionary are interned, and the lookup key is interned, the key comparisons (after hashing) can be done by a pointer compare instead of a string compare. Normally, the names used in Python programs are automatically interned, and the dictionaries used to hold module, class or instance attributes have interned keys.

Interned strings are not immortal; you must keep a reference to the return value of *intern()* around to benefit from it.

sys.is_finalizing()

Return *True* if the Python interpreter is *shutting down*, *False* otherwise.

New in version 3.5.

sys.last_type
sys.last_value
sys.last_traceback

These three variables are not always defined; they are set when an exception is not handled and the

interpreter prints an error message and a stack traceback. Their intended use is to allow an interactive user to import a debugger module and engage in post-mortem debugging without having to re-execute the command that caused the error. (Typical use is `import pdb; pdb.pm()` to enter the post-mortem debugger; see *pdb* module for more information.)

The meaning of the variables is the same as that of the return values from *exc_info()* above.

`sys.maxsize`
An integer giving the maximum value a variable of type `Py_ssize_t` can take. It's usually `2**31 - 1` on a 32-bit platform and `2**63 - 1` on a 64-bit platform.

`sys.maxunicode`
An integer giving the value of the largest Unicode code point, i.e. `1114111` (`0x10FFFF` in hexadecimal).

Changed in version 3.3: Before **PEP 393**, `sys.maxunicode` used to be either `0xFFFF` or `0x10FFFF`, depending on the configuration option that specified whether Unicode characters were stored as UCS-2 or UCS-4.

`sys.meta_path`
A list of *meta path finder* objects that have their *find_spec()* methods called to see if one of the objects can find the module to be imported. The *find_spec()* method is called with at least the absolute name of the module being imported. If the module to be imported is contained in a package, then the parent package's `__path__` attribute is passed in as a second argument. The method returns a *module spec*, or `None` if the module cannot be found.

See also:

importlib.abc.MetaPathFinder The abstract base class defining the interface of finder objects on *meta_path*.

importlib.machinery.ModuleSpec The concrete class which *find_spec()* should return instances of.

Changed in version 3.4: *Module specs* were introduced in Python 3.4, by **PEP 451**. Earlier versions of Python looked for a method called *find_module()*. This is still called as a fallback if a *meta_path* entry doesn't have a *find_spec()* method.

`sys.modules`
This is a dictionary that maps module names to modules which have already been loaded. This can be manipulated to force reloading of modules and other tricks. However, replacing the dictionary will not necessarily work as expected and deleting essential items from the dictionary may cause Python to fail.

`sys.path`
A list of strings that specifies the search path for modules. Initialized from the environment variable `PYTHONPATH`, plus an installation-dependent default.

As initialized upon program startup, the first item of this list, `path[0]`, is the directory containing the script that was used to invoke the Python interpreter. If the script directory is not available (e.g. if the interpreter is invoked interactively or if the script is read from standard input), `path[0]` is the empty string, which directs Python to search modules in the current directory first. Notice that the script directory is inserted *before* the entries inserted as a result of `PYTHONPATH`.

A program is free to modify this list for its own purposes. Only strings and bytes should be added to *sys.path*; all other data types are ignored during import.

See also:

Module *site* This describes how to use .pth files to extend *sys.path*.

sys.path_hooks
: A list of callables that take a path argument to try to create a *finder* for the path. If a finder can be created, it is to be returned by the callable, else raise *ImportError*.

  Originally specified in **PEP 302**.

sys.path_importer_cache
: A dictionary acting as a cache for *finder* objects. The keys are paths that have been passed to *sys.path_hooks* and the values are the finders that are found. If a path is a valid file system path but no finder is found on *sys.path_hooks* then `None` is stored.

  Originally specified in **PEP 302**.

  Changed in version 3.3: `None` is stored instead of *imp.NullImporter* when no finder is found.

sys.platform
: This string contains a platform identifier that can be used to append platform-specific components to *sys.path*, for instance.

  For Unix systems, except on Linux, this is the lowercased OS name as returned by `uname -s` with the first part of the version as returned by `uname -r` appended, e.g. `'sunos5'` or `'freebsd8'`, *at the time when Python was built*. Unless you want to test for a specific system version, it is therefore recommended to use the following idiom:

```
if sys.platform.startswith('freebsd'):
    # FreeBSD-specific code here...
elif sys.platform.startswith('linux'):
    # Linux-specific code here...
```

  For other systems, the values are:

System	platform value
Linux	`'linux'`
Windows	`'win32'`
Windows/Cygwin	`'cygwin'`
Mac OS X	`'darwin'`

  Changed in version 3.3: On Linux, *sys.platform* doesn't contain the major version anymore. It is always `'linux'`, instead of `'linux2'` or `'linux3'`. Since older Python versions include the version number, it is recommended to always use the `startswith` idiom presented above.

  See also:

  os.name has a coarser granularity. *os.uname()* gives system-dependent version information.

  The *platform* module provides detailed checks for the system's identity.

sys.prefix
: A string giving the site-specific directory prefix where the platform independent Python files are installed; by default, this is the string `'/usr/local'`. This can be set at build time with the `--prefix` argument to the `configure` script. The main collection of Python library modules is installed in the directory *prefix*`/lib/python`*X.Y* while the platform independent header files (all except `pyconfig.h`) are stored in *prefix*`/include/python`*X.Y*, where *X.Y* is the version number of Python, for example `3.2`.

  Note: If a *virtual environment* is in effect, this value will be changed in `site.py` to point to the virtual environment. The value for the Python installation will still be available, via *base_prefix*.

sys.ps1

sys.ps2
: Strings specifying the primary and secondary prompt of the interpreter. These are only defined if the interpreter is in interactive mode. Their initial values in this case are `'>>> '` and `'... '`. If a non-string object is assigned to either variable, its *str()* is re-evaluated each time the interpreter prepares to read a new interactive command; this can be used to implement a dynamic prompt.

sys.setcheckinterval(*interval*)
: Set the interpreter's "check interval". This integer value determines how often the interpreter checks for periodic things such as thread switches and signal handlers. The default is `100`, meaning the check is performed every 100 Python virtual instructions. Setting it to a larger value may increase performance for programs using threads. Setting it to a value `<=` 0 checks every virtual instruction, maximizing responsiveness as well as overhead.

  Deprecated since version 3.2: This function doesn't have an effect anymore, as the internal logic for thread switching and asynchronous tasks has been rewritten. Use *setswitchinterval()* instead.

sys.setdlopenflags(*n*)
: Set the flags used by the interpreter for `dlopen()` calls, such as when the interpreter loads extension modules. Among other things, this will enable a lazy resolving of symbols when importing a module, if called as `sys.setdlopenflags(0)`. To share symbols across extension modules, call as `sys.setdlopenflags(os.RTLD_GLOBAL)`. Symbolic names for the flag values can be found in the *os* module (`RTLD_xxx` constants, e.g. *os.RTLD_LAZY*).

  Availability: Unix.

sys.setprofile(*profilefunc*)
: Set the system's profile function, which allows you to implement a Python source code profiler in Python. See chapter *The Python Profilers* for more information on the Python profiler. The system's profile function is called similarly to the system's trace function (see *settrace()*), but it is called with different events, for example it isn't called for each executed line of code (only on call and return, but the return event is reported even when an exception has been set). The function is thread-specific, but there is no way for the profiler to know about context switches between threads, so it does not make sense to use this in the presence of multiple threads. Also, its return value is not used, so it can simply return `None`. Error in the profile function will cause itself unset.

  Profile functions should have three arguments: *frame*, *event*, and *arg*. *frame* is the current stack frame. *event* is a string: `'call'`, `'return'`, `'c_call'`, `'c_return'`, or `'c_exception'`. *arg* depends on the event type.

  The events have the following meaning:

  `'call'` A function is called (or some other code block entered). The profile function is called; *arg* is `None`.

  `'return'` A function (or other code block) is about to return. The profile function is called; *arg* is the value that will be returned, or `None` if the event is caused by an exception being raised.

  `'c_call'` A C function is about to be called. This may be an extension function or a built-in. *arg* is the C function object.

  `'c_return'` A C function has returned. *arg* is the C function object.

  `'c_exception'` A C function has raised an exception. *arg* is the C function object.

sys.setrecursionlimit(*limit*)
: Set the maximum depth of the Python interpreter stack to *limit*. This limit prevents infinite recursion from causing an overflow of the C stack and crashing Python.

  The highest possible limit is platform-dependent. A user may need to set the limit higher when they have a program that requires deep recursion and a platform that supports a higher limit. This should be done with care, because a too-high limit can lead to a crash.

  If the new limit is too low at the current recursion depth, a *RecursionError* exception is raised.

Changed in version 3.5.1: A *RecursionError* exception is now raised if the new limit is too low at the current recursion depth.

sys.**setswitchinterval**(*interval*)
Set the interpreter's thread switch interval (in seconds). This floating-point value determines the ideal duration of the "timeslices" allocated to concurrently running Python threads. Please note that the actual value can be higher, especially if long-running internal functions or methods are used. Also, which thread becomes scheduled at the end of the interval is the operating system's decision. The interpreter doesn't have its own scheduler.

New in version 3.2.

sys.**settrace**(*tracefunc*)
Set the system's trace function, which allows you to implement a Python source code debugger in Python. The function is thread-specific; for a debugger to support multiple threads, it must be registered using *settrace()* for each thread being debugged.

Trace functions should have three arguments: *frame*, *event*, and *arg*. *frame* is the current stack frame. *event* is a string: `'call'`, `'line'`, `'return'`, `'exception'` or `'opcode'`. *arg* depends on the event type.

The trace function is invoked (with *event* set to `'call'`) whenever a new local scope is entered; it should return a reference to a local trace function to be used that scope, or `None` if the scope shouldn't be traced.

The local trace function should return a reference to itself (or to another function for further tracing in that scope), or `None` to turn off tracing in that scope.

If there is any error occurred in the trace function, it will be unset, just like `settrace(None)` is called.

The events have the following meaning:

`'call'` A function is called (or some other code block entered). The global trace function is called; *arg* is `None`; the return value specifies the local trace function.

`'line'` The interpreter is about to execute a new line of code or re-execute the condition of a loop. The local trace function is called; *arg* is `None`; the return value specifies the new local trace function. See `Objects/lnotab_notes.txt` for a detailed explanation of how this works. Per-line events may be disabled for a frame by setting `f_trace_lines` to *False* on that frame.

`'return'` A function (or other code block) is about to return. The local trace function is called; *arg* is the value that will be returned, or `None` if the event is caused by an exception being raised. The trace function's return value is ignored.

`'exception'` An exception has occurred. The local trace function is called; *arg* is a tuple `(exception, value, traceback)`; the return value specifies the new local trace function.

`'opcode'` The interpreter is about to execute a new opcode (see *dis* for opcode details). The local trace function is called; *arg* is `None`; the return value specifies the new local trace function. Per-opcode events are not emitted by default: they must be explicitly requested by setting `f_trace_opcodes` to *True* on the frame.

Note that as an exception is propagated down the chain of callers, an `'exception'` event is generated at each level.

For more information on code and frame objects, refer to types.

CPython implementation detail: The *settrace()* function is intended only for implementing debuggers, profilers, coverage tools and the like. Its behavior is part of the implementation platform, rather than part of the language definition, and thus may not be available in all Python implementations.

Changed in version 3.7: `'opcode'` event type added; `f_trace_lines` and `f_trace_opcodes` attributes added to frames

sys.**set_asyncgen_hooks**(*firstiter*, *finalizer*)

Accepts two optional keyword arguments which are callables that accept an *asynchronous generator iterator* as an argument. The *firstiter* callable will be called when an asynchronous generator is iterated for the first time. The *finalizer* will be called when an asynchronous generator is about to be garbage collected.

New in version 3.6: See **PEP 525** for more details, and for a reference example of a *finalizer* method see the implementation of `asyncio.Loop.shutdown_asyncgens` in Lib/asyncio/base_events.py

---

Note: This function has been added on a provisional basis (see **PEP 411** for details.)

---

sys.**set_coroutine_origin_tracking_depth**(*depth*)

Allows enabling or disabling coroutine origin tracking. When enabled, the `cr_origin` attribute on coroutine objects will contain a tuple of (filename, line number, function name) tuples describing the traceback where the coroutine object was created, with the most recent call first. When disabled, `cr_origin` will be None.

To enable, pass a *depth* value greater than zero; this sets the number of frames whose information will be captured. To disable, pass set *depth* to zero.

This setting is thread-specific.

New in version 3.7.

Note: This function has been added on a provisional basis (see **PEP 411** for details.) Use it only for debugging purposes.

---

sys.**set_coroutine_wrapper**(*wrapper*)

Allows intercepting creation of *coroutine* objects (only ones that are created by an `async def` function; generators decorated with *types.coroutine()* or *asyncio.coroutine()* will not be intercepted).

The *wrapper* argument must be either:

- a callable that accepts one argument (a coroutine object);
- `None`, to reset the wrapper.

If called twice, the new wrapper replaces the previous one. The function is thread-specific.

The *wrapper* callable cannot define new coroutines directly or indirectly:

```
def wrapper(coro):
    async def wrap(coro):
        return await coro
    return wrap(coro)
sys.set_coroutine_wrapper(wrapper)

async def foo():
    pass

# The following line will fail with a RuntimeError, because
# ``wrapper`` creates a ``wrap(coro)`` coroutine:
foo()
```

See also *get_coroutine_wrapper()*.

New in version 3.5: See **PEP 492** for more details.

Note: This function has been added on a provisional basis (see **PEP 411** for details.) Use it only for debugging purposes.

Deprecated since version 3.7: The coroutine wrapper functionality has been deprecated, and will be removed in 3.8. See bpo-32591 for details.

`sys._enablelegacywindowsfsencoding()`
Changes the default filesystem encoding and errors mode to 'mbcs' and 'replace' respectively, for consistency with versions of Python prior to 3.6.

This is equivalent to defining the `PYTHONLEGACYWINDOWSFSENCODING` environment variable before launching Python.

Availability: Windows

New in version 3.6: See **PEP 529** for more details.

`sys.stdin`
`sys.stdout`
`sys.stderr`
File objects used by the interpreter for standard input, output and errors:

- `stdin` is used for all interactive input (including calls to *`input()`*);
- `stdout` is used for the output of *`print()`* and *expression* statements and for the prompts of *`input()`*;
- The interpreter's own prompts and its error messages go to `stderr`.

These streams are regular *text files* like those returned by the *`open()`* function. Their parameters are chosen as follows:

- The character encoding is platform-dependent. Under Windows, if the stream is interactive (that is, if its `isatty()` method returns `True`), the console codepage is used, otherwise the ANSI code page. Under other platforms, the locale encoding is used (see *`locale.getpreferredencoding()`*).

  Under all platforms though, you can override this value by setting the `PYTHONIOENCODING` environment variable before starting Python.
- When interactive, `stdout` and `stderr` streams are line-buffered. Otherwise, they are block-buffered like regular text files. You can override this value with the `-u` command-line option.

Note: To write or read binary data from/to the standard streams, use the underlying binary *`buffer`* object. For example, to write bytes to *`stdout`*, use `sys.stdout.buffer.write(b'abc')`.

However, if you are writing a library (and do not control in which context its code will be executed), be aware that the standard streams may be replaced with file-like objects like *`io.StringIO`* which do not support the `buffer` attribute.

`sys.__stdin__`
`sys.__stdout__`
`sys.__stderr__`
These objects contain the original values of `stdin`, `stderr` and `stdout` at the start of the program. They are used during finalization, and could be useful to print to the actual standard stream no matter if the `sys.std*` object has been redirected.

It can also be used to restore the actual files to known working file objects in case they have been overwritten with a broken object. However, the preferred way to do this is to explicitly save the previous stream before replacing it, and restore the saved object.

Note: Under some conditions `stdin`, `stdout` and `stderr` as well as the original values `__stdin__`, `__stdout__` and `__stderr__` can be `None`. It is usually the case for Windows GUI apps that aren't connected to a console and Python apps started with `pythonw`.

`sys.thread_info`
A *struct sequence* holding information about the thread implementation.

Attribute	Explanation
`name`	Name of the thread implementation: • `'nt'`: Windows threads • `'pthread'`: POSIX threads • `'solaris'`: Solaris threads
`lock`	Name of the lock implementation: • `'semaphore'`: a lock uses a semaphore • `'mutex+cond'`: a lock uses a mutex and a condition variable • `None` if this information is unknown
version	Name and version of the thread library. It is a string, or `None` if this information is unknown.

New in version 3.3.

`sys.tracebacklimit`
When this variable is set to an integer value, it determines the maximum number of levels of traceback information printed when an unhandled exception occurs. The default is `1000`. When set to `0` or less, all traceback information is suppressed and only the exception type and value are printed.

`sys.version`
A string containing the version number of the Python interpreter plus additional information on the build number and compiler used. This string is displayed when the interactive interpreter is started. Do not extract version information out of it, rather, use *version_info* and the functions provided by the *platform* module.

`sys.api_version`
The C API version for this interpreter. Programmers may find this useful when debugging version conflicts between Python and extension modules.

`sys.version_info`
A tuple containing the five components of the version number: *major*, *minor*, *micro*, *releaselevel*, and *serial*. All values except *releaselevel* are integers; the release level is `'alpha'`, `'beta'`, `'candidate'`, or `'final'`. The `version_info` value corresponding to the Python version 2.0 is `(2, 0, 0, 'final', 0)`. The components can also be accessed by name, so `sys.version_info[0]` is equivalent to `sys.version_info.major` and so on.

Changed in version 3.1: Added named component attributes.

`sys.warnoptions`
This is an implementation detail of the warnings framework; do not modify this value. Refer to the *warnings* module for more information on the warnings framework.

`sys.winver`
The version number used to form registry keys on Windows platforms. This is stored as string resource 1000 in the Python DLL. The value is normally the first three characters of *version*. It is provided in the *sys* module for informational purposes; modifying this value has no effect on the registry keys used by Python. Availability: Windows.

sys._xoptions
: A dictionary of the various implementation-specific flags passed through the `-X` command-line option. Option names are either mapped to their values, if given explicitly, or to *True*. Example:

```
$ ./python -Xa=b -Xc
Python 3.2a3+ (py3k, Oct 16 2010, 20:14:50)
[GCC 4.4.3] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>> import sys
>>> sys._xoptions
{'a': 'b', 'c': True}
```

CPython implementation detail: This is a CPython-specific way of accessing options passed through `-X`. Other implementations may export them through other means, or not at all.

New in version 3.2.

Citations

30.2 sysconfig — Provide access to Python's configuration information

New in version 3.2.

Source code: Lib/sysconfig.py

The *sysconfig* module provides access to Python's configuration information like the list of installation paths and the configuration variables relevant for the current platform.

30.2.1 Configuration variables

A Python distribution contains a `Makefile` and a `pyconfig.h` header file that are necessary to build both the Python binary itself and third-party C extensions compiled using *distutils*.

sysconfig puts all variables found in these files in a dictionary that can be accessed using *get_config_vars()* or *get_config_var()*.

Notice that on Windows, it's a much smaller set.

sysconfig.get_config_vars(**args*)
: With no arguments, return a dictionary of all configuration variables relevant for the current platform.

  With arguments, return a list of values that result from looking up each argument in the configuration variable dictionary.

  For each argument, if the value is not found, return `None`.

sysconfig.get_config_var(*name*)
: Return the value of a single variable *name*. Equivalent to `get_config_vars().get(name)`.

  If *name* is not found, return `None`.

Example of usage:

```
>>> import sysconfig
>>> sysconfig.get_config_var('Py_ENABLE_SHARED')
0
>>> sysconfig.get_config_var('LIBDIR')
```

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```
'/usr/local/lib'
>>> sysconfig.get_config_vars('AR', 'CXX')
['ar', 'g++']
```

30.2.2 Installation paths

Python uses an installation scheme that differs depending on the platform and on the installation options. These schemes are stored in *sysconfig* under unique identifiers based on the value returned by *os.name*.

Every new component that is installed using *distutils* or a Distutils-based system will follow the same scheme to copy its file in the right places.

Python currently supports seven schemes:

- *posix_prefix*: scheme for Posix platforms like Linux or Mac OS X. This is the default scheme used when Python or a component is installed.
- *posix_home*: scheme for Posix platforms used when a *home* option is used upon installation. This scheme is used when a component is installed through Distutils with a specific home prefix.
- *posix_user*: scheme for Posix platforms used when a component is installed through Distutils and the *user* option is used. This scheme defines paths located under the user home directory.
- *nt*: scheme for NT platforms like Windows.
- *nt_user*: scheme for NT platforms, when the *user* option is used.

Each scheme is itself composed of a series of paths and each path has a unique identifier. Python currently uses eight paths:

- *stdlib*: directory containing the standard Python library files that are not platform-specific.
- *platstdlib*: directory containing the standard Python library files that are platform-specific.
- *platlib*: directory for site-specific, platform-specific files.
- *purelib*: directory for site-specific, non-platform-specific files.
- *include*: directory for non-platform-specific header files.
- *platinclude*: directory for platform-specific header files.
- *scripts*: directory for script files.
- *data*: directory for data files.

sysconfig provides some functions to determine these paths.

sysconfig.get_scheme_names()
Return a tuple containing all schemes currently supported in *sysconfig*.

sysconfig.get_path_names()
Return a tuple containing all path names currently supported in *sysconfig*.

sysconfig.get_path(*name*[, *scheme*[, *vars*[, *expand*]]])
Return an installation path corresponding to the path *name*, from the install scheme named *scheme*.

name has to be a value from the list returned by *get_path_names()*.

sysconfig stores installation paths corresponding to each path name, for each platform, with variables to be expanded. For instance the *stdlib* path for the *nt* scheme is: `{base}/Lib`.

get_path() will use the variables returned by *get_config_vars()* to expand the path. All variables have default values for each platform so one may call this function and get the default value.

If *scheme* is provided, it must be a value from the list returned by *get_scheme_names()*. Otherwise, the default scheme for the current platform is used.

If *vars* is provided, it must be a dictionary of variables that will update the dictionary return by *get_config_vars()*.

If *expand* is set to `False`, the path will not be expanded using the variables.

If *name* is not found, return `None`.

sysconfig.**get_paths**([*scheme*[, *vars*[, *expand*]]])
Return a dictionary containing all installation paths corresponding to an installation scheme. See *get_path()* for more information.

If *scheme* is not provided, will use the default scheme for the current platform.

If *vars* is provided, it must be a dictionary of variables that will update the dictionary used to expand the paths.

If *expand* is set to false, the paths will not be expanded.

If *scheme* is not an existing scheme, *get_paths()* will raise a *KeyError*.

30.2.3 Other functions

sysconfig.**get_python_version**()
Return the `MAJOR.MINOR` Python version number as a string. Similar to `'%d.%d' % sys.version_info[:2]`.

sysconfig.**get_platform**()
Return a string that identifies the current platform.

This is used mainly to distinguish platform-specific build directories and platform-specific built distributions. Typically includes the OS name and version and the architecture (as supplied by 'os.uname()'), although the exact information included depends on the OS; e.g., on Linux, the kernel version isn't particularly important.

Examples of returned values:

- linux-i586
- linux-alpha (?)
- solaris-2.6-sun4u

Windows will return one of:

- win-amd64 (64bit Windows on AMD64 (aka x86_64, Intel64, EM64T, etc)
- win32 (all others - specifically, sys.platform is returned)

Mac OS X can return:

- macosx-10.6-ppc
- macosx-10.4-ppc64
- macosx-10.3-i386
- macosx-10.4-fat

For other non-POSIX platforms, currently just returns *sys.platform*.

sysconfig.**is_python_build**()
Return `True` if the running Python interpreter was built from source and is being run from its built location, and not from a location resulting from e.g. running `make install` or installing via a binary installer.

sysconfig.**parse_config_h**(*fp*[, *vars*])
Parse a `config.h`-style file.

fp is a file-like object pointing to the `config.h`-like file.

A dictionary containing name/value pairs is returned. If an optional dictionary is passed in as the second argument, it is used instead of a new dictionary, and updated with the values read in the file.

sysconfig.**get_config_h_filename**()
Return the path of `pyconfig.h`.

sysconfig.**get_makefile_filename**()
Return the path of `Makefile`.

30.2.4 Using `sysconfig` as a script

You can use *sysconfig* as a script with Python's *-m* option:

```
$ python -m sysconfig
Platform: "macosx-10.4-i386"
Python version: "3.2"
Current installation scheme: "posix_prefix"

Paths:
        data = "/usr/local"
        include = "/Users/tarek/Dev/svn.python.org/py3k/Include"
        platinclude = "."
        platlib = "/usr/local/lib/python3.2/site-packages"
        platstdlib = "/usr/local/lib/python3.2"
        purelib = "/usr/local/lib/python3.2/site-packages"
        scripts = "/usr/local/bin"
        stdlib = "/usr/local/lib/python3.2"

Variables:
        AC_APPLE_UNIVERSAL_BUILD = "0"
        AIX_GENUINE_CPLUSPLUS = "0"
        AR = "ar"
        ARFLAGS = "rc"
        ...
```

This call will print in the standard output the information returned by *get_platform()*, *get_python_version()*, *get_path()* and *get_config_vars()*.

30.3 `builtins` — Built-in objects

This module provides direct access to all 'built-in' identifiers of Python; for example, `builtins.open` is the full name for the built-in function *open()*. See *Built-in Functions* and *Built-in Constants* for documentation.

This module is not normally accessed explicitly by most applications, but can be useful in modules that provide objects with the same name as a built-in value, but in which the built-in of that name is also needed. For example, in a module that wants to implement an *open()* function that wraps the built-in *open()*, this module can be used directly:

```
import builtins

def open(path):
    f = builtins.open(path, 'r')
    return UpperCaser(f)

class UpperCaser:
    '''Wrapper around a file that converts output to upper-case.'''

    def __init__(self, f):
        self._f = f

    def read(self, count=-1):
        return self._f.read(count).upper()

    # ...
```

As an implementation detail, most modules have the name `__builtins__` made available as part of their globals. The value of `__builtins__` is normally either this module or the value of this module's *__dict__* attribute. Since this is an implementation detail, it may not be used by alternate implementations of Python.

30.4 `__main__` — Top-level script environment

`'__main__'` is the name of the scope in which top-level code executes. A module's ___name___ is set equal to `'__main__'` when read from standard input, a script, or from an interactive prompt.

A module can discover whether or not it is running in the main scope by checking its own `__name__`, which allows a common idiom for conditionally executing code in a module when it is run as a script or with `python -m` but not when it is imported:

```
if __name__ == "__main__":
    # execute only if run as a script
    main()
```

For a package, the same effect can be achieved by including a `__main__.py` module, the contents of which will be executed when the module is run with `-m`.

30.5 `warnings` — Warning control

Source code: Lib/warnings.py

Warning messages are typically issued in situations where it is useful to alert the user of some condition in a program, where that condition (normally) doesn't warrant raising an exception and terminating the program. For example, one might want to issue a warning when a program uses an obsolete module.

Python programmers issue warnings by calling the *warn()* function defined in this module. (C programmers use `PyErr_WarnEx()`; see exceptionhandling for details).

Warning messages are normally written to `sys.stderr`, but their disposition can be changed flexibly, from ignoring all warnings to turning them into exceptions. The disposition of warnings can vary based on the

warning category (see below), the text of the warning message, and the source location where it is issued. Repetitions of a particular warning for the same source location are typically suppressed.

There are two stages in warning control: first, each time a warning is issued, a determination is made whether a message should be issued or not; next, if a message is to be issued, it is formatted and printed using a user-settable hook.

The determination whether to issue a warning message is controlled by the warning filter, which is a sequence of matching rules and actions. Rules can be added to the filter by calling *filterwarnings()* and reset to its default state by calling *resetwarnings()*.

The printing of warning messages is done by calling *showwarning()*, which may be overridden; the default implementation of this function formats the message by calling *formatwarning()*, which is also available for use by custom implementations.

See also:

logging.captureWarnings() allows you to handle all warnings with the standard logging infrastructure.

30.5.1 Warning Categories

There are a number of built-in exceptions that represent warning categories. This categorization is useful to be able to filter out groups of warnings.

While these are technically *built-in exceptions*, they are documented here, because conceptually they belong to the warnings mechanism.

User code can define additional warning categories by subclassing one of the standard warning categories. A warning category must always be a subclass of the *Warning* class.

The following warnings category classes are currently defined:

Class	Description
Warning	This is the base class of all warning category classes. It is a subclass of *Exception*.
UserWarning	The default category for *warn()*.
DeprecationWarning	Base category for warnings about deprecated features when those warnings are intended for other Python developers (ignored by default, unless triggered by code in `__main__`).
SyntaxWarning	Base category for warnings about dubious syntactic features.
RuntimeWarning	Base category for warnings about dubious runtime features.
FutureWarning	Base category for warnings about deprecated features when those warnings are intended for end users of applications that are written in Python.
PendingDeprecationWarning	Base category for warnings about features that will be deprecated in the future (ignored by default).
ImportWarning	Base category for warnings triggered during the process of importing a module (ignored by default).
UnicodeWarning	Base category for warnings related to Unicode.
BytesWarning	Base category for warnings related to *bytes* and *bytearray*.
ResourceWarning	Base category for warnings related to resource usage.

Changed in version 3.7: Previously *DeprecationWarning* and *FutureWarning* were distinguished based on whether a feature was being removed entirely or changing its behaviour. They are now distinguished based on their intended audience and the way they're handled by the default warnings filters.

30.5.2 The Warnings Filter

The warnings filter controls whether warnings are ignored, displayed, or turned into errors (raising an exception).

Conceptually, the warnings filter maintains an ordered list of filter specifications; any specific warning is matched against each filter specification in the list in turn until a match is found; the filter determines the disposition of the match. Each entry is a tuple of the form (*action*, *message*, *category*, *module*, *lineno*), where:

- *action* is one of the following strings:

Value	Disposition
`"default"`	print the first occurrence of matching warnings for each location (module + line number) where the warning is issued
`"error"`	turn matching warnings into exceptions
`"ignore"`	never print matching warnings
`"always"`	always print matching warnings
`"module"`	print the first occurrence of matching warnings for each module where the warning is issued (regardless of line number)
`"once"`	print only the first occurrence of matching warnings, regardless of location

- *message* is a string containing a regular expression that the start of the warning message must match. The expression is compiled to always be case-insensitive.
- *category* is a class (a subclass of *Warning*) of which the warning category must be a subclass in order to match.
- *module* is a string containing a regular expression that the module name must match. The expression is compiled to be case-sensitive.
- *lineno* is an integer that the line number where the warning occurred must match, or `0` to match all line numbers.

Since the *Warning* class is derived from the built-in *Exception* class, to turn a warning into an error we simply raise `category(message)`.

If a warning is reported and doesn't match any registered filter then the "default" action is applied (hence its name).

Describing Warning Filters

The warnings filter is initialized by `-W` options passed to the Python interpreter command line and the `PYTHONWARNINGS` environment variable. The interpreter saves the arguments for all supplied entries without interpretation in `sys.warnoptions`; the *warnings* module parses these when it is first imported (invalid options are ignored, after printing a message to `sys.stderr`).

Individual warnings filters are specified as a sequence of fields separated by colons:

```
action:message:category:module:line
```

The meaning of each of these fields is as described in *The Warnings Filter*. When listing multiple filters on a single line (as for `PYTHONWARNINGS`), the individual filters are separated by commas,and the filters listed later take precedence over those listed before them (as they're applied left-to-right, and the most recently applied filters take precedence over earlier ones).

Commonly used warning filters apply to either all warnings, warnings in a particular category, or warnings raised by particular modules or packages. Some examples:

```
default                      # Show all warnings (even those ignored by default)
ignore                       # Ignore all warnings
error                        # Convert all warnings to errors
error::ResourceWarning       # Treat ResourceWarning messages as errors
default::DeprecationWarning  # Show DeprecationWarning messages
ignore,default:::mymodule    # Only report warnings triggered by "mymodule"
error:::mymodule[.*]         # Convert warnings to errors in "mymodule"
                             # and any subpackages of "mymodule"
```

Default Warning Filter

By default, Python installs several warning filters, which can be overridden by the `-W` command-line option, the `PYTHONWARNINGS` environment variable and calls to *filterwarnings()*.

In regular release builds, the default warning filter has the following entries (in order of precedence):

```
default::DeprecationWarning:__main__
ignore::DeprecationWarning
ignore::PendingDeprecationWarning
ignore::ImportWarning
ignore::ResourceWarning
```

In debug builds, the list of default warning filters is empty.

Changed in version 3.2: *DeprecationWarning* is now ignored by default in addition to *PendingDeprecationWarning*.

Changed in version 3.7: *DeprecationWarning* is once again shown by default when triggered directly by code in `__main__`.

Changed in version 3.7: *BytesWarning* no longer appears in the default filter list and is instead configured via *sys.warnoptions* when `-b` is specified twice.

Overriding the default filter

Developers of applications written in Python may wish to hide *all* Python level warnings from their users by default, and only display them when running tests or otherwise working on the application. The *sys.warnoptions* attribute used to pass filter configurations to the interpreter can be used as a marker to indicate whether or not warnings should be disabled:

```
import sys

if not sys.warnoptions:
    import warnings
    warnings.simplefilter("ignore")
```

Developers of test runners for Python code are advised to instead ensure that *all* warnings are displayed by default for the code under test, using code like:

```
import sys

if not sys.warnoptions:
    import os, warnings
    warnings.simplefilter("default") # Change the filter in this process
    os.environ["PYTHONWARNINGS"] = "default" # Also affect subprocesses
```

Finally, developers of interactive shells that run user code in a namespace other than `__main__` are advised to ensure that *DeprecationWarning* messages are made visible by default, using code like the following (where `user_ns` is the module used to execute code entered interactively):

```
import warnings
warnings.filterwarnings("default", category=DeprecationWarning,
                                   module=user_ns.get("__name__"))
```

30.5.3 Temporarily Suppressing Warnings

If you are using code that you know will raise a warning, such as a deprecated function, but do not want to see the warning (even when warnings have been explicitly configured via the command line), then it is possible to suppress the warning using the *catch_warnings* context manager:

```
import warnings

def fxn():
    warnings.warn("deprecated", DeprecationWarning)

with warnings.catch_warnings():
    warnings.simplefilter("ignore")
    fxn()
```

While within the context manager all warnings will simply be ignored. This allows you to use known-deprecated code without having to see the warning while not suppressing the warning for other code that might not be aware of its use of deprecated code. Note: this can only be guaranteed in a single-threaded application. If two or more threads use the *catch_warnings* context manager at the same time, the behavior is undefined.

30.5.4 Testing Warnings

To test warnings raised by code, use the *catch_warnings* context manager. With it you can temporarily mutate the warnings filter to facilitate your testing. For instance, do the following to capture all raised warnings to check:

```
import warnings

def fxn():
    warnings.warn("deprecated", DeprecationWarning)

with warnings.catch_warnings(record=True) as w:
    # Cause all warnings to always be triggered.
    warnings.simplefilter("always")
    # Trigger a warning.
    fxn()
    # Verify some things
    assert len(w) == 1
    assert issubclass(w[-1].category, DeprecationWarning)
    assert "deprecated" in str(w[-1].message)
```

One can also cause all warnings to be exceptions by using `error` instead of `always`. One thing to be aware of is that if a warning has already been raised because of a `once`/`default` rule, then no matter what filters are set the warning will not be seen again unless the warnings registry related to the warning has been cleared.

Once the context manager exits, the warnings filter is restored to its state when the context was entered. This prevents tests from changing the warnings filter in unexpected ways between tests and leading to inde-

terminate test results. The *showwarning()* function in the module is also restored to its original value. Note: this can only be guaranteed in a single-threaded application. If two or more threads use the *catch_warnings* context manager at the same time, the behavior is undefined.

When testing multiple operations that raise the same kind of warning, it is important to test them in a manner that confirms each operation is raising a new warning (e.g. set warnings to be raised as exceptions and check the operations raise exceptions, check that the length of the warning list continues to increase after each operation, or else delete the previous entries from the warnings list before each new operation).

30.5.5 Updating Code For New Versions of Dependencies

Warning categories that are primarily of interest to Python developers (rather than end users of applications written in Python) are ignored by default.

Notably, this "ignored by default" list includes *DeprecationWarning* (for every module except `__main__`), which means developers should make sure to test their code with typically ignored warnings made visible in order to receive timely notifications of future breaking API changes (whether in the standard library or third party packages).

In the ideal case, the code will have a suitable test suite, and the test runner will take care of implicitly enabling all warnings when running tests (the test runner provided by the *unittest* module does this).

In less ideal cases, applications can be checked for use of deprecated interfaces by passing `-Wd` to the Python interpreter (this is shorthand for `-W default`) or setting `PYTHONWARNINGS=default` in the environment. This enables default handling for all warnings, including those that are ignored by default. To change what action is taken for encountered warnings you can change what argument is passed to `-W` (e.g. `-W error`). See the `-W` flag for more details on what is possible.

30.5.6 Available Functions

`warnings.warn`(*message*, *category=None*, *stacklevel=1*, *source=None*)

Issue a warning, or maybe ignore it or raise an exception. The *category* argument, if given, must be a warning category class (see above); it defaults to *UserWarning*. Alternatively *message* can be a *Warning* instance, in which case *category* will be ignored and `message.__class__` will be used. In this case the message text will be `str(message)`. This function raises an exception if the particular warning issued is changed into an error by the warnings filter see above. The *stacklevel* argument can be used by wrapper functions written in Python, like this:

```
def deprecation(message):
    warnings.warn(message, DeprecationWarning, stacklevel=2)
```

This makes the warning refer to `deprecation()`'s caller, rather than to the source of `deprecation()` itself (since the latter would defeat the purpose of the warning message).

source, if supplied, is the destroyed object which emitted a *ResourceWarning*.

Changed in version 3.6: Added *source* parameter.

`warnings.warn_explicit`(*message*, *category*, *filename*, *lineno*, *module=None*, *registry=None*, *module_globals=None*, *source=None*)

This is a low-level interface to the functionality of *warn()*, passing in explicitly the message, category, filename and line number, and optionally the module name and the registry (which should be the `__warningregistry__` dictionary of the module). The module name defaults to the filename with `.py` stripped; if no registry is passed, the warning is never suppressed. *message* must be a string and *category* a subclass of *Warning* or *message* may be a *Warning* instance, in which case *category* will be ignored.

module_globals, if supplied, should be the global namespace in use by the code for which the warning is issued. (This argument is used to support displaying source for modules found in zipfiles or other non-filesystem import sources).

source, if supplied, is the destroyed object which emitted a *ResourceWarning*.

Changed in version 3.6: Add the *source* parameter.

warnings.showwarning(*message*, *category*, *filename*, *lineno*, *file=None*, *line=None*)
Write a warning to a file. The default implementation calls `formatwarning(message, category, filename, lineno, line)` and writes the resulting string to *file*, which defaults to `sys.stderr`. You may replace this function with any callable by assigning to `warnings.showwarning`. *line* is a line of source code to be included in the warning message; if *line* is not supplied, *showwarning()* will try to read the line specified by *filename* and *lineno*.

warnings.formatwarning(*message*, *category*, *filename*, *lineno*, *line=None*)
Format a warning the standard way. This returns a string which may contain embedded newlines and ends in a newline. *line* is a line of source code to be included in the warning message; if *line* is not supplied, *formatwarning()* will try to read the line specified by *filename* and *lineno*.

warnings.filterwarnings(*action*, *message=''*, *category=Warning*, *module=''*, *lineno=0*, *append=False*)
Insert an entry into the list of *warnings filter specifications*. The entry is inserted at the front by default; if *append* is true, it is inserted at the end. This checks the types of the arguments, compiles the *message* and *module* regular expressions, and inserts them as a tuple in the list of warnings filters. Entries closer to the front of the list override entries later in the list, if both match a particular warning. Omitted arguments default to a value that matches everything.

warnings.simplefilter(*action*, *category=Warning*, *lineno=0*, *append=False*)
Insert a simple entry into the list of *warnings filter specifications*. The meaning of the function parameters is as for *filterwarnings()*, but regular expressions are not needed as the filter inserted always matches any message in any module as long as the category and line number match.

warnings.resetwarnings()
Reset the warnings filter. This discards the effect of all previous calls to *filterwarnings()*, including that of the `-W` command line options and calls to *simplefilter()*.

30.5.7 Available Context Managers

class warnings.catch_warnings(***, *record=False*, *module=None*)
A context manager that copies and, upon exit, restores the warnings filter and the *showwarning()* function. If the *record* argument is *False* (the default) the context manager returns *None* on entry. If *record* is *True*, a list is returned that is progressively populated with objects as seen by a custom *showwarning()* function (which also suppresses output to `sys.stdout`). Each object in the list has attributes with the same names as the arguments to *showwarning()*.

The *module* argument takes a module that will be used instead of the module returned when you import *warnings* whose filter will be protected. This argument exists primarily for testing the *warnings* module itself.

Note: The *catch_warnings* manager works by replacing and then later restoring the module's *showwarning()* function and internal list of filter specifications. This means the context manager is modifying global state and therefore is not thread-safe.

30.6 dataclasses — Data Classes

Source code: Lib/dataclasses.py

This module provides a decorator and functions for automatically adding generated *special method*s such as `__init__()` and `__repr__()` to user-defined classes. It was originally described in **PEP 557**.

The member variables to use in these generated methods are defined using **PEP 526** type annotations. For example this code:

```
@dataclass
class InventoryItem:
    '''Class for keeping track of an item in inventory.'''
    name: str
    unit_price: float
    quantity_on_hand: int = 0

    def total_cost(self) -> float:
        return self.unit_price * self.quantity_on_hand
```

Will add, among other things, a `__init__()` that looks like:

```
def __init__(self, name: str, unit_price: float, quantity_on_hand: int=0):
    self.name = name
    self.unit_price = unit_price
    self.quantity_on_hand = quantity_on_hand
```

Note that this method is automatically added to the class: it is not directly specified in the `InventoryItem` definition shown above.

New in version 3.7.

30.6.1 Module-level decorators, classes, and functions

@dataclasses.dataclass(*, *init=True*, *repr=True*, *eq=True*, *order=False*, *unsafe_hash=False*, *frozen=False*)

This function is a *decorator* that is used to add generated *special method*s to classes, as described below.

The *dataclass()* decorator examines the class to find `field`s. A `field` is defined as class variable that has a type annotation. With two exceptions described below, nothing in *dataclass()* examines the type specified in the variable annotation.

The order of the fields in all of the generated methods is the order in which they appear in the class definition.

The *dataclass()* decorator will add various "dunder" methods to the class, described below. If any of the added methods already exist on the class, the behavior depends on the parameter, as documented below. The decorator returns the same class that is called on; no new class is created.

If *dataclass()* is used just as a simple decorator with no parameters, it acts as if it has the default values documented in this signature. That is, these three uses of *dataclass()* are equivalent:

```
@dataclass
class C:
    ...
```

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```
@dataclass()
class C:
    ...

@dataclass(init=True, repr=True, eq=True, order=False, unsafe_hash=False, frozen=False)
class C:
   ...
```

The parameters to *dataclass()* are:

- `init`: If true (the default), a `__init__()` method will be generated.

  If the class already defines `__init__()`, this parameter is ignored.

- `repr`: If true (the default), a `__repr__()` method will be generated. The generated repr string will have the class name and the name and repr of each field, in the order they are defined in the class. Fields that are marked as being excluded from the repr are not included. For example: `InventoryItem(name='widget', unit_price=3.0, quantity_on_hand=10)`.

  If the class already defines `__repr__()`, this parameter is ignored.

- `eq`: If true (the default), an `__eq__()` method will be generated. This method compares the class as if it were a tuple of its fields, in order. Both instances in the comparison must be of the identical type.

  If the class already defines `__eq__()`, this parameter is ignored.

- `order`: If true (the default is `False`), `__lt__()`, `__le__()`, `__gt__()`, and `__ge__()` methods will be generated. These compare the class as if it were a tuple of its fields, in order. Both instances in the comparison must be of the identical type. If `order` is true and `eq` is false, a *ValueError* is raised.

  If the class already defines any of `__lt__()`, `__le__()`, `__gt__()`, or `__ge__()`, then *TypeError* is raised.

- `unsafe_hash`: If `False` (the default), a `__hash__()` method is generated according to how `eq` and `frozen` are set.

  `__hash__()` is used by built-in *hash()*, and when objects are added to hashed collections such as dictionaries and sets. Having a `__hash__()` implies that instances of the class are immutable. Mutability is a complicated property that depends on the programmer's intent, the existence and behavior of `__eq__()`, and the values of the `eq` and `frozen` flags in the *dataclass()* decorator.

  By default, *dataclass()* will not implicitly add a `__hash__()` method unless it is safe to do so. Neither will it add or change an existing explicitly defined `__hash__()` method. Setting the class attribute `__hash__ = None` has a specific meaning to Python, as described in the `__hash__()` documentation.

  If `__hash__()` is not explicit defined, or if it is set to `None`, then *dataclass() may* add an implicit `__hash__()` method. Although not recommended, you can force *dataclass()* to create a `__hash__()` method with `unsafe_hash=True`. This might be the case if your class is logically immutable but can nonetheless be mutated. This is a specialized use case and should be considered carefully.

  Here are the rules governing implicit creation of a `__hash__()` method. Note that you cannot both have an explicit `__hash__()` method in your dataclass and set `unsafe_hash=True`; this will result in a *TypeError*.

  If `eq` and `frozen` are both true, by default *dataclass()* will generate a `__hash__()` method for you. If `eq` is true and `frozen` is false, `__hash__()` will be set to `None`, marking it unhashable (which it is, since it is mutable). If `eq` is false, `__hash__()` will be left untouched meaning the

`__hash__()` method of the superclass will be used (if the superclass is *object*, this means it will fall back to id-based hashing).

- `frozen`: If true (the default is False), assigning to fields will generate an exception. This emulates read-only frozen instances. If `__setattr__()` or `__delattr__()` is defined in the class, then *TypeError* is raised. See the discussion below.

`field`s may optionally specify a default value, using normal Python syntax:

```
@dataclass
class C:
    a: int       # 'a' has no default value
    b: int = 0   # assign a default value for 'b'
```

In this example, both `a` and `b` will be included in the added `__init__()` method, which will be defined as:

```
def __init__(self, a: int, b: int = 0):
```

TypeError will be raised if a field without a default value follows a field with a default value. This is true either when this occurs in a single class, or as a result of class inheritance.

`dataclasses.field`(*, *default=MISSING*, *default_factory=MISSING*, *repr=True*, *hash=None*, *init=True*, *compare=True*, *metadata=None*)

For common and simple use cases, no other functionality is required. There are, however, some dataclass features that require additional per-field information. To satisfy this need for additional information, you can replace the default field value with a call to the provided *field()* function. For example:

```
@dataclass
class C:
    mylist: List[int] = field(default_factory=list)

c = C()
c.mylist += [1, 2, 3]
```

As shown above, the `MISSING` value is a sentinel object used to detect if the `default` and `default_factory` parameters are provided. This sentinel is used because `None` is a valid value for `default`. No code should directly use the `MISSING` value.

The parameters to *field()* are:

- `default`: If provided, this will be the default value for this field. This is needed because the *field()* call itself replaces the normal position of the default value.
- `default_factory`: If provided, it must be a zero-argument callable that will be called when a default value is needed for this field. Among other purposes, this can be used to specify fields with mutable default values, as discussed below. It is an error to specify both `default` and `default_factory`.
- `init`: If true (the default), this field is included as a parameter to the generated `__init__()` method.
- `repr`: If true (the default), this field is included in the string returned by the generated `__repr__()` method.
- `compare`: If true (the default), this field is included in the generated equality and comparison methods (`__eq__()`, `__gt__()`, et al.).
- `hash`: This can be a bool or `None`. If true, this field is included in the generated `__hash__()` method. If `None` (the default), use the value of `compare`: this would normally be the expected behavior. A field should be considered in the hash if it's used for comparisons. Setting this value to anything other than `None` is discouraged.

One possible reason to set `hash=False` but `compare=True` would be if a field is expensive to compute a hash value for, that field is needed for equality testing, and there are other fields that contribute to the type's hash value. Even if a field is excluded from the hash, it will still be used for comparisons.

- `metadata`: This can be a mapping or None. None is treated as an empty dict. This value is wrapped in *MappingProxyType()* to make it read-only, and exposed on the *Field* object. It is not used at all by Data Classes, and is provided as a third-party extension mechanism. Multiple third-parties can each have their own key, to use as a namespace in the metadata.

If the default value of a field is specified by a call to *field()*, then the class attribute for this field will be replaced by the specified `default` value. If no `default` is provided, then the class attribute will be deleted. The intent is that after the *dataclass()* decorator runs, the class attributes will all contain the default values for the fields, just as if the default value itself were specified. For example, after:

```
@dataclass
class C:
    x: int
    y: int = field(repr=False)
    z: int = field(repr=False, default=10)
    t: int = 20
```

The class attribute `C.z` will be `10`, the class attribute `C.t` will be `20`, and the class attributes `C.x` and `C.y` will not be set.

class dataclasses.Field

Field objects describe each defined field. These objects are created internally, and are returned by the *fields()* module-level method (see below). Users should never instantiate a *Field* object directly. Its documented attributes are:

- `name`: The name of the field.
- `type`: The type of the field.
- `default`, `default_factory`, `init`, `repr`, `hash`, `compare`, and `metadata` have the identical meaning and values as they do in the *field()* declaration.

Other attributes may exist, but they are private and must not be inspected or relied on.

dataclasses.fields(*class_or_instance*)

Returns a tuple of *Field* objects that define the fields for this dataclass. Accepts either a dataclass, or an instance of a dataclass. Raises *TypeError* if not passed a dataclass or instance of one. Does not return pseudo-fields which are `ClassVar` or `InitVar`.

dataclasses.asdict(*instance*, *, *dict_factory=dict*)

Converts the dataclass `instance` to a dict (by using the factory function `dict_factory`). Each dataclass is converted to a dict of its fields, as `name: value` pairs. dataclasses, dicts, lists, and tuples are recursed into. For example:

```
@dataclass
class Point:
     x: int
     y: int

@dataclass
class C:
     mylist: List[Point]

p = Point(10, 20)
assert asdict(p) == {'x': 10, 'y': 20}
```

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```
c = C([Point(0, 0), Point(10, 4)])
assert asdict(c) == {'mylist': [{'x': 0, 'y': 0}, {'x': 10, 'y': 4}]}
```

Raises *TypeError* if `instance` is not a dataclass instance.

`dataclasses.astuple(`*, *tuple_factory=tuple*`)`

Converts the dataclass `instance` to a tuple (by using the factory function `tuple_factory`). Each dataclass is converted to a tuple of its field values. dataclasses, dicts, lists, and tuples are recursed into.

Continuing from the previous example:

```
assert astuple(p) == (10, 20)
assert astuple(c) == ([(0, 0), (10, 4)],)
```

Raises *TypeError* if `instance` is not a dataclass instance.

`dataclasses.make_dataclass(`*cls_name*, *fields*, *, *bases=()*, *namespace=None*, *init=True*, *repr=True*, *eq=True*, *order=False*, *unsafe_hash=False*, *frozen=False*`)`

Creates a new dataclass with name `cls_name`, fields as defined in `fields`, base classes as given in `bases`, and initialized with a namespace as given in `namespace`. `fields` is an iterable whose elements are each either `name`, `(name, type)`, or `(name, type, Field)`. If just `name` is supplied, `typing.Any` is used for `type`. The values of `init`, `repr`, `eq`, `order`, `unsafe_hash`, and `frozen` have the same meaning as they do in *dataclass()*.

This function is not strictly required, because any Python mechanism for creating a new class with `__annotations__` can then apply the *dataclass()* function to convert that class to a dataclass. This function is provided as a convenience. For example:

```
C = make_dataclass('C',
                   [('x', int),
                     'y',
                    ('z', int, field(default=5))],
                   namespace={'add_one': lambda self: self.x + 1})
```

Is equivalent to:

```
@dataclass
class C:
    x: int
    y: 'typing.Any'
    z: int = 5

    def add_one(self):
        return self.x + 1
```

`dataclasses.replace(`*instance*, ***changes*`)`

Creates a new object of the same type of `instance`, replacing fields with values from `changes`. If `instance` is not a Data Class, raises *TypeError*. If values in `changes` do not specify fields, raises *TypeError*.

The newly returned object is created by calling the `__init__()` method of the dataclass. This ensures that `__post_init__()`, if present, is also called.

Init-only variables without default values, if any exist, must be specified on the call to *replace()* so that they can be passed to `__init__()` and `__post_init__()`.

It is an error for `changes` to contain any fields that are defined as having `init=False`. A *ValueError* will be raised in this case.

Be forewarned about how `init=False` fields work during a call to *replace()*. They are not copied from the source object, but rather are initialized in `__post_init__()`, if they're initialized at all. It is expected that `init=False` fields will be rarely and judiciously used. If they are used, it might be wise to have alternate class constructors, or perhaps a custom `replace()` (or similarly named) method which handles instance copying.

`dataclasses.is_dataclass`(*class_or_instance*)

Returns True if its parameter is a dataclass or an instance of one, otherwise returns False.

If you need to know if a class is an instance of a dataclass (and not a dataclass itself), then add a further check for `not isinstance(obj, type)`:

```
def is_dataclass_instance(obj):
    return is_dataclass(obj) and not isinstance(obj, type)
```

30.6.2 Post-init processing

The generated `__init__()` code will call a method named `__post_init__()`, if `__post_init__()` is defined on the class. It will normally be called as `self.__post_init__()`. However, if any `InitVar` fields are defined, they will also be passed to `__post_init__()` in the order they were defined in the class. If no `__init__()` method is generated, then `__post_init__()` will not automatically be called.

Among other uses, this allows for initializing field values that depend on one or more other fields. For example:

```
@dataclass
class C:
    a: float
    b: float
    c: float = field(init=False)

    def __post_init__(self):
        self.c = self.a + self.b
```

See the section below on init-only variables for ways to pass parameters to `__post_init__()`. Also see the warning about how *replace()* handles `init=False` fields.

30.6.3 Class variables

One of two places where *dataclass()* actually inspects the type of a field is to determine if a field is a class variable as defined in **PEP 526**. It does this by checking if the type of the field is `typing.ClassVar`. If a field is a `ClassVar`, it is excluded from consideration as a field and is ignored by the dataclass mechanisms. Such `ClassVar` pseudo-fields are not returned by the module-level *fields()* function.

30.6.4 Init-only variables

The other place where *dataclass()* inspects a type annotation is to determine if a field is an init-only variable. It does this by seeing if the type of a field is of type `dataclasses.InitVar`. If a field is an `InitVar`, it is considered a pseudo-field called an init-only field. As it is not a true field, it is not returned by the module-level *fields()* function. Init-only fields are added as parameters to the generated `__init__()` method, and are passed to the optional `__post_init__()` method. They are not otherwise used by dataclasses.

For example, suppose a field will be initialzed from a database, if a value is not provided when creating the class:

```
@dataclass
class C:
    i: int
    j: int = None
    database: InitVar[DatabaseType] = None

    def __post_init__(self, database):
        if self.j is None and database is not None:
            self.j = database.lookup('j')

c = C(10, database=my_database)
```

In this case, *fields()* will return *Field* objects for `i` and `j`, but not for `database`.

30.6.5 Frozen instances

It is not possible to create truly immutable Python objects. However, by passing `frozen=True` to the *dataclass()* decorator you can emulate immutability. In that case, dataclasses will add `__setattr__()` and `__delattr__()` methods to the class. These methods will raise a *FrozenInstanceError* when invoked.

There is a tiny performance penalty when using `frozen=True`: `__init__()` cannot use simple assignment to initialize fields, and must use `object.__setattr__()`.

30.6.6 Inheritance

When the dataclass is being created by the *dataclass()* decorator, it looks through all of the class's base classes in reverse MRO (that is, starting at *object*) and, for each dataclass that it finds, adds the fields from that base class to an ordered mapping of fields. After all of the base class fields are added, it adds its own fields to the ordered mapping. All of the generated methods will use this combined, calculated ordered mapping of fields. Because the fields are in insertion order, derived classes override base classes. An example:

```
@dataclass
class Base:
    x: Any = 15.0
    y: int = 0

@dataclass
class C(Base):
    z: int = 10
    x: int = 15
```

The final list of fields is, in order, `x`, `y`, `z`. The final type of `x` is `int`, as specified in class `C`.

The generated `__init__()` method for `C` will look like:

```
def __init__(self, x: int = 15, y: int = 0, z: int = 10):
```

30.6.7 Default factory functions

If a *field()* specifies a `default_factory`, it is called with zero arguments when a default value for the field is needed. For example, to create a new instance of a list, use:

```
mylist: list = field(default_factory=list)
```

If a field is excluded from `__init__()` (using `init=False`) and the field also specifies `default_factory`, then the default factory function will always be called from the generated `__init__()` function. This happens because there is no other way to give the field an initial value.

30.6.8 Mutable default values

Python stores default member variable values in class attributes. Consider this example, not using dataclasses:

```
class C:
    x = []
    def add(self, element):
        self.x += element

o1 = C()
o2 = C()
o1.add(1)
o2.add(2)
assert o1.x == [1, 2]
assert o1.x is o2.x
```

Note that the two instances of class `C` share the same class variable `x`, as expected.

Using dataclasses, *if* this code was valid:

```
@dataclass
class D:
    x: List = []
    def add(self, element):
        self.x += element
```

it would generate code similar to:

```
class D:
    x = []
    def __init__(self, x=x):
        self.x = x
    def add(self, element):
        self.x += element

assert D().x is D().x
```

This has the same issue as the original example using class `C`. That is, two instances of class `D` that do not specify a value for `x` when creating a class instance will share the same copy of `x`. Because dataclasses just use normal Python class creation they also share this behavior. There is no general way for Data Classes to detect this condition. Instead, dataclasses will raise a *TypeError* if it detects a default parameter of type `list`, `dict`, or `set`. This is a partial solution, but it does protect against many common errors.

Using default factory functions is a way to create new instances of mutable types as default values for fields:

```
@dataclass
class D:
    x: list = field(default_factory=list)

assert D().x is not D().x
```

30.6.9 Exceptions

exception dataclasses.FrozenInstanceError
Raised when an implicitly defined `__setattr__()` or `__delattr__()` is called on a dataclass which was defined with `frozen=True`.

30.7 `contextlib` — Utilities for `with`-statement contexts

Source code: Lib/contextlib.py

This module provides utilities for common tasks involving the `with` statement. For more information see also *Context Manager Types* and context-managers.

30.7.1 Utilities

Functions and classes provided:

class contextlib.AbstractContextManager
An *abstract base class* for classes that implement `object.__enter__()` and `object.__exit__()`. A default implementation for `object.__enter__()` is provided which returns `self` while `object.__exit__()` is an abstract method which by default returns `None`. See also the definition of *Context Manager Types*.

New in version 3.6.

class contextlib.AbstractAsyncContextManager
An *abstract base class* for classes that implement `object.__aenter__()` and `object.__aexit__()`. A default implementation for `object.__aenter__()` is provided which returns `self` while `object.__aexit__()` is an abstract method which by default returns `None`. See also the definition of async-context-managers.

New in version 3.7.

@contextlib.contextmanager
This function is a *decorator* that can be used to define a factory function for `with` statement context managers, without needing to create a class or separate `__enter__()` and `__exit__()` methods.

A simple example (this is not recommended as a real way of generating HTML!):

```
from contextlib import contextmanager

@contextmanager
def tag(name):
    print("<%s>" % name)
    yield
    print("</%s>" % name)
```

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```
>>> with tag("h1"):
...     print("foo")
...
<h1>
foo
</h1>
```

The function being decorated must return a *generator*-iterator when called. This iterator must yield exactly one value, which will be bound to the targets in the `with` statement's `as` clause, if any.

At the point where the generator yields, the block nested in the `with` statement is executed. The generator is then resumed after the block is exited. If an unhandled exception occurs in the block, it is reraised inside the generator at the point where the yield occurred. Thus, you can use a `try…except…finally` statement to trap the error (if any), or ensure that some cleanup takes place. If an exception is trapped merely in order to log it or to perform some action (rather than to suppress it entirely), the generator must reraise that exception. Otherwise the generator context manager will indicate to the `with` statement that the exception has been handled, and execution will resume with the statement immediately following the `with` statement.

contextmanager() uses *ContextDecorator* so the context managers it creates can be used as decorators as well as in `with` statements. When used as a decorator, a new generator instance is implicitly created on each function call (this allows the otherwise "one-shot" context managers created by *contextmanager()* to meet the requirement that context managers support multiple invocations in order to be used as decorators).

Changed in version 3.2: Use of *ContextDecorator*.

@contextlib.asynccontextmanager

Similar to *contextmanager()*, but creates an asynchronous context manager.

This function is a *decorator* that can be used to define a factory function for `async with` statement asynchronous context managers, without needing to create a class or separate `__aenter__()` and `__aexit__()` methods. It must be applied to an *asynchronous generator* function.

A simple example:

```
from contextlib import asynccontextmanager

@asynccontextmanager
async def get_connection():
    conn = await acquire_db_connection()
    try:
        yield
    finally:
        await release_db_connection(conn)

async def get_all_users():
    async with get_connection() as conn:
        return conn.query('SELECT ...')
```

New in version 3.7.

contextlib.closing(*thing*)

Return a context manager that closes *thing* upon completion of the block. This is basically equivalent to:

```
from contextlib import contextmanager
```

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```
@contextmanager
def closing(thing):
    try:
        yield thing
    finally:
        thing.close()
```

And lets you write code like this:

```
from contextlib import closing
from urllib.request import urlopen

with closing(urlopen('http://www.python.org')) as page:
    for line in page:
        print(line)
```

without needing to explicitly close `page`. Even if an error occurs, `page.close()` will be called when the `with` block is exited.

`contextlib.nullcontext(`*enter_result=None*`)`

Return a context manager that returns enter_result from `__enter__`, but otherwise does nothing. It is intended to be used as a stand-in for an optional context manager, for example:

```
def process_file(file_or_path):
    if isinstance(file_or_path, str):
        # If string, open file
        cm = open(file_or_path)
    else:
        # Caller is responsible for closing file
        cm = nullcontext(file_or_path)

    with cm as file:
        # Perform processing on the file
```

New in version 3.7.

`contextlib.suppress(`**exceptions*`)`

Return a context manager that suppresses any of the specified exceptions if they occur in the body of a with statement and then resumes execution with the first statement following the end of the with statement.

As with any other mechanism that completely suppresses exceptions, this context manager should be used only to cover very specific errors where silently continuing with program execution is known to be the right thing to do.

For example:

```
from contextlib import suppress

with suppress(FileNotFoundError):
    os.remove('somefile.tmp')

with suppress(FileNotFoundError):
    os.remove('someotherfile.tmp')
```

This code is equivalent to:

```
try:
    os.remove('somefile.tmp')
except FileNotFoundError:
    pass

try:
    os.remove('someotherfile.tmp')
except FileNotFoundError:
    pass
```

This context manager is *reentrant*.

New in version 3.4.

contextlib.redirect_stdout(*new_target*)

Context manager for temporarily redirecting *sys.stdout* to another file or file-like object.

This tool adds flexibility to existing functions or classes whose output is hardwired to stdout.

For example, the output of *help()* normally is sent to *sys.stdout*. You can capture that output in a string by redirecting the output to an *io.StringIO* object:

```
f = io.StringIO()
with redirect_stdout(f):
    help(pow)
s = f.getvalue()
```

To send the output of *help()* to a file on disk, redirect the output to a regular file:

```
with open('help.txt', 'w') as f:
    with redirect_stdout(f):
        help(pow)
```

To send the output of *help()* to *sys.stderr*:

```
with redirect_stdout(sys.stderr):
    help(pow)
```

Note that the global side effect on *sys.stdout* means that this context manager is not suitable for use in library code and most threaded applications. It also has no effect on the output of subprocesses. However, it is still a useful approach for many utility scripts.

This context manager is *reentrant*.

New in version 3.4.

contextlib.redirect_stderr(*new_target*)

Similar to *redirect_stdout()* but redirecting *sys.stderr* to another file or file-like object.

This context manager is *reentrant*.

New in version 3.5.

class contextlib.ContextDecorator

A base class that enables a context manager to also be used as a decorator.

Context managers inheriting from `ContextDecorator` have to implement `__enter__` and `__exit__` as normal. `__exit__` retains its optional exception handling even when used as a decorator.

`ContextDecorator` is used by *contextmanager()*, so you get this functionality automatically.

Example of `ContextDecorator`:

```
from contextlib import ContextDecorator

class mycontext(ContextDecorator):
    def __enter__(self):
        print('Starting')
        return self

    def __exit__(self, *exc):
        print('Finishing')
        return False

>>> @mycontext()
... def function():
...     print('The bit in the middle')
...
>>> function()
Starting
The bit in the middle
Finishing

>>> with mycontext():
...     print('The bit in the middle')
...
Starting
The bit in the middle
Finishing
```

This change is just syntactic sugar for any construct of the following form:

```
def f():
    with cm():
        # Do stuff
```

`ContextDecorator` lets you instead write:

```
@cm()
def f():
    # Do stuff
```

It makes it clear that the `cm` applies to the whole function, rather than just a piece of it (and saving an indentation level is nice, too).

Existing context managers that already have a base class can be extended by using `ContextDecorator` as a mixin class:

```
from contextlib import ContextDecorator

class mycontext(ContextBaseClass, ContextDecorator):
    def __enter__(self):
        return self

    def __exit__(self, *exc):
        return False
```

Note: As the decorated function must be able to be called multiple times, the underlying context manager must support use in multiple `with` statements. If this is not the case, then the original

construct with the explicit `with` statement inside the function should be used.

New in version 3.2.

class contextlib.ExitStack

A context manager that is designed to make it easy to programmatically combine other context managers and cleanup functions, especially those that are optional or otherwise driven by input data.

For example, a set of files may easily be handled in a single with statement as follows:

```
with ExitStack() as stack:
    files = [stack.enter_context(open(fname)) for fname in filenames]
    # All opened files will automatically be closed at the end of
    # the with statement, even if attempts to open files later
    # in the list raise an exception
```

Each instance maintains a stack of registered callbacks that are called in reverse order when the instance is closed (either explicitly or implicitly at the end of a `with` statement). Note that callbacks are *not* invoked implicitly when the context stack instance is garbage collected.

This stack model is used so that context managers that acquire their resources in their `__init__` method (such as file objects) can be handled correctly.

Since registered callbacks are invoked in the reverse order of registration, this ends up behaving as if multiple nested `with` statements had been used with the registered set of callbacks. This even extends to exception handling - if an inner callback suppresses or replaces an exception, then outer callbacks will be passed arguments based on that updated state.

This is a relatively low level API that takes care of the details of correctly unwinding the stack of exit callbacks. It provides a suitable foundation for higher level context managers that manipulate the exit stack in application specific ways.

New in version 3.3.

enter_context(*cm*)

Enters a new context manager and adds its `__exit__()` method to the callback stack. The return value is the result of the context manager's own `__enter__()` method.

These context managers may suppress exceptions just as they normally would if used directly as part of a `with` statement.

push(*exit*)

Adds a context manager's `__exit__()` method to the callback stack.

As `__enter__` is *not* invoked, this method can be used to cover part of an `__enter__()` implementation with a context manager's own `__exit__()` method.

If passed an object that is not a context manager, this method assumes it is a callback with the same signature as a context manager's `__exit__()` method and adds it directly to the callback stack.

By returning true values, these callbacks can suppress exceptions the same way context manager `__exit__()` methods can.

The passed in object is returned from the function, allowing this method to be used as a function decorator.

callback(*callback*, **args*, ***kwds*)

Accepts an arbitrary callback function and arguments and adds it to the callback stack.

Unlike the other methods, callbacks added this way cannot suppress exceptions (as they are never passed the exception details).

The passed in callback is returned from the function, allowing this method to be used as a function decorator.

pop_all()
Transfers the callback stack to a fresh *ExitStack* instance and returns it. No callbacks are invoked by this operation - instead, they will now be invoked when the new stack is closed (either explicitly or implicitly at the end of a **with** statement).

For example, a group of files can be opened as an "all or nothing" operation as follows:

```
with ExitStack() as stack:
    files = [stack.enter_context(open(fname)) for fname in filenames]
    # Hold onto the close method, but don't call it yet.
    close_files = stack.pop_all().close
    # If opening any file fails, all previously opened files will be
    # closed automatically. If all files are opened successfully,
    # they will remain open even after the with statement ends.
    # close_files() can then be invoked explicitly to close them all.
```

close()
Immediately unwinds the callback stack, invoking callbacks in the reverse order of registration. For any context managers and exit callbacks registered, the arguments passed in will indicate that no exception occurred.

class contextlib.AsyncExitStack
An asynchronous context manager, similar to *ExitStack*, that supports combining both synchronous and asynchronous context managers, as well as having coroutines for cleanup logic.

The **close()** method is not implemented, *aclose()* must be used instead.

enter_async_context(*cm*)
Similar to **enter_context()** but expects an asynchronous context manager.

push_async_exit(*exit*)
Similar to **push()** but expects either an asynchronous context manager or a coroutine.

push_async_callback(*callback*, **args*, ***kwds*)
Similar to **callback()** but expects a coroutine.

aclose()
Similar to **close()** but properly handles awaitables.

Continuing the example for *asynccontextmanager()*:

```
async with AsyncExitStack() as stack:
    connections = [await stack.enter_async_context(get_connection())
        for i in range(5)]
    # All opened connections will automatically be released at the end of
    # the async with statement, even if attempts to open a connection
    # later in the list raise an exception.
```

New in version 3.7.

30.7.2 Examples and Recipes

This section describes some examples and recipes for making effective use of the tools provided by *contextlib*.

Supporting a variable number of context managers

The primary use case for *ExitStack* is the one given in the class documentation: supporting a variable number of context managers and other cleanup operations in a single `with` statement. The variability may come from the number of context managers needed being driven by user input (such as opening a user specified collection of files), or from some of the context managers being optional:

```
with ExitStack() as stack:
    for resource in resources:
        stack.enter_context(resource)
    if need_special_resource():
        special = acquire_special_resource()
        stack.callback(release_special_resource, special)
    # Perform operations that use the acquired resources
```

As shown, *ExitStack* also makes it quite easy to use `with` statements to manage arbitrary resources that don't natively support the context management protocol.

Catching exceptions from `__enter__` methods

It is occasionally desirable to catch exceptions from an `__enter__` method implementation, *without* inadvertently catching exceptions from the `with` statement body or the context manager's `__exit__` method. By using *ExitStack* the steps in the context management protocol can be separated slightly in order to allow this:

```
stack = ExitStack()
try:
    x = stack.enter_context(cm)
except Exception:
    # handle __enter__ exception
else:
    with stack:
        # Handle normal case
```

Actually needing to do this is likely to indicate that the underlying API should be providing a direct resource management interface for use with `try/except/finally` statements, but not all APIs are well designed in that regard. When a context manager is the only resource management API provided, then *ExitStack* can make it easier to handle various situations that can't be handled directly in a `with` statement.

Cleaning up in an `__enter__` implementation

As noted in the documentation of *ExitStack.push()*, this method can be useful in cleaning up an already allocated resource if later steps in the `__enter__()` implementation fail.

Here's an example of doing this for a context manager that accepts resource acquisition and release functions, along with an optional validation function, and maps them to the context management protocol:

```
from contextlib import contextmanager, AbstractContextManager, ExitStack

class ResourceManager(AbstractContextManager):

    def __init__(self, acquire_resource, release_resource, check_resource_ok=None):
        self.acquire_resource = acquire_resource
        self.release_resource = release_resource
        if check_resource_ok is None:
```

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```
            def check_resource_ok(resource):
                return True
        self.check_resource_ok = check_resource_ok

    @contextmanager
    def _cleanup_on_error(self):
        with ExitStack() as stack:
            stack.push(self)
            yield
            # The validation check passed and didn't raise an exception
            # Accordingly, we want to keep the resource, and pass it
            # back to our caller
            stack.pop_all()

    def __enter__(self):
        resource = self.acquire_resource()
        with self._cleanup_on_error():
            if not self.check_resource_ok(resource):
                msg = "Failed validation for {!r}"
                raise RuntimeError(msg.format(resource))
        return resource

    def __exit__(self, *exc_details):
        # We don't need to duplicate any of our resource release logic
        self.release_resource()
```

Replacing any use of `try-finally` and flag variables

A pattern you will sometimes see is a `try-finally` statement with a flag variable to indicate whether or not the body of the `finally` clause should be executed. In its simplest form (that can't already be handled just by using an `except` clause instead), it looks something like this:

```
cleanup_needed = True
try:
    result = perform_operation()
    if result:
        cleanup_needed = False
finally:
    if cleanup_needed:
        cleanup_resources()
```

As with any `try` statement based code, this can cause problems for development and review, because the setup code and the cleanup code can end up being separated by arbitrarily long sections of code.

ExitStack makes it possible to instead register a callback for execution at the end of a `with` statement, and then later decide to skip executing that callback:

```
from contextlib import ExitStack

with ExitStack() as stack:
    stack.callback(cleanup_resources)
    result = perform_operation()
    if result:
        stack.pop_all()
```

This allows the intended cleanup up behaviour to be made explicit up front, rather than requiring a separate flag variable.

If a particular application uses this pattern a lot, it can be simplified even further by means of a small helper class:

```
from contextlib import ExitStack

class Callback(ExitStack):
    def __init__(self, callback, *args, **kwds):
        super(Callback, self).__init__()
        self.callback(callback, *args, **kwds)

    def cancel(self):
        self.pop_all()

with Callback(cleanup_resources) as cb:
    result = perform_operation()
    if result:
        cb.cancel()
```

If the resource cleanup isn't already neatly bundled into a standalone function, then it is still possible to use the decorator form of *ExitStack.callback()* to declare the resource cleanup in advance:

```
from contextlib import ExitStack

with ExitStack() as stack:
    @stack.callback
    def cleanup_resources():
        ...
    result = perform_operation()
    if result:
        stack.pop_all()
```

Due to the way the decorator protocol works, a callback function declared this way cannot take any parameters. Instead, any resources to be released must be accessed as closure variables.

Using a context manager as a function decorator

ContextDecorator makes it possible to use a context manager in both an ordinary `with` statement and also as a function decorator.

For example, it is sometimes useful to wrap functions or groups of statements with a logger that can track the time of entry and time of exit. Rather than writing both a function decorator and a context manager for the task, inheriting from *ContextDecorator* provides both capabilities in a single definition:

```
from contextlib import ContextDecorator
import logging

logging.basicConfig(level=logging.INFO)

class track_entry_and_exit(ContextDecorator):
    def __init__(self, name):
        self.name = name

    def __enter__(self):
        logging.info('Entering: %s', self.name)
```

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```
    def __exit__(self, exc_type, exc, exc_tb):
        logging.info('Exiting: %s', self.name)
```

Instances of this class can be used as both a context manager:

```
with track_entry_and_exit('widget loader'):
    print('Some time consuming activity goes here')
    load_widget()
```

And also as a function decorator:

```
@track_entry_and_exit('widget loader')
def activity():
    print('Some time consuming activity goes here')
    load_widget()
```

Note that there is one additional limitation when using context managers as function decorators: there's no way to access the return value of `__enter__()`. If that value is needed, then it is still necessary to use an explicit `with` statement.

See also:

PEP 343 - The "with" statement The specification, background, and examples for the Python `with` statement.

30.7.3 Single use, reusable and reentrant context managers

Most context managers are written in a way that means they can only be used effectively in a `with` statement once. These single use context managers must be created afresh each time they're used - attempting to use them a second time will trigger an exception or otherwise not work correctly.

This common limitation means that it is generally advisable to create context managers directly in the header of the `with` statement where they are used (as shown in all of the usage examples above).

Files are an example of effectively single use context managers, since the first `with` statement will close the file, preventing any further IO operations using that file object.

Context managers created using *contextmanager()* are also single use context managers, and will complain about the underlying generator failing to yield if an attempt is made to use them a second time:

```
>>> from contextlib import contextmanager
>>> @contextmanager
... def singleuse():
...     print("Before")
...     yield
...     print("After")
...
>>> cm = singleuse()
>>> with cm:
...     pass
...
Before
After
>>> with cm:
...     pass
...
```

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```
Traceback (most recent call last):
    ...
RuntimeError: generator didn't yield
```

Reentrant context managers

More sophisticated context managers may be "reentrant". These context managers can not only be used in multiple `with` statements, but may also be used *inside* a `with` statement that is already using the same context manager.

threading.RLock is an example of a reentrant context manager, as are *suppress()* and *redirect_stdout()*. Here's a very simple example of reentrant use:

```
>>> from contextlib import redirect_stdout
>>> from io import StringIO
>>> stream = StringIO()
>>> write_to_stream = redirect_stdout(stream)
>>> with write_to_stream:
...     print("This is written to the stream rather than stdout")
...     with write_to_stream:
...         print("This is also written to the stream")
...
>>> print("This is written directly to stdout")
This is written directly to stdout
>>> print(stream.getvalue())
This is written to the stream rather than stdout
This is also written to the stream
```

Real world examples of reentrancy are more likely to involve multiple functions calling each other and hence be far more complicated than this example.

Note also that being reentrant is *not* the same thing as being thread safe. *redirect_stdout()*, for example, is definitely not thread safe, as it makes a global modification to the system state by binding *sys.stdout* to a different stream.

Reusable context managers

Distinct from both single use and reentrant context managers are "reusable" context managers (or, to be completely explicit, "reusable, but not reentrant" context managers, since reentrant context managers are also reusable). These context managers support being used multiple times, but will fail (or otherwise not work correctly) if the specific context manager instance has already been used in a containing with statement.

threading.Lock is an example of a reusable, but not reentrant, context manager (for a reentrant lock, it is necessary to use *threading.RLock* instead).

Another example of a reusable, but not reentrant, context manager is *ExitStack*, as it invokes *all* currently registered callbacks when leaving any with statement, regardless of where those callbacks were added:

```
>>> from contextlib import ExitStack
>>> stack = ExitStack()
>>> with stack:
...     stack.callback(print, "Callback: from first context")
...     print("Leaving first context")
...
Leaving first context
```

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```
Callback: from first context
>>> with stack:
...     stack.callback(print, "Callback: from second context")
...     print("Leaving second context")
...
Leaving second context
Callback: from second context
>>> with stack:
...     stack.callback(print, "Callback: from outer context")
...     with stack:
...         stack.callback(print, "Callback: from inner context")
...         print("Leaving inner context")
...     print("Leaving outer context")
...
Leaving inner context
Callback: from inner context
Callback: from outer context
Leaving outer context
```

As the output from the example shows, reusing a single stack object across multiple with statements works correctly, but attempting to nest them will cause the stack to be cleared at the end of the innermost with statement, which is unlikely to be desirable behaviour.

Using separate *ExitStack* instances instead of reusing a single instance avoids that problem:

```
>>> from contextlib import ExitStack
>>> with ExitStack() as outer_stack:
...     outer_stack.callback(print, "Callback: from outer context")
...     with ExitStack() as inner_stack:
...         inner_stack.callback(print, "Callback: from inner context")
...         print("Leaving inner context")
...     print("Leaving outer context")
...
Leaving inner context
Callback: from inner context
Leaving outer context
Callback: from outer context
```

30.8 abc — Abstract Base Classes

Source code: Lib/abc.py

This module provides the infrastructure for defining *abstract base classes* (ABCs) in Python, as outlined in **PEP 3119**; see the PEP for why this was added to Python. (See also **PEP 3141** and the *numbers* module regarding a type hierarchy for numbers based on ABCs.)

The *collections* module has some concrete classes that derive from ABCs; these can, of course, be further derived. In addition the *collections.abc* submodule has some ABCs that can be used to test whether a class or instance provides a particular interface, for example, is it hashable or a mapping.

This module provides the metaclass *ABCMeta* for defining ABCs and a helper class *ABC* to alternatively define ABCs through inheritance:

class abc.ABC

A helper class that has *ABCMeta* as its metaclass. With this class, an abstract base class can be created by simply deriving from *ABC* avoiding sometimes confusing metaclass usage, for example:

```
from abc import ABC

class MyABC(ABC):
    pass
```

Note that the type of *ABC* is still *ABCMeta*, therefore inheriting from *ABC* requires the usual precautions regarding metaclass usage, as multiple inheritance may lead to metaclass conflicts. One may also define an abstract base class by passing the metaclass keyword and using *ABCMeta* directly, for example:

```
from abc import ABCMeta

class MyABC(metaclass=ABCMeta):
    pass
```

New in version 3.4.

class abc.ABCMeta

Metaclass for defining Abstract Base Classes (ABCs).

Use this metaclass to create an ABC. An ABC can be subclassed directly, and then acts as a mix-in class. You can also register unrelated concrete classes (even built-in classes) and unrelated ABCs as "virtual subclasses" – these and their descendants will be considered subclasses of the registering ABC by the built-in *issubclass()* function, but the registering ABC won't show up in their MRO (Method Resolution Order) nor will method implementations defined by the registering ABC be callable (not even via *super()*).[1]

Classes created with a metaclass of *ABCMeta* have the following method:

register(*subclass*)

Register *subclass* as a "virtual subclass" of this ABC. For example:

```
from abc import ABC

class MyABC(ABC):
    pass

MyABC.register(tuple)

assert issubclass(tuple, MyABC)
assert isinstance((), MyABC)
```

Changed in version 3.3: Returns the registered subclass, to allow usage as a class decorator.

Changed in version 3.4: To detect calls to *register()*, you can use the *get_cache_token()* function.

You can also override this method in an abstract base class:

__subclasshook__(*subclass*)

(Must be defined as a class method.)

Check whether *subclass* is considered a subclass of this ABC. This means that you can customize the behavior of `issubclass` further without the need to call *register()* on every class you want to consider a subclass of the ABC. (This class method is called from the `__subclasscheck__()` method of the ABC.)

[1] C++ programmers should note that Python's virtual base class concept is not the same as C++'s.

This method should return `True`, `False` or `NotImplemented`. If it returns `True`, the *subclass* is considered a subclass of this ABC. If it returns `False`, the *subclass* is not considered a subclass of this ABC, even if it would normally be one. If it returns `NotImplemented`, the subclass check is continued with the usual mechanism.

For a demonstration of these concepts, look at this example ABC definition:

```
class Foo:
    def __getitem__(self, index):
        ...
    def __len__(self):
        ...
    def get_iterator(self):
        return iter(self)

class MyIterable(ABC):

    @abstractmethod
    def __iter__(self):
        while False:
            yield None

    def get_iterator(self):
        return self.__iter__()

    @classmethod
    def __subclasshook__(cls, C):
        if cls is MyIterable:
            if any("__iter__" in B.__dict__ for B in C.__mro__):
                return True
        return NotImplemented

MyIterable.register(Foo)
```

The ABC `MyIterable` defines the standard iterable method, *__iter__()*, as an abstract method. The implementation given here can still be called from subclasses. The `get_iterator()` method is also part of the `MyIterable` abstract base class, but it does not have to be overridden in non-abstract derived classes.

The *__subclasshook__()* class method defined here says that any class that has an *__iter__()* method in its *__dict__* (or in that of one of its base classes, accessed via the *__mro__* list) is considered a `MyIterable` too.

Finally, the last line makes `Foo` a virtual subclass of `MyIterable`, even though it does not define an *__iter__()* method (it uses the old-style iterable protocol, defined in terms of `__len__()` and `__getitem__()`). Note that this will not make `get_iterator` available as a method of `Foo`, so it is provided separately.

The *abc* module also provides the following decorator:

@abc.abstractmethod

A decorator indicating abstract methods.

Using this decorator requires that the class's metaclass is *ABCMeta* or is derived from it. A class that has a metaclass derived from *ABCMeta* cannot be instantiated unless all of its abstract methods and properties are overridden. The abstract methods can be called using any of the normal 'super' call mechanisms. *abstractmethod()* may be used to declare abstract methods for properties and descriptors.

Dynamically adding abstract methods to a class, or attempting to modify the abstraction status of a

method or class once it is created, are not supported. The *abstractmethod()* only affects subclasses derived using regular inheritance; "virtual subclasses" registered with the ABC's `register()` method are not affected.

When *abstractmethod()* is applied in combination with other method descriptors, it should be applied as the innermost decorator, as shown in the following usage examples:

```
class C(ABC):
    @abstractmethod
    def my_abstract_method(self, ...):
        ...
    @classmethod
    @abstractmethod
    def my_abstract_classmethod(cls, ...):
        ...
    @staticmethod
    @abstractmethod
    def my_abstract_staticmethod(...):
        ...

    @property
    @abstractmethod
    def my_abstract_property(self):
        ...
    @my_abstract_property.setter
    @abstractmethod
    def my_abstract_property(self, val):
        ...

    @abstractmethod
    def _get_x(self):
        ...
    @abstractmethod
    def _set_x(self, val):
        ...
    x = property(_get_x, _set_x)
```

In order to correctly interoperate with the abstract base class machinery, the descriptor must identify itself as abstract using `__isabstractmethod__`. In general, this attribute should be `True` if any of the methods used to compose the descriptor are abstract. For example, Python's built-in property does the equivalent of:

```
class Descriptor:
    ...
    @property
    def __isabstractmethod__(self):
        return any(getattr(f, '__isabstractmethod__', False) for
                   f in (self._fget, self._fset, self._fdel))
```

Note: Unlike Java abstract methods, these abstract methods may have an implementation. This implementation can be called via the *super()* mechanism from the class that overrides it. This could be useful as an end-point for a super-call in a framework that uses cooperative multiple-inheritance.

The *abc* module also supports the following legacy decorators:

`@abc.abstractclassmethod`
New in version 3.2.

Deprecated since version 3.3: It is now possible to use *classmethod* with *abstractmethod()*, making this decorator redundant.

A subclass of the built-in *classmethod()*, indicating an abstract classmethod. Otherwise it is similar to *abstractmethod()*.

This special case is deprecated, as the *classmethod()* decorator is now correctly identified as abstract when applied to an abstract method:

```
class C(ABC):
    @classmethod
    @abstractmethod
    def my_abstract_classmethod(cls, ...):
        ...
```

@abc.abstractstaticmethod

New in version 3.2.

Deprecated since version 3.3: It is now possible to use *staticmethod* with *abstractmethod()*, making this decorator redundant.

A subclass of the built-in *staticmethod()*, indicating an abstract staticmethod. Otherwise it is similar to *abstractmethod()*.

This special case is deprecated, as the *staticmethod()* decorator is now correctly identified as abstract when applied to an abstract method:

```
class C(ABC):
    @staticmethod
    @abstractmethod
    def my_abstract_staticmethod(...):
        ...
```

@abc.abstractproperty

Deprecated since version 3.3: It is now possible to use *property*, `property.getter()`, `property.setter()` and `property.deleter()` with *abstractmethod()*, making this decorator redundant.

A subclass of the built-in *property()*, indicating an abstract property.

This special case is deprecated, as the *property()* decorator is now correctly identified as abstract when applied to an abstract method:

```
class C(ABC):
    @property
    @abstractmethod
    def my_abstract_property(self):
        ...
```

The above example defines a read-only property; you can also define a read-write abstract property by appropriately marking one or more of the underlying methods as abstract:

```
class C(ABC):
    @property
    def x(self):
        ...

    @x.setter
    @abstractmethod
    def x(self, val):
        ...
```

If only some components are abstract, only those components need to be updated to create a concrete property in a subclass:

```
class D(C):
    @C.x.setter
    def x(self, val):
        ...
```

The *abc* module also provides the following functions:

abc.**get_cache_token**()
Returns the current abstract base class cache token.

The token is an opaque object (that supports equality testing) identifying the current version of the abstract base class cache for virtual subclasses. The token changes with every call to *ABCMeta.register()* on any ABC.

New in version 3.4.

30.9 atexit — Exit handlers

The *atexit* module defines functions to register and unregister cleanup functions. Functions thus registered are automatically executed upon normal interpreter termination. *atexit* runs these functions in the *reverse* order in which they were registered; if you register A, B, and C, at interpreter termination time they will be run in the order C, B, A.

Note: The functions registered via this module are not called when the program is killed by a signal not handled by Python, when a Python fatal internal error is detected, or when *os._exit()* is called.

Changed in version 3.7: When used with C-API subinterpreters, registered functions are local to the interpreter they were registered in.

atexit.**register**(*func*, **args*, ***kwargs*)
Register *func* as a function to be executed at termination. Any optional arguments that are to be passed to *func* must be passed as arguments to *register()*. It is possible to register the same function and arguments more than once.

At normal program termination (for instance, if *sys.exit()* is called or the main module's execution completes), all functions registered are called in last in, first out order. The assumption is that lower level modules will normally be imported before higher level modules and thus must be cleaned up later.

If an exception is raised during execution of the exit handlers, a traceback is printed (unless *SystemExit* is raised) and the exception information is saved. After all exit handlers have had a chance to run the last exception to be raised is re-raised.

This function returns *func*, which makes it possible to use it as a decorator.

atexit.**unregister**(*func*)
Remove *func* from the list of functions to be run at interpreter shutdown. After calling *unregister()*, *func* is guaranteed not to be called when the interpreter shuts down, even if it was registered more than once. *unregister()* silently does nothing if *func* was not previously registered.

See also:

Module *readline* Useful example of *atexit* to read and write *readline* history files.

30.9.1 atexit Example

The following simple example demonstrates how a module can initialize a counter from a file when it is imported and save the counter's updated value automatically when the program terminates without relying on the application making an explicit call into this module at termination.

```
try:
    with open("counterfile") as infile:
        _count = int(infile.read())
except FileNotFoundError:
    _count = 0

def incrcounter(n):
    global _count
    _count = _count + n

def savecounter():
    with open("counterfile", "w") as outfile:
        outfile.write("%d" % _count)

import atexit
atexit.register(savecounter)
```

Positional and keyword arguments may also be passed to *register()* to be passed along to the registered function when it is called:

```
def goodbye(name, adjective):
    print('Goodbye, %s, it was %s to meet you.' % (name, adjective))

import atexit
atexit.register(goodbye, 'Donny', 'nice')

# or:
atexit.register(goodbye, adjective='nice', name='Donny')
```

Usage as a *decorator*:

```
import atexit

@atexit.register
def goodbye():
    print("You are now leaving the Python sector.")
```

This only works with functions that can be called without arguments.

30.10 traceback — Print or retrieve a stack traceback

Source code: Lib/traceback.py

This module provides a standard interface to extract, format and print stack traces of Python programs. It exactly mimics the behavior of the Python interpreter when it prints a stack trace. This is useful when you want to print stack traces under program control, such as in a "wrapper" around the interpreter.

The module uses traceback objects — this is the object type that is stored in the *sys.last_traceback* variable and returned as the third item from *sys.exc_info()*.

The module defines the following functions:

traceback.**print_tb**(*tb*, *limit=None*, *file=None*)
Print up to *limit* stack trace entries from traceback object *tb* (starting from the caller's frame) if *limit* is positive. Otherwise, print the last `abs(limit)` entries. If *limit* is omitted or `None`, all entries are printed. If *file* is omitted or `None`, the output goes to `sys.stderr`; otherwise it should be an open file or file-like object to receive the output.

Changed in version 3.5: Added negative *limit* support.

traceback.**print_exception**(*etype*, *value*, *tb*, *limit=None*, *file=None*, *chain=True*)
Print exception information and stack trace entries from traceback object *tb* to *file*. This differs from *print_tb()* in the following ways:

- if *tb* is not `None`, it prints a header `Traceback (most recent call last):`
- it prints the exception *etype* and *value* after the stack trace
- if *type(value)* is *SyntaxError* and *value* has the appropriate format, it prints the line where the syntax error occurred with a caret indicating the approximate position of the error.

The optional *limit* argument has the same meaning as for *print_tb()*. If *chain* is true (the default), then chained exceptions (the `__cause__` or `__context__` attributes of the exception) will be printed as well, like the interpreter itself does when printing an unhandled exception.

Changed in version 3.5: The *etype* argument is ignored and inferred from the type of *value*.

traceback.**print_exc**(*limit=None*, *file=None*, *chain=True*)
This is a shorthand for `print_exception(*sys.exc_info(), limit, file, chain)`.

traceback.**print_last**(*limit=None*, *file=None*, *chain=True*)
This is a shorthand for `print_exception(sys.last_type, sys.last_value, sys.last_traceback, limit, file, chain)`. In general it will work only after an exception has reached an interactive prompt (see *sys.last_type*).

traceback.**print_stack**(*f=None*, *limit=None*, *file=None*)
Print up to *limit* stack trace entries (starting from the invocation point) if *limit* is positive. Otherwise, print the last `abs(limit)` entries. If *limit* is omitted or `None`, all entries are printed. The optional *f* argument can be used to specify an alternate stack frame to start. The optional *file* argument has the same meaning as for *print_tb()*.

Changed in version 3.5: Added negative *limit* support.

traceback.**extract_tb**(*tb*, *limit=None*)
Return a list of "pre-processed" stack trace entries extracted from the traceback object *tb*. It is useful for alternate formatting of stack traces. The optional *limit* argument has the same meaning as for *print_tb()*. A "pre-processed" stack trace entry is a 4-tuple (*filename*, *line number*, *function name*, *text*) representing the information that is usually printed for a stack trace. The *text* is a string with leading and trailing whitespace stripped; if the source is not available it is `None`.

traceback.**extract_stack**(*f=None*, *limit=None*)
Extract the raw traceback from the current stack frame. The return value has the same format as for *extract_tb()*. The optional *f* and *limit* arguments have the same meaning as for *print_stack()*.

traceback.**format_list**(*extracted_list*)
Given a list of tuples as returned by *extract_tb()* or *extract_stack()*, return a list of strings ready for printing. Each string in the resulting list corresponds to the item with the same index in the argument list. Each string ends in a newline; the strings may contain internal newlines as well, for those items whose source text line is not `None`.

traceback.**format_exception_only**(*etype*, *value*)
Format the exception part of a traceback. The arguments are the exception type and value such as given by `sys.last_type` and `sys.last_value`. The return value is a list of strings, each ending in a

newline. Normally, the list contains a single string; however, for *SyntaxError* exceptions, it contains several lines that (when printed) display detailed information about where the syntax error occurred. The message indicating which exception occurred is the always last string in the list.

traceback.format_exception(*etype*, *value*, *tb*, *limit=None*, *chain=True*)
Format a stack trace and the exception information. The arguments have the same meaning as the corresponding arguments to *print_exception()*. The return value is a list of strings, each ending in a newline and some containing internal newlines. When these lines are concatenated and printed, exactly the same text is printed as does *print_exception()*.

Changed in version 3.5: The *etype* argument is ignored and inferred from the type of *value*.

traceback.format_exc(*limit=None*, *chain=True*)
This is like `print_exc(limit)` but returns a string instead of printing to a file.

traceback.format_tb(*tb*, *limit=None*)
A shorthand for `format_list(extract_tb(tb, limit))`.

traceback.format_stack(*f=None*, *limit=None*)
A shorthand for `format_list(extract_stack(f, limit))`.

traceback.clear_frames(*tb*)
Clears the local variables of all the stack frames in a traceback *tb* by calling the `clear()` method of each frame object.

New in version 3.4.

traceback.walk_stack(*f*)
Walk a stack following `f.f_back` from the given frame, yielding the frame and line number for each frame. If *f* is `None`, the current stack is used. This helper is used with *StackSummary.extract()*.

New in version 3.5.

traceback.walk_tb(*tb*)
Walk a traceback following `tb_next` yielding the frame and line number for each frame. This helper is used with *StackSummary.extract()*.

New in version 3.5.

The module also defines the following classes:

30.10.1 `TracebackException` Objects

New in version 3.5.

TracebackException objects are created from actual exceptions to capture data for later printing in a lightweight fashion.

class traceback.TracebackException(*exc_type*, *exc_value*, *exc_traceback*, ***, *limit=None*, *lookup_lines=True*, *capture_locals=False*)
Capture an exception for later rendering. *limit*, *lookup_lines* and *capture_locals* are as for the *StackSummary* class.

Note that when locals are captured, they are also shown in the traceback.

__cause__
A *TracebackException* of the original `__cause__`.

__context__
A *TracebackException* of the original `__context__`.

__suppress_context__
The `__suppress_context__` value from the original exception.

stack
A *StackSummary* representing the traceback.

exc_type
The class of the original traceback.

filename
For syntax errors - the file name where the error occurred.

lineno
For syntax errors - the line number where the error occurred.

text
For syntax errors - the text where the error occurred.

offset
For syntax errors - the offset into the text where the error occurred.

msg
For syntax errors - the compiler error message.

classmethod from_exception(*exc*, ***, *limit=None*, *lookup_lines=True*, *capture_locals=False*)
Capture an exception for later rendering. *limit*, *lookup_lines* and *capture_locals* are as for the *StackSummary* class.

Note that when locals are captured, they are also shown in the traceback.

format(***, *chain=True*)
Format the exception.

If *chain* is not `True`, `__cause__` and `__context__` will not be formatted.

The return value is a generator of strings, each ending in a newline and some containing internal newlines. *print_exception()* is a wrapper around this method which just prints the lines to a file.

The message indicating which exception occurred is always the last string in the output.

format_exception_only()
Format the exception part of the traceback.

The return value is a generator of strings, each ending in a newline.

Normally, the generator emits a single string; however, for *SyntaxError* exceptions, it emits several lines that (when printed) display detailed information about where the syntax error occurred.

The message indicating which exception occurred is always the last string in the output.

30.10.2 StackSummary Objects

New in version 3.5.

StackSummary objects represent a call stack ready for formatting.

class traceback.**StackSummary**

classmethod extract(*frame_gen*, ***, *limit=None*, *lookup_lines=True*, *capture_locals=False*)
Construct a *StackSummary* object from a frame generator (such as is returned by *walk_stack()* or *walk_tb()*).

If *limit* is supplied, only this many frames are taken from *frame_gen*. If *lookup_lines* is `False`, the returned *FrameSummary* objects will not have read their lines in yet, making the cost of creating the *StackSummary* cheaper (which may be valuable if it may not actually get formatted). If

capture_locals is `True` the local variables in each *FrameSummary* are captured as object representations.

classmethod from_list(*a_list*)
Construct a *StackSummary* object from a supplied old-style list of tuples. Each tuple should be a 4-tuple with filename, lineno, name, line as the elements.

format()
Returns a list of strings ready for printing. Each string in the resulting list corresponds to a single frame from the stack. Each string ends in a newline; the strings may contain internal newlines as well, for those items with source text lines.

For long sequences of the same frame and line, the first few repetitions are shown, followed by a summary line stating the exact number of further repetitions.

Changed in version 3.6: Long sequences of repeated frames are now abbreviated.

30.10.3 `FrameSummary` Objects

New in version 3.5.

FrameSummary objects represent a single frame in a traceback.

class traceback.FrameSummary(*filename*, *lineno*, *name*, *lookup_line=True*, *locals=None*, *line=None*)
Represent a single frame in the traceback or stack that is being formatted or printed. It may optionally have a stringified version of the frames locals included in it. If *lookup_line* is `False`, the source code is not looked up until the *FrameSummary* has the `line` attribute accessed (which also happens when casting it to a tuple). `line` may be directly provided, and will prevent line lookups happening at all. *locals* is an optional local variable dictionary, and if supplied the variable representations are stored in the summary for later display.

30.10.4 Traceback Examples

This simple example implements a basic read-eval-print loop, similar to (but less useful than) the standard Python interactive interpreter loop. For a more complete implementation of the interpreter loop, refer to the *code* module.

```
import sys, traceback

def run_user_code(envdir):
    source = input(">>> ")
    try:
        exec(source, envdir)
    except Exception:
        print("Exception in user code:")
        print("-"*60)
        traceback.print_exc(file=sys.stdout)
        print("-"*60)

envdir = {}
while True:
    run_user_code(envdir)
```

The following example demonstrates the different ways to print and format the exception and traceback:

```
import sys, traceback

def lumberjack():
    bright_side_of_death()

def bright_side_of_death():
    return tuple()[0]

try:
    lumberjack()
except IndexError:
    exc_type, exc_value, exc_traceback = sys.exc_info()
    print("*** print_tb:")
    traceback.print_tb(exc_traceback, limit=1, file=sys.stdout)
    print("*** print_exception:")
    # exc_type below is ignored on 3.5 and later
    traceback.print_exception(exc_type, exc_value, exc_traceback,
                              limit=2, file=sys.stdout)
    print("*** print_exc:")
    traceback.print_exc(limit=2, file=sys.stdout)
    print("*** format_exc, first and last line:")
    formatted_lines = traceback.format_exc().splitlines()
    print(formatted_lines[0])
    print(formatted_lines[-1])
    print("*** format_exception:")
    # exc_type below is ignored on 3.5 and later
    print(repr(traceback.format_exception(exc_type, exc_value,
                                          exc_traceback)))
    print("*** extract_tb:")
    print(repr(traceback.extract_tb(exc_traceback)))
    print("*** format_tb:")
    print(repr(traceback.format_tb(exc_traceback)))
    print("*** tb_lineno:", exc_traceback.tb_lineno)
```

The output for the example would look similar to this:

```
*** print_tb:
  File "<doctest...>", line 10, in <module>
    lumberjack()
*** print_exception:
Traceback (most recent call last):
  File "<doctest...>", line 10, in <module>
    lumberjack()
  File "<doctest...>", line 4, in lumberjack
    bright_side_of_death()
IndexError: tuple index out of range
*** print_exc:
Traceback (most recent call last):
  File "<doctest...>", line 10, in <module>
    lumberjack()
  File "<doctest...>", line 4, in lumberjack
    bright_side_of_death()
IndexError: tuple index out of range
*** format_exc, first and last line:
Traceback (most recent call last):
IndexError: tuple index out of range
*** format_exception:
```

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```
['Traceback (most recent call last):\n',
 '  File "<doctest...>", line 10, in <module>\n    lumberjack()\n',
 '  File "<doctest...>", line 4, in lumberjack\n    bright_side_of_death()\n',
 '  File "<doctest...>", line 7, in bright_side_of_death\n    return tuple()[0]\n',
 'IndexError: tuple index out of range\n']
*** extract_tb:
[<FrameSummary file <doctest...>, line 10 in <module>>,
 <FrameSummary file <doctest...>, line 4 in lumberjack>,
 <FrameSummary file <doctest...>, line 7 in bright_side_of_death>]
*** format_tb:
['  File "<doctest...>", line 10, in <module>\n    lumberjack()\n',
 '  File "<doctest...>", line 4, in lumberjack\n    bright_side_of_death()\n',
 '  File "<doctest...>", line 7, in bright_side_of_death\n    return tuple()[0]\n']
*** tb_lineno: 10
```

The following example shows the different ways to print and format the stack:

```
>>> import traceback
>>> def another_function():
...     lumberstack()
...
>>> def lumberstack():
...     traceback.print_stack()
...     print(repr(traceback.extract_stack()))
...     print(repr(traceback.format_stack()))
...
>>> another_function()
  File "<doctest>", line 10, in <module>
    another_function()
  File "<doctest>", line 3, in another_function
    lumberstack()
  File "<doctest>", line 6, in lumberstack
    traceback.print_stack()
[('<doctest>', 10, '<module>', 'another_function()'),
 ('<doctest>', 3, 'another_function', 'lumberstack()'),
 ('<doctest>', 7, 'lumberstack', 'print(repr(traceback.extract_stack()))')]
['  File "<doctest>", line 10, in <module>\n    another_function()\n',
 '  File "<doctest>", line 3, in another_function\n    lumberstack()\n',
 '  File "<doctest>", line 8, in lumberstack\n    print(repr(traceback.format_stack()))\n']
```

This last example demonstrates the final few formatting functions:

```
>>> import traceback
>>> traceback.format_list([('spam.py', 3, '<module>', 'spam.eggs()'),
...                        ('eggs.py', 42, 'eggs', 'return "bacon"')])
['  File "spam.py", line 3, in <module>\n    spam.eggs()\n',
 '  File "eggs.py", line 42, in eggs\n    return "bacon"\n']
>>> an_error = IndexError('tuple index out of range')
>>> traceback.format_exception_only(type(an_error), an_error)
['IndexError: tuple index out of range\n']
```

30.11 __future__ — Future statement definitions

Source code: Lib/__future__.py

__future__ is a real module, and serves three purposes:

- To avoid confusing existing tools that analyze import statements and expect to find the modules they're importing.
- To ensure that future statements run under releases prior to 2.1 at least yield runtime exceptions (the import of *__future__* will fail, because there was no module of that name prior to 2.1).
- To document when incompatible changes were introduced, and when they will be — or were — made mandatory. This is a form of executable documentation, and can be inspected programmatically via importing *__future__* and examining its contents.

Each statement in `__future__.py` is of the form:

```
FeatureName = _Feature(OptionalRelease, MandatoryRelease,
                       CompilerFlag)
```

where, normally, *OptionalRelease* is less than *MandatoryRelease*, and both are 5-tuples of the same form as *sys.version_info*:

```
(PY_MAJOR_VERSION, # the 2 in 2.1.0a3; an int
 PY_MINOR_VERSION, # the 1; an int
 PY_MICRO_VERSION, # the 0; an int
 PY_RELEASE_LEVEL, # "alpha", "beta", "candidate" or "final"; string
 PY_RELEASE_SERIAL # the 3; an int
)
```

OptionalRelease records the first release in which the feature was accepted.

In the case of a *MandatoryRelease* that has not yet occurred, *MandatoryRelease* predicts the release in which the feature will become part of the language.

Else *MandatoryRelease* records when the feature became part of the language; in releases at or after that, modules no longer need a future statement to use the feature in question, but may continue to use such imports.

MandatoryRelease may also be `None`, meaning that a planned feature got dropped.

Instances of class `_Feature` have two corresponding methods, `getOptionalRelease()` and `getMandatoryRelease()`.

CompilerFlag is the (bitfield) flag that should be passed in the fourth argument to the built-in function *compile()* to enable the feature in dynamically compiled code. This flag is stored in the `compiler_flag` attribute on `_Feature` instances.

No feature description will ever be deleted from *__future__*. Since its introduction in Python 2.1 the following features have found their way into the language using this mechanism:

feature	optional in	mandatory in	effect
nested_scopes	2.1.0b1	2.2	**PEP 227**: *Statically Nested Scopes*
generators	2.2.0a1	2.3	**PEP 255**: *Simple Generators*
division	2.2.0a2	3.0	**PEP 238**: *Changing the Division Operator*
absolute_import	2.5.0a1	3.0	**PEP 328**: *Imports: Multi-Line and Absolute/Relative*
with_statement	2.5.0a1	2.6	**PEP 343**: *The "with" Statement*
print_function	2.6.0a2	3.0	**PEP 3105**: *Make print a function*
unicode_literals	2.6.0a2	3.0	**PEP 3112**: *Bytes literals in Python 3000*
generator_stop	3.5.0b1	3.7	**PEP 479**: *StopIteration handling inside generators*
annotations	3.7.0b1	4.0	**PEP 563**: *Postponed evaluation of annotations*

See also:

future How the compiler treats future imports.

30.12 gc — Garbage Collector interface

This module provides an interface to the optional garbage collector. It provides the ability to disable the collector, tune the collection frequency, and set debugging options. It also provides access to unreachable objects that the collector found but cannot free. Since the collector supplements the reference counting already used in Python, you can disable the collector if you are sure your program does not create reference cycles. Automatic collection can be disabled by calling `gc.disable()`. To debug a leaking program call `gc.set_debug(gc.DEBUG_LEAK)`. Notice that this includes `gc.DEBUG_SAVEALL`, causing garbage-collected objects to be saved in gc.garbage for inspection.

The *gc* module provides the following functions:

`gc.enable()`
Enable automatic garbage collection.

`gc.disable()`
Disable automatic garbage collection.

`gc.isenabled()`
Returns true if automatic collection is enabled.

`gc.collect(`*generation=2*`)`
With no arguments, run a full collection. The optional argument *generation* may be an integer specifying which generation to collect (from 0 to 2). A *ValueError* is raised if the generation number is invalid. The number of unreachable objects found is returned.

The free lists maintained for a number of built-in types are cleared whenever a full collection or collection of the highest generation (2) is run. Not all items in some free lists may be freed due to the particular implementation, in particular *float*.

`gc.set_debug(`*flags*`)`
Set the garbage collection debugging flags. Debugging information will be written to `sys.stderr`. See below for a list of debugging flags which can be combined using bit operations to control debugging.

gc.**get_debug**()
Return the debugging flags currently set.

gc.**get_objects**()
Returns a list of all objects tracked by the collector, excluding the list returned.

gc.**get_stats**()
Return a list of three per-generation dictionaries containing collection statistics since interpreter start. The number of keys may change in the future, but currently each dictionary will contain the following items:

- `collections` is the number of times this generation was collected;
- `collected` is the total number of objects collected inside this generation;
- `uncollectable` is the total number of objects which were found to be uncollectable (and were therefore moved to the *garbage* list) inside this generation.

New in version 3.4.

gc.**set_threshold**(*threshold0*[, *threshold1*[, *threshold2*]])
Set the garbage collection thresholds (the collection frequency). Setting *threshold0* to zero disables collection.

The GC classifies objects into three generations depending on how many collection sweeps they have survived. New objects are placed in the youngest generation (generation `0`). If an object survives a collection it is moved into the next older generation. Since generation `2` is the oldest generation, objects in that generation remain there after a collection. In order to decide when to run, the collector keeps track of the number object allocations and deallocations since the last collection. When the number of allocations minus the number of deallocations exceeds *threshold0*, collection starts. Initially only generation `0` is examined. If generation `0` has been examined more than *threshold1* times since generation `1` has been examined, then generation `1` is examined as well. Similarly, *threshold2* controls the number of collections of generation `1` before collecting generation `2`.

gc.**get_count**()
Return the current collection counts as a tuple of `(count0, count1, count2)`.

gc.**get_threshold**()
Return the current collection thresholds as a tuple of `(threshold0, threshold1, threshold2)`.

gc.**get_referrers**(**objs*)
Return the list of objects that directly refer to any of objs. This function will only locate those containers which support garbage collection; extension types which do refer to other objects but do not support garbage collection will not be found.

Note that objects which have already been dereferenced, but which live in cycles and have not yet been collected by the garbage collector can be listed among the resulting referrers. To get only currently live objects, call *collect()* before calling *get_referrers()*.

Care must be taken when using objects returned by *get_referrers()* because some of them could still be under construction and hence in a temporarily invalid state. Avoid using *get_referrers()* for any purpose other than debugging.

gc.**get_referents**(**objs*)
Return a list of objects directly referred to by any of the arguments. The referents returned are those objects visited by the arguments' C-level `tp_traverse` methods (if any), and may not be all objects actually directly reachable. `tp_traverse` methods are supported only by objects that support garbage collection, and are only required to visit objects that may be involved in a cycle. So, for example, if an integer is directly reachable from an argument, that integer object may or may not appear in the result list.

gc.**is_tracked**(*obj*)
Returns `True` if the object is currently tracked by the garbage collector, `False` otherwise. As a general

rule, instances of atomic types aren't tracked and instances of non-atomic types (containers, user-defined objects…) are. However, some type-specific optimizations can be present in order to suppress the garbage collector footprint of simple instances (e.g. dicts containing only atomic keys and values):

```
>>> gc.is_tracked(0)
False
>>> gc.is_tracked("a")
False
>>> gc.is_tracked([])
True
>>> gc.is_tracked({})
False
>>> gc.is_tracked({"a": 1})
False
>>> gc.is_tracked({"a": []})
True
```

New in version 3.1.

gc.freeze()

Freeze all the objects tracked by gc - move them to a permanent generation and ignore all the future collections. This can be used before a POSIX fork() call to make the gc copy-on-write friendly or to speed up collection. Also collection before a POSIX fork() call may free pages for future allocation which can cause copy-on-write too so it's advised to disable gc in master process and freeze before fork and enable gc in child process.

New in version 3.7.

gc.unfreeze()

Unfreeze the objects in the permanent generation, put them back into the oldest generation.

New in version 3.7.

gc.get_freeze_count()

Return the number of objects in the permanent generation.

New in version 3.7.

The following variables are provided for read-only access (you can mutate the values but should not rebind them):

gc.garbage

A list of objects which the collector found to be unreachable but could not be freed (uncollectable objects). Starting with Python 3.4, this list should be empty most of the time, except when using instances of C extension types with a non-NULL `tp_del` slot.

If *DEBUG_SAVEALL* is set, then all unreachable objects will be added to this list rather than freed.

Changed in version 3.2: If this list is non-empty at *interpreter shutdown*, a *ResourceWarning* is emitted, which is silent by default. If *DEBUG_UNCOLLECTABLE* is set, in addition all uncollectable objects are printed.

Changed in version 3.4: Following **PEP 442**, objects with a `__del__()` method don't end up in *gc.garbage* anymore.

gc.callbacks

A list of callbacks that will be invoked by the garbage collector before and after collection. The callbacks will be called with two arguments, *phase* and *info*.

phase can be one of two values:

"start": The garbage collection is about to start.

"stop": The garbage collection has finished.

info is a dict providing more information for the callback. The following keys are currently defined:

"generation": The oldest generation being collected.

"collected": When *phase* is "stop", the number of objects successfully collected.

"uncollectable": When *phase* is "stop", the number of objects that could not be collected and were put in *garbage*.

Applications can add their own callbacks to this list. The primary use cases are:

Gathering statistics about garbage collection, such as how often various generations are collected, and how long the collection takes.

Allowing applications to identify and clear their own uncollectable types when they appear in *garbage*.

New in version 3.3.

The following constants are provided for use with *set_debug()*:

gc.DEBUG_STATS
Print statistics during collection. This information can be useful when tuning the collection frequency.

gc.DEBUG_COLLECTABLE
Print information on collectable objects found.

gc.DEBUG_UNCOLLECTABLE
Print information of uncollectable objects found (objects which are not reachable but cannot be freed by the collector). These objects will be added to the garbage list.

Changed in version 3.2: Also print the contents of the *garbage* list at *interpreter shutdown*, if it isn't empty.

gc.DEBUG_SAVEALL
When set, all unreachable objects found will be appended to *garbage* rather than being freed. This can be useful for debugging a leaking program.

gc.DEBUG_LEAK
The debugging flags necessary for the collector to print information about a leaking program (equal to DEBUG_COLLECTABLE | DEBUG_UNCOLLECTABLE | DEBUG_SAVEALL).

30.13 inspect — Inspect live objects

Source code: Lib/inspect.py

The *inspect* module provides several useful functions to help get information about live objects such as modules, classes, methods, functions, tracebacks, frame objects, and code objects. For example, it can help you examine the contents of a class, retrieve the source code of a method, extract and format the argument list for a function, or get all the information you need to display a detailed traceback.

There are four main kinds of services provided by this module: type checking, getting source code, inspecting classes and functions, and examining the interpreter stack.

30.13.1 Types and members

The *getmembers()* function retrieves the members of an object such as a class or module. The functions whose names begin with "is" are mainly provided as convenient choices for the second argument to *getmembers()*. They also help you determine when you can expect to find the following special attributes:

Type	Attribute	Description
module	__doc__	documentation string
	__file__	filename (missing for built-in modules)
class	__doc__	documentation string
	__name__	name with which this class was defined
	__qualname__	qualified name
	__module__	name of module in which this class was defined
method	__doc__	documentation string
	__name__	name with which this method was defined
	__qualname__	qualified name
	__func__	function object containing implementation of method
	__self__	instance to which this method is bound, or `None`
function	__doc__	documentation string
	__name__	name with which this function was defined
	__qualname__	qualified name
	__code__	code object containing compiled function *bytecode*
	__defaults__	tuple of any default values for positional or keyword parameters
	__kwdefaults__	mapping of any default values for keyword-only parameters
	__globals__	global namespace in which this function was defined
	__annotations__	mapping of parameters names to annotations; `"return"` key is reserved for return anno
traceback	tb_frame	frame object at this level
	tb_lasti	index of last attempted instruction in bytecode
	tb_lineno	current line number in Python source code
	tb_next	next inner traceback object (called by this level)
frame	f_back	next outer frame object (this frame's caller)
	f_builtins	builtins namespace seen by this frame
	f_code	code object being executed in this frame
	f_globals	global namespace seen by this frame
	f_lasti	index of last attempted instruction in bytecode
	f_lineno	current line number in Python source code
	f_locals	local namespace seen by this frame
	f_restricted	0 or 1 if frame is in restricted execution mode
	f_trace	tracing function for this frame, or `None`
code	co_argcount	number of arguments (not including keyword only arguments, * or ** args)
	co_code	string of raw compiled bytecode
	co_cellvars	tuple of names of cell variables (referenced by containing scopes)
	co_consts	tuple of constants used in the bytecode
	co_filename	name of file in which this code object was created
	co_firstlineno	number of first line in Python source code
	co_flags	bitmap of `CO_*` flags, read more *here*
	co_lnotab	encoded mapping of line numbers to bytecode indices
	co_freevars	tuple of names of free variables (referenced via a function's closure)
	co_kwonlyargcount	number of keyword only arguments (not including ** arg)
	co_name	name with which this code object was defined
	co_names	tuple of names of local variables
	co_nlocals	number of local variables
	co_stacksize	virtual machine stack space required
	co_varnames	tuple of names of arguments and local variables
generator	__name__	name
	__qualname__	qualified name

Continued on ne

Table 1 – continued from previous page

Type	Attribute	Description
	gi_frame	frame
	gi_running	is the generator running?
	gi_code	code
	gi_yieldfrom	object being iterated by `yield from`, or `None`
coroutine	__name__	name
	__qualname__	qualified name
	cr_await	object being awaited on, or `None`
	cr_frame	frame
	cr_running	is the coroutine running?
	cr_code	code
	cr_origin	where coroutine was created, or `None`. See *sys.set_coroutine_origin_tracking_dep*
builtin	__doc__	documentation string
	__name__	original name of this function or method
	__qualname__	qualified name
	__self__	instance to which a method is bound, or `None`

Changed in version 3.5: Add `__qualname__` and `gi_yieldfrom` attributes to generators.

The `__name__` attribute of generators is now set from the function name, instead of the code name, and it can now be modified.

Changed in version 3.7: Add `cr_origin` attribute to coroutines.

`inspect.getmembers(`*object*[, *predicate*]`)`
Return all the members of an object in a list of (name, value) pairs sorted by name. If the optional *predicate* argument is supplied, only members for which the predicate returns a true value are included.

Note: *getmembers()* will only return class attributes defined in the metaclass when the argument is a class and those attributes have been listed in the metaclass' custom `__dir__()`.

`inspect.getmodulename(`*path*`)`
Return the name of the module named by the file *path*, without including the names of enclosing packages. The file extension is checked against all of the entries in *importlib.machinery.all_suffixes()*. If it matches, the final path component is returned with the extension removed. Otherwise, `None` is returned.

Note that this function *only* returns a meaningful name for actual Python modules - paths that potentially refer to Python packages will still return `None`.

Changed in version 3.3: The function is based directly on *importlib*.

`inspect.ismodule(`*object*`)`
Return true if the object is a module.

`inspect.isclass(`*object*`)`
Return true if the object is a class, whether built-in or created in Python code.

`inspect.ismethod(`*object*`)`
Return true if the object is a bound method written in Python.

`inspect.isfunction(`*object*`)`
Return true if the object is a Python function, which includes functions created by a *lambda* expression.

`inspect.isgeneratorfunction(`*object*`)`
Return true if the object is a Python generator function.

inspect.**isgenerator**(*object*)
Return true if the object is a generator.

inspect.**iscoroutinefunction**(*object*)
Return true if the object is a *coroutine function* (a function defined with an `async def` syntax).

New in version 3.5.

inspect.**iscoroutine**(*object*)
Return true if the object is a *coroutine* created by an `async def` function.

New in version 3.5.

inspect.**isawaitable**(*object*)
Return true if the object can be used in `await` expression.

Can also be used to distinguish generator-based coroutines from regular generators:

```
def gen():
    yield
@types.coroutine
def gen_coro():
    yield

assert not isawaitable(gen())
assert isawaitable(gen_coro())
```

New in version 3.5.

inspect.**isasyncgenfunction**(*object*)
Return true if the object is an *asynchronous generator* function, for example:

```
>>> async def agen():
...     yield 1
...
>>> inspect.isasyncgenfunction(agen)
True
```

New in version 3.6.

inspect.**isasyncgen**(*object*)
Return true if the object is an *asynchronous generator iterator* created by an *asynchronous generator* function.

New in version 3.6.

inspect.**istraceback**(*object*)
Return true if the object is a traceback.

inspect.**isframe**(*object*)
Return true if the object is a frame.

inspect.**iscode**(*object*)
Return true if the object is a code.

inspect.**isbuiltin**(*object*)
Return true if the object is a built-in function or a bound built-in method.

inspect.**isroutine**(*object*)
Return true if the object is a user-defined or built-in function or method.

inspect.**isabstract**(*object*)
Return true if the object is an abstract base class.

inspect.ismethoddescriptor(*object*)
Return true if the object is a method descriptor, but not if *ismethod()*, *isclass()*, *isfunction()* or *isbuiltin()* are true.

This, for example, is true of `int.__add__`. An object passing this test has a `__get__()` method but not a `__set__()` method, but beyond that the set of attributes varies. A *__name__* attribute is usually sensible, and `__doc__` often is.

Methods implemented via descriptors that also pass one of the other tests return false from the *ismethoddescriptor()* test, simply because the other tests promise more – you can, e.g., count on having the `__func__` attribute (etc) when an object passes *ismethod()*.

inspect.isdatadescriptor(*object*)
Return true if the object is a data descriptor.

Data descriptors have both a `__get__` and a `__set__` method. Examples are properties (defined in Python), getsets, and members. The latter two are defined in C and there are more specific tests available for those types, which is robust across Python implementations. Typically, data descriptors will also have *__name__* and `__doc__` attributes (properties, getsets, and members have both of these attributes), but this is not guaranteed.

inspect.isgetsetdescriptor(*object*)
Return true if the object is a getset descriptor.

CPython implementation detail: getsets are attributes defined in extension modules via `PyGetSetDef` structures. For Python implementations without such types, this method will always return `False`.

inspect.ismemberdescriptor(*object*)
Return true if the object is a member descriptor.

CPython implementation detail: Member descriptors are attributes defined in extension modules via `PyMemberDef` structures. For Python implementations without such types, this method will always return `False`.

30.13.2 Retrieving source code

inspect.getdoc(*object*)
Get the documentation string for an object, cleaned up with *cleandoc()*. If the documentation string for an object is not provided and the object is a class, a method, a property or a descriptor, retrieve the documentation string from the inheritance hierarchy.

Changed in version 3.5: Documentation strings are now inherited if not overridden.

inspect.getcomments(*object*)
Return in a single string any lines of comments immediately preceding the object's source code (for a class, function, or method), or at the top of the Python source file (if the object is a module). If the object's source code is unavailable, return `None`. This could happen if the object has been defined in C or the interactive shell.

inspect.getfile(*object*)
Return the name of the (text or binary) file in which an object was defined. This will fail with a *TypeError* if the object is a built-in module, class, or function.

inspect.getmodule(*object*)
Try to guess which module an object was defined in.

inspect.getsourcefile(*object*)
Return the name of the Python source file in which an object was defined. This will fail with a *TypeError* if the object is a built-in module, class, or function.

inspect.**getsourcelines**(*object*)
Return a list of source lines and starting line number for an object. The argument may be a module, class, method, function, traceback, frame, or code object. The source code is returned as a list of the lines corresponding to the object and the line number indicates where in the original source file the first line of code was found. An *OSError* is raised if the source code cannot be retrieved.

Changed in version 3.3: *OSError* is raised instead of *IOError*, now an alias of the former.

inspect.**getsource**(*object*)
Return the text of the source code for an object. The argument may be a module, class, method, function, traceback, frame, or code object. The source code is returned as a single string. An *OSError* is raised if the source code cannot be retrieved.

Changed in version 3.3: *OSError* is raised instead of *IOError*, now an alias of the former.

inspect.**cleandoc**(*doc*)
Clean up indentation from docstrings that are indented to line up with blocks of code.

All leading whitespace is removed from the first line. Any leading whitespace that can be uniformly removed from the second line onwards is removed. Empty lines at the beginning and end are subsequently removed. Also, all tabs are expanded to spaces.

30.13.3 Introspecting callables with the Signature object

New in version 3.3.

The Signature object represents the call signature of a callable object and its return annotation. To retrieve a Signature object, use the *signature()* function.

inspect.**signature**(*callable*, ***, *follow_wrapped=True*)
Return a *Signature* object for the given `callable`:

```
>>> from inspect import signature
>>> def foo(a, *, b:int, **kwargs):
...     pass

>>> sig = signature(foo)

>>> str(sig)
'(a, *, b:int, **kwargs)'

>>> str(sig.parameters['b'])
'b:int'

>>> sig.parameters['b'].annotation
<class 'int'>
```

Accepts a wide range of python callables, from plain functions and classes to *functools.partial()* objects.

Raises *ValueError* if no signature can be provided, and *TypeError* if that type of object is not supported.

New in version 3.5: `follow_wrapped` parameter. Pass `False` to get a signature of `callable` specifically (`callable.__wrapped__` will not be used to unwrap decorated callables.)

Note: Some callables may not be introspectable in certain implementations of Python. For example, in CPython, some built-in functions defined in C provide no metadata about their arguments.

---

class inspect.Signature(*parameters=None*, ***, *return_annotation=Signature.empty*)

A Signature object represents the call signature of a function and its return annotation. For each parameter accepted by the function it stores a *Parameter* object in its *parameters* collection.

The optional *parameters* argument is a sequence of *Parameter* objects, which is validated to check that there are no parameters with duplicate names, and that the parameters are in the right order, i.e. positional-only first, then positional-or-keyword, and that parameters with defaults follow parameters without defaults.

The optional *return_annotation* argument, can be an arbitrary Python object, is the "return" annotation of the callable.

Signature objects are *immutable*. Use *Signature.replace()* to make a modified copy.

Changed in version 3.5: Signature objects are picklable and hashable.

empty

A special class-level marker to specify absence of a return annotation.

parameters

An ordered mapping of parameters' names to the corresponding *Parameter* objects. Parameters appear in strict definition order, including keyword-only parameters.

Changed in version 3.7: Python only explicitly guaranteed that it preserved the declaration order of keyword-only parameters as of version 3.7, although in practice this order had always been preserved in Python 3.

return_annotation

The "return" annotation for the callable. If the callable has no "return" annotation, this attribute is set to *Signature.empty*.

bind(**args*, ***kwargs*)

Create a mapping from positional and keyword arguments to parameters. Returns *BoundArguments* if `*args` and `**kwargs` match the signature, or raises a *TypeError*.

bind_partial(**args*, ***kwargs*)

Works the same way as *Signature.bind()*, but allows the omission of some required arguments (mimics *functools.partial()* behavior.) Returns *BoundArguments*, or raises a *TypeError* if the passed arguments do not match the signature.

replace(**[, parameters][, return_annotation]*)

Create a new Signature instance based on the instance replace was invoked on. It is possible to pass different `parameters` and/or `return_annotation` to override the corresponding properties of the base signature. To remove return_annotation from the copied Signature, pass in *Signature.empty*.

```
>>> def test(a, b):
...     pass
>>> sig = signature(test)
>>> new_sig = sig.replace(return_annotation="new return anno")
>>> str(new_sig)
"(a, b) -> 'new return anno'"
```

classmethod from_callable(*obj*, ***, *follow_wrapped=True*)

Return a *Signature* (or its subclass) object for a given callable `obj`. Pass `follow_wrapped=False` to get a signature of `obj` without unwrapping its `__wrapped__` chain.

This method simplifies subclassing of *Signature*:

```
class MySignature(Signature):
    pass
```

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```
sig = MySignature.from_callable(min)
assert isinstance(sig, MySignature)
```

New in version 3.5.

class inspect.Parameter(*name*, *kind*, ***, *default=Parameter.empty*, *annotation=Parameter.empty*)

Parameter objects are *immutable*. Instead of modifying a Parameter object, you can use *Parameter.replace()* to create a modified copy.

Changed in version 3.5: Parameter objects are picklable and hashable.

empty

A special class-level marker to specify absence of default values and annotations.

name

The name of the parameter as a string. The name must be a valid Python identifier.

CPython implementation detail: CPython generates implicit parameter names of the form `.0` on the code objects used to implement comprehensions and generator expressions.

Changed in version 3.6: These parameter names are exposed by this module as names like `implicit0`.

default

The default value for the parameter. If the parameter has no default value, this attribute is set to *Parameter.empty*.

annotation

The annotation for the parameter. If the parameter has no annotation, this attribute is set to *Parameter.empty*.

kind

Describes how argument values are bound to the parameter. Possible values (accessible via *Parameter*, like `Parameter.KEYWORD_ONLY`):

Name	Meaning
POSITIONAL_ONLY	Value must be supplied as a positional argument. Python has no explicit syntax for defining positional-only parameters, but many built-in and extension module functions (especially those that accept only one or two parameters) accept them.
POSITIONAL_OR_KEYWORD	Value may be supplied as either a keyword or positional argument (this is the standard binding behaviour for functions implemented in Python.)
VAR_POSITIONAL	A tuple of positional arguments that aren't bound to any other parameter. This corresponds to a `*args` parameter in a Python function definition.
KEYWORD_ONLY	Value must be supplied as a keyword argument. Keyword only parameters are those which appear after a `*` or `*args` entry in a Python function definition.
VAR_KEYWORD	A dict of keyword arguments that aren't bound to any other parameter. This corresponds to a `**kwargs` parameter in a Python function definition.

Example: print all keyword-only arguments without default values:

```
>>> def foo(a, b, *, c, d=10):
...     pass

>>> sig = signature(foo)
>>> for param in sig.parameters.values():
...     if (param.kind == param.KEYWORD_ONLY and
...                       param.default is param.empty):
...         print('Parameter:', param)
Parameter: c
```

replace(**[, name][, kind][, default][, annotation]*)

Create a new Parameter instance based on the instance replaced was invoked on. To override a *Parameter* attribute, pass the corresponding argument. To remove a default value or/and an annotation from a Parameter, pass *Parameter.empty*.

```
>>> from inspect import Parameter
>>> param = Parameter('foo', Parameter.KEYWORD_ONLY, default=42)
>>> str(param)
'foo=42'

>>> str(param.replace()) # Will create a shallow copy of 'param'
'foo=42'

>>> str(param.replace(default=Parameter.empty, annotation='spam'))
"foo:'spam'"
```

Changed in version 3.4: In Python 3.3 Parameter objects were allowed to have `name` set to `None` if their `kind` was set to `POSITIONAL_ONLY`. This is no longer permitted.

class inspect.BoundArguments

Result of a *Signature.bind()* or *Signature.bind_partial()* call. Holds the mapping of arguments to the function's parameters.

arguments

An ordered, mutable mapping (*collections.OrderedDict*) of parameters' names to arguments' values. Contains only explicitly bound arguments. Changes in *arguments* will reflect in *args* and *kwargs*.

Should be used in conjunction with *Signature.parameters* for any argument processing purposes.

Note: Arguments for which *Signature.bind()* or *Signature.bind_partial()* relied on a default value are skipped. However, if needed, use *BoundArguments.apply_defaults()* to add them.

---

args

A tuple of positional arguments values. Dynamically computed from the *arguments* attribute.

kwargs

A dict of keyword arguments values. Dynamically computed from the *arguments* attribute.

signature

A reference to the parent *Signature* object.

apply_defaults()

Set default values for missing arguments.

For variable-positional arguments (`*args`) the default is an empty tuple.

For variable-keyword arguments (`**kwargs`) the default is an empty dict.

```
>>> def foo(a, b='ham', *args): pass
>>> ba = inspect.signature(foo).bind('spam')
>>> ba.apply_defaults()
>>> ba.arguments
OrderedDict([('a', 'spam'), ('b', 'ham'), ('args', ())])
```

New in version 3.5.

The *args* and *kwargs* properties can be used to invoke functions:

```
def test(a, *, b):
    ...

sig = signature(test)
ba = sig.bind(10, b=20)
test(*ba.args, **ba.kwargs)
```

See also:

PEP 362 - Function Signature Object. The detailed specification, implementation details and examples.

30.13.4 Classes and functions

`inspect.getclasstree`(*classes*, *unique=False*)

Arrange the given list of classes into a hierarchy of nested lists. Where a nested list appears, it contains classes derived from the class whose entry immediately precedes the list. Each entry is a 2-tuple containing a class and a tuple of its base classes. If the *unique* argument is true, exactly one entry appears in the returned structure for each class in the given list. Otherwise, classes using multiple inheritance and their descendants will appear multiple times.

`inspect.getargspec`(*func*)

Get the names and default values of a Python function's parameters. A *named tuple* `ArgSpec(args, varargs, keywords, defaults)` is returned. *args* is a list of the parameter names. *varargs* and *keywords* are the names of the `*` and `**` parameters or `None`. *defaults* is a tuple of default argument values or `None` if there are no default arguments; if this tuple has *n* elements, they correspond to the last *n* elements listed in *args*.

Deprecated since version 3.0: Use *getfullargspec()* for an updated API that is usually a drop-in replacement, but also correctly handles function annotations and keyword-only parameters.

Alternatively, use *signature()* and *Signature Object*, which provide a more structured introspection API for callables.

`inspect.getfullargspec`(*func*)

Get the names and default values of a Python function's parameters. A *named tuple* is returned:

`FullArgSpec(args, varargs, varkw, defaults, kwonlyargs, kwonlydefaults, annotations)`

args is a list of the positional parameter names. *varargs* is the name of the `*` parameter or `None` if arbitrary positional arguments are not accepted. *varkw* is the name of the `**` parameter or `None` if arbitrary keyword arguments are not accepted. *defaults* is an *n*-tuple of default argument values corresponding to the last *n* positional parameters, or `None` if there are no such defaults defined. *kwonlyargs* is a list of keyword-only parameter names in declaration order. *kwonlydefaults* is a dictionary mapping parameter names from *kwonlyargs* to the default values used if no argument is supplied. *annotations* is a dictionary mapping parameter names to annotations. The special key `"return"` is used to report the function return value annotation (if any).

Note that *signature()* and *Signature Object* provide the recommended API for callable introspection, and support additional behaviours (like positional-only arguments) that are sometimes encountered in extension module APIs. This function is retained primarily for use in code that needs to maintain compatibility with the Python 2 `inspect` module API.

Changed in version 3.4: This function is now based on *signature()*, but still ignores `__wrapped__` attributes and includes the already bound first parameter in the signature output for bound methods.

Changed in version 3.6: This method was previously documented as deprecated in favour of *signature()* in Python 3.5, but that decision has been reversed in order to restore a clearly supported standard interface for single-source Python 2/3 code migrating away from the legacy *getargspec()* API.

Changed in version 3.7: Python only explicitly guaranteed that it preserved the declaration order of keyword-only parameters as of version 3.7, although in practice this order had always been preserved in Python 3.

`inspect.getargvalues`(*frame*)

Get information about arguments passed into a particular frame. A *named tuple* `ArgInfo(args, varargs, keywords, locals)` is returned. *args* is a list of the argument names. *varargs* and *keywords* are the names of the `*` and `**` arguments or `None`. *locals* is the locals dictionary of the given frame.

Note: This function was inadvertently marked as deprecated in Python 3.5.

`inspect.formatargspec`(*args*[, *varargs*, *varkw*, *defaults*, *kwonlyargs*, *kwonlydefaults*, *annotations*[, *formatarg*, *formatvarargs*, *formatvarkw*, *formatvalue*, *formatreturns*, *formatannotations*]])

Format a pretty argument spec from the values returned by *getfullargspec()*.

The first seven arguments are (`args`, `varargs`, `varkw`, `defaults`, `kwonlyargs`, `kwonlydefaults`, `annotations`).

The other six arguments are functions that are called to turn argument names, `*` argument name, `**` argument name, default values, return annotation and individual annotations into strings, respectively.

For example:

```
>>> from inspect import formatargspec, getfullargspec
>>> def f(a: int, b: float):
...     pass
...
>>> formatargspec(*getfullargspec(f))
'(a: int, b: float)'
```

Deprecated since version 3.5: Use *signature()* and *Signature Object*, which provide a better introspecting API for callables.

`inspect.formatargvalues`(*args*[, *varargs*, *varkw*, *locals*, *formatarg*, *formatvarargs*, *formatvarkw*, *formatvalue*])

Format a pretty argument spec from the four values returned by *getargvalues()*. The format* arguments are the corresponding optional formatting functions that are called to turn names and values into strings.

Note: This function was inadvertently marked as deprecated in Python 3.5.

`inspect.getmro`(*cls*)

Return a tuple of class cls's base classes, including cls, in method resolution order. No class appears

more than once in this tuple. Note that the method resolution order depends on cls's type. Unless a very peculiar user-defined metatype is in use, cls will be the first element of the tuple.

`inspect.getcallargs`(*func*, **args*, ***kwds*)

Bind the *args* and *kwds* to the argument names of the Python function or method *func*, as if it was called with them. For bound methods, bind also the first argument (typically named `self`) to the associated instance. A dict is returned, mapping the argument names (including the names of the `*` and `**` arguments, if any) to their values from *args* and *kwds*. In case of invoking *func* incorrectly, i.e. whenever `func(*args, **kwds)` would raise an exception because of incompatible signature, an exception of the same type and the same or similar message is raised. For example:

```
>>> from inspect import getcallargs
>>> def f(a, b=1, *pos, **named):
...     pass
>>> getcallargs(f, 1, 2, 3) == {'a': 1, 'named': {}, 'b': 2, 'pos': (3,)}
True
>>> getcallargs(f, a=2, x=4) == {'a': 2, 'named': {'x': 4}, 'b': 1, 'pos': ()}
True
>>> getcallargs(f)
Traceback (most recent call last):
...
TypeError: f() missing 1 required positional argument: 'a'
```

New in version 3.2.

Deprecated since version 3.5: Use *Signature.bind()* and *Signature.bind_partial()* instead.

`inspect.getclosurevars`(*func*)

Get the mapping of external name references in a Python function or method *func* to their current values. A *named tuple* `ClosureVars(nonlocals, globals, builtins, unbound)` is returned. *nonlocals* maps referenced names to lexical closure variables, *globals* to the function's module globals and *builtins* to the builtins visible from the function body. *unbound* is the set of names referenced in the function that could not be resolved at all given the current module globals and builtins.

TypeError is raised if *func* is not a Python function or method.

New in version 3.3.

`inspect.unwrap`(*func*, ***, *stop=None*)

Get the object wrapped by *func*. It follows the chain of `__wrapped__` attributes returning the last object in the chain.

stop is an optional callback accepting an object in the wrapper chain as its sole argument that allows the unwrapping to be terminated early if the callback returns a true value. If the callback never returns a true value, the last object in the chain is returned as usual. For example, *signature()* uses this to stop unwrapping if any object in the chain has a `__signature__` attribute defined.

ValueError is raised if a cycle is encountered.

New in version 3.4.

30.13.5 The interpreter stack

When the following functions return "frame records," each record is a *named tuple* `FrameInfo(frame, filename, lineno, function, code_context, index)`. The tuple contains the frame object, the filename, the line number of the current line, the function name, a list of lines of context from the source code, and the index of the current line within that list.

Changed in version 3.5: Return a named tuple instead of a tuple.

Note: Keeping references to frame objects, as found in the first element of the frame records these functions return, can cause your program to create reference cycles. Once a reference cycle has been created, the lifespan of all objects which can be accessed from the objects which form the cycle can become much longer even if Python's optional cycle detector is enabled. If such cycles must be created, it is important to ensure they are explicitly broken to avoid the delayed destruction of objects and increased memory consumption which occurs.

Though the cycle detector will catch these, destruction of the frames (and local variables) can be made deterministic by removing the cycle in a `finally` clause. This is also important if the cycle detector was disabled when Python was compiled or using *gc.disable()*. For example:

```
def handle_stackframe_without_leak():
    frame = inspect.currentframe()
    try:
        # do something with the frame
    finally:
        del frame
```

If you want to keep the frame around (for example to print a traceback later), you can also break reference cycles by using the `frame.clear()` method.

The optional *context* argument supported by most of these functions specifies the number of lines of context to return, which are centered around the current line.

`inspect.getframeinfo`(*frame*, *context=1*)
: Get information about a frame or traceback object. A *named tuple* `Traceback(filename, lineno, function, code_context, index)` is returned.

`inspect.getouterframes`(*frame*, *context=1*)
: Get a list of frame records for a frame and all outer frames. These frames represent the calls that lead to the creation of *frame*. The first entry in the returned list represents *frame*; the last entry represents the outermost call on *frame*'s stack.

  Changed in version 3.5: A list of *named tuples* `FrameInfo(frame, filename, lineno, function, code_context, index)` is returned.

`inspect.getinnerframes`(*traceback*, *context=1*)
: Get a list of frame records for a traceback's frame and all inner frames. These frames represent calls made as a consequence of *frame*. The first entry in the list represents *traceback*; the last entry represents where the exception was raised.

  Changed in version 3.5: A list of *named tuples* `FrameInfo(frame, filename, lineno, function, code_context, index)` is returned.

`inspect.currentframe`()
: Return the frame object for the caller's stack frame.

  CPython implementation detail: This function relies on Python stack frame support in the interpreter, which isn't guaranteed to exist in all implementations of Python. If running in an implementation without Python stack frame support this function returns `None`.

`inspect.stack`(*context=1*)
: Return a list of frame records for the caller's stack. The first entry in the returned list represents the caller; the last entry represents the outermost call on the stack.

  Changed in version 3.5: A list of *named tuples* `FrameInfo(frame, filename, lineno, function, code_context, index)` is returned.

`inspect.trace`(*context=1*)
: Return a list of frame records for the stack between the current frame and the frame in which an

exception currently being handled was raised in. The first entry in the list represents the caller; the last entry represents where the exception was raised.

Changed in version 3.5: A list of *named tuples* `FrameInfo(frame, filename, lineno, function, code_context, index)` is returned.

30.13.6 Fetching attributes statically

Both *getattr()* and *hasattr()* can trigger code execution when fetching or checking for the existence of attributes. Descriptors, like properties, will be invoked and `__getattr__()` and `__getattribute__()` may be called.

For cases where you want passive introspection, like documentation tools, this can be inconvenient. *getattr_static()* has the same signature as *getattr()* but avoids executing code when it fetches attributes.

`inspect.getattr_static(`*obj*, *attr*, *default=None*`)`

Retrieve attributes without triggering dynamic lookup via the descriptor protocol, `__getattr__()` or `__getattribute__()`.

Note: this function may not be able to retrieve all attributes that getattr can fetch (like dynamically created attributes) and may find attributes that getattr can't (like descriptors that raise AttributeError). It can also return descriptors objects instead of instance members.

If the instance *__dict__* is shadowed by another member (for example a property) then this function will be unable to find instance members.

New in version 3.2.

getattr_static() does not resolve descriptors, for example slot descriptors or getset descriptors on objects implemented in C. The descriptor object is returned instead of the underlying attribute.

You can handle these with code like the following. Note that for arbitrary getset descriptors invoking these may trigger code execution:

```
# example code for resolving the builtin descriptor types
class _foo:
    __slots__ = ['foo']

slot_descriptor = type(_foo.foo)
getset_descriptor = type(type(open(__file__)).name)
wrapper_descriptor = type(str.__dict__['__add__'])
descriptor_types = (slot_descriptor, getset_descriptor, wrapper_descriptor)

result = getattr_static(some_object, 'foo')
if type(result) in descriptor_types:
    try:
        result = result.__get__()
    except AttributeError:
        # descriptors can raise AttributeError to
        # indicate there is no underlying value
        # in which case the descriptor itself will
        # have to do
        pass
```

30.13.7 Current State of Generators and Coroutines

When implementing coroutine schedulers and for other advanced uses of generators, it is useful to determine whether a generator is currently executing, is waiting to start or resume or execution, or has already

terminated. *getgeneratorstate()* allows the current state of a generator to be determined easily.

inspect.**getgeneratorstate**(*generator*)
Get current state of a generator-iterator.

Possible states are:

- GEN_CREATED: Waiting to start execution.
- GEN_RUNNING: Currently being executed by the interpreter.
- GEN_SUSPENDED: Currently suspended at a yield expression.
- GEN_CLOSED: Execution has completed.

New in version 3.2.

inspect.**getcoroutinestate**(*coroutine*)
Get current state of a coroutine object. The function is intended to be used with coroutine objects created by `async def` functions, but will accept any coroutine-like object that has `cr_running` and `cr_frame` attributes.

Possible states are:

- CORO_CREATED: Waiting to start execution.
- CORO_RUNNING: Currently being executed by the interpreter.
- CORO_SUSPENDED: Currently suspended at an await expression.
- CORO_CLOSED: Execution has completed.

New in version 3.5.

The current internal state of the generator can also be queried. This is mostly useful for testing purposes, to ensure that internal state is being updated as expected:

inspect.**getgeneratorlocals**(*generator*)
Get the mapping of live local variables in *generator* to their current values. A dictionary is returned that maps from variable names to values. This is the equivalent of calling *locals()* in the body of the generator, and all the same caveats apply.

If *generator* is a *generator* with no currently associated frame, then an empty dictionary is returned. *TypeError* is raised if *generator* is not a Python generator object.

CPython implementation detail: This function relies on the generator exposing a Python stack frame for introspection, which isn't guaranteed to be the case in all implementations of Python. In such cases, this function will always return an empty dictionary.

New in version 3.3.

inspect.**getcoroutinelocals**(*coroutine*)
This function is analogous to *getgeneratorlocals()*, but works for coroutine objects created by `async def` functions.

New in version 3.5.

30.13.8 Code Objects Bit Flags

Python code objects have a `co_flags` attribute, which is a bitmap of the following flags:

inspect.**CO_OPTIMIZED**
The code object is optimized, using fast locals.

inspect.**CO_NEWLOCALS**
If set, a new dict will be created for the frame's `f_locals` when the code object is executed.

`inspect.CO_VARARGS`
The code object has a variable positional parameter (`*args`-like).

`inspect.CO_VARKEYWORDS`
The code object has a variable keyword parameter (`**kwargs`-like).

`inspect.CO_NESTED`
The flag is set when the code object is a nested function.

`inspect.CO_GENERATOR`
The flag is set when the code object is a generator function, i.e. a generator object is returned when the code object is executed.

`inspect.CO_NOFREE`
The flag is set if there are no free or cell variables.

`inspect.CO_COROUTINE`
The flag is set when the code object is a coroutine function. When the code object is executed it returns a coroutine object. See **PEP 492** for more details.

New in version 3.5.

`inspect.CO_ITERABLE_COROUTINE`
The flag is used to transform generators into generator-based coroutines. Generator objects with this flag can be used in `await` expression, and can `yield from` coroutine objects. See **PEP 492** for more details.

New in version 3.5.

`inspect.CO_ASYNC_GENERATOR`
The flag is set when the code object is an asynchronous generator function. When the code object is executed it returns an asynchronous generator object. See **PEP 525** for more details.

New in version 3.6.

Note: The flags are specific to CPython, and may not be defined in other Python implementations. Furthermore, the flags are an implementation detail, and can be removed or deprecated in future Python releases. It's recommended to use public APIs from the *inspect* module for any introspection needs.

30.13.9 Command Line Interface

The *inspect* module also provides a basic introspection capability from the command line.

By default, accepts the name of a module and prints the source of that module. A class or function within the module can be printed instead by appended a colon and the qualified name of the target object.

`--details`
Print information about the specified object rather than the source code

30.14 `site` — Site-specific configuration hook

Source code: Lib/site.py

This module is automatically imported during initialization. The automatic import can be suppressed using the interpreter's `-S` option.

Importing this module will append site-specific paths to the module search path and add a few builtins, unless `-S` was used. In that case, this module can be safely imported with no automatic modifications to the module search path or additions to the builtins. To explicitly trigger the usual site-specific additions, call the *site.main()* function.

Changed in version 3.3: Importing the module used to trigger paths manipulation even when using `-S`.

It starts by constructing up to four directories from a head and a tail part. For the head part, it uses `sys.prefix` and `sys.exec_prefix`; empty heads are skipped. For the tail part, it uses the empty string and then `lib/site-packages` (on Windows) or `lib/pythonX.Y/site-packages` (on Unix and Macintosh). For each of the distinct head-tail combinations, it sees if it refers to an existing directory, and if so, adds it to `sys.path` and also inspects the newly added path for configuration files.

Changed in version 3.5: Support for the "site-python" directory has been removed.

If a file named "pyvenv.cfg" exists one directory above sys.executable, sys.prefix and sys.exec_prefix are set to that directory and it is also checked for site-packages (sys.base_prefix and sys.base_exec_prefix will always be the "real" prefixes of the Python installation). If "pyvenv.cfg" (a bootstrap configuration file) contains the key "include-system-site-packages" set to anything other than "false" (case-insensitive), the system-level prefixes will still also be searched for site-packages; otherwise they won't.

A path configuration file is a file whose name has the form *name*`.pth` and exists in one of the four directories mentioned above; its contents are additional items (one per line) to be added to `sys.path`. Non-existing items are never added to `sys.path`, and no check is made that the item refers to a directory rather than a file. No item is added to `sys.path` more than once. Blank lines and lines beginning with `#` are skipped. Lines starting with `import` (followed by space or tab) are executed.

For example, suppose `sys.prefix` and `sys.exec_prefix` are set to `/usr/local`. The Python X.Y library is then installed in `/usr/local/lib/pythonX.Y`. Suppose this has a subdirectory `/usr/local/lib/pythonX.Y/site-packages` with three subsubdirectories, `foo`, `bar` and `spam`, and two path configuration files, `foo.pth` and `bar.pth`. Assume `foo.pth` contains the following:

```
# foo package configuration

foo
bar
bletch
```

and `bar.pth` contains:

```
# bar package configuration

bar
```

Then the following version-specific directories are added to `sys.path`, in this order:

```
/usr/local/lib/pythonX.Y/site-packages/bar
/usr/local/lib/pythonX.Y/site-packages/foo
```

Note that `bletch` is omitted because it doesn't exist; the `bar` directory precedes the `foo` directory because `bar.pth` comes alphabetically before `foo.pth`; and `spam` is omitted because it is not mentioned in either path configuration file.

After these path manipulations, an attempt is made to import a module named `sitecustomize`, which can perform arbitrary site-specific customizations. It is typically created by a system administrator in the site-packages directory. If this import fails with an *ImportError* or its subclass exception, and the exception's `name` attribute equals to `'sitecustomize'`, it is silently ignored. If Python is started without output streams available, as with `pythonw.exe` on Windows (which is used by default to start IDLE), attempted output from `sitecustomize` is ignored. Any other exception causes a silent and perhaps mysterious failure of the process.

After this, an attempt is made to import a module named `usercustomize`, which can perform arbitrary user-specific customizations, if *ENABLE_USER_SITE* is true. This file is intended to be created in the user site-packages directory (see below), which is part of `sys.path` unless disabled by `-s`. If this import fails with an *ImportError* or its subclass exception, and the exception's `name` attribute equals to `'usercustomize'`, it is silently ignored.

Note that for some non-Unix systems, `sys.prefix` and `sys.exec_prefix` are empty, and the path manipulations are skipped; however the import of `sitecustomize` and `usercustomize` is still attempted.

30.14.1 Readline configuration

On systems that support *readline*, this module will also import and configure the *rlcompleter* module, if Python is started in interactive mode and without the `-S` option. The default behavior is enable tab-completion and to use `~/.python_history` as the history save file. To disable it, delete (or override) the *sys.__interactivehook__* attribute in your `sitecustomize` or `usercustomize` module or your `PYTHONSTARTUP` file.

Changed in version 3.4: Activation of rlcompleter and history was made automatic.

30.14.2 Module contents

`site.PREFIXES`
: A list of prefixes for site-packages directories.

`site.ENABLE_USER_SITE`
: Flag showing the status of the user site-packages directory. `True` means that it is enabled and was added to `sys.path`. `False` means that it was disabled by user request (with `-s` or `PYTHONNOUSERSITE`). `None` means it was disabled for security reasons (mismatch between user or group id and effective id) or by an administrator.

`site.USER_SITE`
: Path to the user site-packages for the running Python. Can be `None` if *getusersitepackages()* hasn't been called yet. Default value is `~/.local/lib/python`*X.Y*`/site-packages` for UNIX and non-framework Mac OS X builds, `~/Library/Python/`*X.Y*`/lib/python/site-packages` for Mac framework builds, and *%APPDATA%*`\Python\Python`*XY*`\site-packages` on Windows. This directory is a site directory, which means that `.pth` files in it will be processed.

`site.USER_BASE`
: Path to the base directory for the user site-packages. Can be `None` if *getuserbase()* hasn't been called yet. Default value is `~/.local` for UNIX and Mac OS X non-framework builds, `~/Library/Python/`*X.Y* for Mac framework builds, and *%APPDATA%*`\Python` for Windows. This value is used by Distutils to compute the installation directories for scripts, data files, Python modules, etc. for the user installation scheme. See also `PYTHONUSERBASE`.

`site.main()`
: Adds all the standard site-specific directories to the module search path. This function is called automatically when this module is imported, unless the Python interpreter was started with the `-S` flag.

  Changed in version 3.3: This function used to be called unconditionally.

`site.addsitedir(`*sitedir*, *known_paths=None*`)`
: Add a directory to sys.path and process its `.pth` files. Typically used in `sitecustomize` or `usercustomize` (see above).

`site.getsitepackages()`
: Return a list containing all global site-packages directories.

New in version 3.2.

site.getuserbase()
Return the path of the user base directory, *USER_BASE*. If it is not initialized yet, this function will also set it, respecting PYTHONUSERBASE.

New in version 3.2.

site.getusersitepackages()
Return the path of the user-specific site-packages directory, *USER_SITE*. If it is not initialized yet, this function will also set it, respecting PYTHONNOUSERSITE and *USER_BASE*.

New in version 3.2.

The *site* module also provides a way to get the user directories from the command line:

```
$ python3 -m site --user-site
/home/user/.local/lib/python3.3/site-packages
```

If it is called without arguments, it will print the contents of *sys.path* on the standard output, followed by the value of *USER_BASE* and whether the directory exists, then the same thing for *USER_SITE*, and finally the value of *ENABLE_USER_SITE*.

--user-base
Print the path to the user base directory.

--user-site
Print the path to the user site-packages directory.

If both options are given, user base and user site will be printed (always in this order), separated by *os.pathsep*.

If any option is given, the script will exit with one of these values: 0 if the user site-packages directory is enabled, 1 if it was disabled by the user, 2 if it is disabled for security reasons or by an administrator, and a value greater than 2 if there is an error.

See also:

PEP 370 – Per user site-packages directory

CHAPTER

THIRTYONE

CUSTOM PYTHON INTERPRETERS

The modules described in this chapter allow writing interfaces similar to Python's interactive interpreter. If you want a Python interpreter that supports some special feature in addition to the Python language, you should look at the *code* module. (The *codeop* module is lower-level, used to support compiling a possibly-incomplete chunk of Python code.)

The full list of modules described in this chapter is:

31.1 code — Interpreter base classes

Source code: Lib/code.py

The `code` module provides facilities to implement read-eval-print loops in Python. Two classes and convenience functions are included which can be used to build applications which provide an interactive interpreter prompt.

class `code.InteractiveInterpreter`(*locals=None*)
: This class deals with parsing and interpreter state (the user's namespace); it does not deal with input buffering or prompting or input file naming (the filename is always passed in explicitly). The optional *locals* argument specifies the dictionary in which code will be executed; it defaults to a newly created dictionary with key `'__name__'` set to `'__console__'` and key `'__doc__'` set to `None`.

class `code.InteractiveConsole`(*locals=None*, *filename="<console>"*)
: Closely emulate the behavior of the interactive Python interpreter. This class builds on *InteractiveInterpreter* and adds prompting using the familiar `sys.ps1` and `sys.ps2`, and input buffering.

`code.interact`(*banner=None*, *readfunc=None*, *local=None*, *exitmsg=None*)
: Convenience function to run a read-eval-print loop. This creates a new instance of *InteractiveConsole* and sets *readfunc* to be used as the *InteractiveConsole.raw_input()* method, if provided. If *local* is provided, it is passed to the *InteractiveConsole* constructor for use as the default namespace for the interpreter loop. The *interact()* method of the instance is then run with *banner* and *exitmsg* passed as the banner and exit message to use, if provided. The console object is discarded after use.

  Changed in version 3.6: Added *exitmsg* parameter.

`code.compile_command`(*source*, *filename="<input>"*, *symbol="single"*)
: This function is useful for programs that want to emulate Python's interpreter main loop (a.k.a. the read-eval-print loop). The tricky part is to determine when the user has entered an incomplete command that can be completed by entering more text (as opposed to a complete command or a syntax error). This function *almost* always makes the same decision as the real interpreter main loop.

source is the source string; *filename* is the optional filename from which source was read, defaulting to `'<input>'`; and *symbol* is the optional grammar start symbol, which should be either `'single'` (the default) or `'eval'`.

Returns a code object (the same as `compile(source, filename, symbol)`) if the command is complete and valid; `None` if the command is incomplete; raises *SyntaxError* if the command is complete and contains a syntax error, or raises *OverflowError* or *ValueError* if the command contains an invalid literal.

31.1.1 Interactive Interpreter Objects

`InteractiveInterpreter.runsource`(*source*, *filename="<input>"*, *symbol="single"*)

Compile and run some source in the interpreter. Arguments are the same as for *compile_command()*; the default for *filename* is `'<input>'`, and for *symbol* is `'single'`. One several things can happen:

- The input is incorrect; *compile_command()* raised an exception (*SyntaxError* or *OverflowError*). A syntax traceback will be printed by calling the *showsyntaxerror()* method. *runsource()* returns `False`.
- The input is incomplete, and more input is required; *compile_command()* returned `None`. *runsource()* returns `True`.
- The input is complete; *compile_command()* returned a code object. The code is executed by calling the *runcode()* (which also handles run-time exceptions, except for *SystemExit*). *runsource()* returns `False`.

The return value can be used to decide whether to use `sys.ps1` or `sys.ps2` to prompt the next line.

`InteractiveInterpreter.runcode`(*code*)

Execute a code object. When an exception occurs, *showtraceback()* is called to display a traceback. All exceptions are caught except *SystemExit*, which is allowed to propagate.

A note about *KeyboardInterrupt*: this exception may occur elsewhere in this code, and may not always be caught. The caller should be prepared to deal with it.

`InteractiveInterpreter.showsyntaxerror`(*filename=None*)

Display the syntax error that just occurred. This does not display a stack trace because there isn't one for syntax errors. If *filename* is given, it is stuffed into the exception instead of the default filename provided by Python's parser, because it always uses `'<string>'` when reading from a string. The output is written by the *write()* method.

`InteractiveInterpreter.showtraceback`()

Display the exception that just occurred. We remove the first stack item because it is within the interpreter object implementation. The output is written by the *write()* method.

Changed in version 3.5: The full chained traceback is displayed instead of just the primary traceback.

`InteractiveInterpreter.write`(*data*)

Write a string to the standard error stream (`sys.stderr`). Derived classes should override this to provide the appropriate output handling as needed.

31.1.2 Interactive Console Objects

The *InteractiveConsole* class is a subclass of *InteractiveInterpreter*, and so offers all the methods of the interpreter objects as well as the following additions.

`InteractiveConsole.interact`(*banner=None*, *exitmsg=None*)

Closely emulate the interactive Python console. The optional *banner* argument specify the banner to print before the first interaction; by default it prints a banner similar to the one printed by the

standard Python interpreter, followed by the class name of the console object in parentheses (so as not to confuse this with the real interpreter – since it's so close!).

The optional *exitmsg* argument specifies an exit message printed when exiting. Pass the empty string to suppress the exit message. If *exitmsg* is not given or `None`, a default message is printed.

Changed in version 3.4: To suppress printing any banner, pass an empty string.

Changed in version 3.6: Print an exit message when exiting.

`InteractiveConsole.push(`*line*`)`
Push a line of source text to the interpreter. The line should not have a trailing newline; it may have internal newlines. The line is appended to a buffer and the interpreter's `runsource()` method is called with the concatenated contents of the buffer as source. If this indicates that the command was executed or invalid, the buffer is reset; otherwise, the command is incomplete, and the buffer is left as it was after the line was appended. The return value is `True` if more input is required, `False` if the line was dealt with in some way (this is the same as `runsource()`).

`InteractiveConsole.resetbuffer()`
Remove any unhandled source text from the input buffer.

`InteractiveConsole.raw_input(`*prompt=""*`)`
Write a prompt and read a line. The returned line does not include the trailing newline. When the user enters the EOF key sequence, *EOFError* is raised. The base implementation reads from `sys.stdin`; a subclass may replace this with a different implementation.

31.2 codeop — Compile Python code

Source code: Lib/codeop.py

The *codeop* module provides utilities upon which the Python read-eval-print loop can be emulated, as is done in the *code* module. As a result, you probably don't want to use the module directly; if you want to include such a loop in your program you probably want to use the *code* module instead.

There are two parts to this job:

1. Being able to tell if a line of input completes a Python statement: in short, telling whether to print '`>>>`' or '`...`' next.
2. Remembering which future statements the user has entered, so subsequent input can be compiled with these in effect.

The *codeop* module provides a way of doing each of these things, and a way of doing them both.

To do just the former:

`codeop.compile_command(`*source*, *filename="<input>"*, *symbol="single"*`)`
Tries to compile *source*, which should be a string of Python code and return a code object if *source* is valid Python code. In that case, the filename attribute of the code object will be *filename*, which defaults to `'<input>'`. Returns `None` if *source* is *not* valid Python code, but is a prefix of valid Python code.

If there is a problem with *source*, an exception will be raised. *SyntaxError* is raised if there is invalid Python syntax, and *OverflowError* or *ValueError* if there is an invalid literal.

The *symbol* argument determines whether *source* is compiled as a statement (`'single'`, the default) or as an *expression* (`'eval'`). Any other value will cause *ValueError* to be raised.

Note: It is possible (but not likely) that the parser stops parsing with a successful outcome before reaching the end of the source; in this case, trailing symbols may be ignored instead of causing an error. For example, a backslash followed by two newlines may be followed by arbitrary garbage. This will be fixed once the API for the parser is better.

class codeop.**Compile**

Instances of this class have `__call__()` methods identical in signature to the built-in function *compile()*, but with the difference that if the instance compiles program text containing a *__future__* statement, the instance 'remembers' and compiles all subsequent program texts with the statement in force.

class codeop.**CommandCompiler**

Instances of this class have `__call__()` methods identical in signature to *compile_command()*; the difference is that if the instance compiles program text containing a `__future__` statement, the instance 'remembers' and compiles all subsequent program texts with the statement in force.

CHAPTER

THIRTYTWO

IMPORTING MODULES

The modules described in this chapter provide new ways to import other Python modules and hooks for customizing the import process.

The full list of modules described in this chapter is:

32.1 zipimport — Import modules from Zip archives

This module adds the ability to import Python modules (`*.py`, `*.pyc`) and packages from ZIP-format archives. It is usually not needed to use the *zipimport* module explicitly; it is automatically used by the built-in `import` mechanism for *sys.path* items that are paths to ZIP archives.

Typically, *sys.path* is a list of directory names as strings. This module also allows an item of *sys.path* to be a string naming a ZIP file archive. The ZIP archive can contain a subdirectory structure to support package imports, and a path within the archive can be specified to only import from a subdirectory. For example, the path `example.zip/lib/` would only import from the `lib/` subdirectory within the archive.

Any files may be present in the ZIP archive, but only files `.py` and `.pyc` are available for import. ZIP import of dynamic modules (`.pyd`, `.so`) is disallowed. Note that if an archive only contains `.py` files, Python will not attempt to modify the archive by adding the corresponding `.pyc` file, meaning that if a ZIP archive doesn't contain `.pyc` files, importing may be rather slow.

ZIP archives with an archive comment are currently not supported.

See also:

PKZIP Application Note Documentation on the ZIP file format by Phil Katz, the creator of the format and algorithms used.

PEP 273 - Import Modules from Zip Archives Written by James C. Ahlstrom, who also provided an implementation. Python 2.3 follows the specification in PEP 273, but uses an implementation written by Just van Rossum that uses the import hooks described in PEP 302.

PEP 302 - New Import Hooks The PEP to add the import hooks that help this module work.

This module defines an exception:

`exception zipimport.ZipImportError`
Exception raised by zipimporter objects. It's a subclass of *ImportError*, so it can be caught as *ImportError*, too.

32.1.1 zipimporter Objects

zipimporter is the class for importing ZIP files.

class zipimport.zipimporter(*archivepath*)

Create a new zipimporter instance. *archivepath* must be a path to a ZIP file, or to a specific path within a ZIP file. For example, an *archivepath* of `foo/bar.zip/lib` will look for modules in the `lib` directory inside the ZIP file `foo/bar.zip` (provided that it exists).

ZipImportError is raised if *archivepath* doesn't point to a valid ZIP archive.

find_module(*fullname*[, *path*])

Search for a module specified by *fullname*. *fullname* must be the fully qualified (dotted) module name. It returns the zipimporter instance itself if the module was found, or *None* if it wasn't. The optional *path* argument is ignored—it's there for compatibility with the importer protocol.

get_code(*fullname*)

Return the code object for the specified module. Raise *ZipImportError* if the module couldn't be found.

get_data(*pathname*)

Return the data associated with *pathname*. Raise *OSError* if the file wasn't found.

Changed in version 3.3: *IOError* used to be raised instead of *OSError*.

get_filename(*fullname*)

Return the value `__file__` would be set to if the specified module was imported. Raise *ZipImportError* if the module couldn't be found.

New in version 3.1.

get_source(*fullname*)

Return the source code for the specified module. Raise *ZipImportError* if the module couldn't be found, return *None* if the archive does contain the module, but has no source for it.

is_package(*fullname*)

Return `True` if the module specified by *fullname* is a package. Raise *ZipImportError* if the module couldn't be found.

load_module(*fullname*)

Load the module specified by *fullname*. *fullname* must be the fully qualified (dotted) module name. It returns the imported module, or raises *ZipImportError* if it wasn't found.

archive

The file name of the importer's associated ZIP file, without a possible subpath.

prefix

The subpath within the ZIP file where modules are searched. This is the empty string for zipimporter objects which point to the root of the ZIP file.

The *archive* and *prefix* attributes, when combined with a slash, equal the original *archivepath* argument given to the *zipimporter* constructor.

32.1.2 Examples

Here is an example that imports a module from a ZIP archive - note that the *zipimport* module is not explicitly used.

```
$ unzip -l example.zip
Archive:  example.zip
  Length     Date   Time    Name
```

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```
 --------    ----    ----    ----
     8467  11-26-02 22:30   jwzthreading.py
 --------                    -------
     8467                    1 file
$ ./python
Python 2.3 (#1, Aug 1 2003, 19:54:32)
>>> import sys
>>> sys.path.insert(0, 'example.zip')  # Add .zip file to front of path
>>> import jwzthreading
>>> jwzthreading.__file__
'example.zip/jwzthreading.py'
```

32.2 pkgutil — Package extension utility

Source code: Lib/pkgutil.py

This module provides utilities for the import system, in particular package support.

class pkgutil.**ModuleInfo**(*module_finder*, *name*, *ispkg*)
A namedtuple that holds a brief summary of a module's info.

New in version 3.6.

pkgutil.**extend_path**(*path*, *name*)
Extend the search path for the modules which comprise a package. Intended use is to place the following code in a package's `__init__.py`:

```
from pkgutil import extend_path
__path__ = extend_path(__path__, __name__)
```

This will add to the package's `__path__` all subdirectories of directories on `sys.path` named after the package. This is useful if one wants to distribute different parts of a single logical package as multiple directories.

It also looks for `*.pkg` files beginning where `*` matches the *name* argument. This feature is similar to `*.pth` files (see the *site* module for more information), except that it doesn't special-case lines starting with `import`. A `*.pkg` file is trusted at face value: apart from checking for duplicates, all entries found in a `*.pkg` file are added to the path, regardless of whether they exist on the filesystem. (This is a feature.)

If the input path is not a list (as is the case for frozen packages) it is returned unchanged. The input path is not modified; an extended copy is returned. Items are only appended to the copy at the end.

It is assumed that *sys.path* is a sequence. Items of *sys.path* that are not strings referring to existing directories are ignored. Unicode items on *sys.path* that cause errors when used as filenames may cause this function to raise an exception (in line with *os.path.isdir()* behavior).

class pkgutil.**ImpImporter**(*dirname=None*)
PEP 302 Finder that wraps Python's "classic" import algorithm.

If *dirname* is a string, a **PEP 302** finder is created that searches that directory. If *dirname* is `None`, a **PEP 302** finder is created that searches the current *sys.path*, plus any modules that are frozen or built-in.

Note that *ImpImporter* does not currently support being used by placement on *sys.meta_path*.

Deprecated since version 3.3: This emulation is no longer needed, as the standard import mechanism is now fully PEP 302 compliant and available in *importlib*.

class pkgutil.**ImpLoader**(*fullname*, *file*, *filename*, *etc*)
Loader that wraps Python's "classic" import algorithm.

Deprecated since version 3.3: This emulation is no longer needed, as the standard import mechanism is now fully PEP 302 compliant and available in *importlib*.

pkgutil.**find_loader**(*fullname*)
Retrieve a module *loader* for the given *fullname*.

This is a backwards compatibility wrapper around *importlib.util.find_spec()* that converts most failures to *ImportError* and only returns the loader rather than the full `ModuleSpec`.

Changed in version 3.3: Updated to be based directly on *importlib* rather than relying on the package internal PEP 302 import emulation.

Changed in version 3.4: Updated to be based on **PEP 451**

pkgutil.**get_importer**(*path_item*)
Retrieve a *finder* for the given *path_item*.

The returned finder is cached in *sys.path_importer_cache* if it was newly created by a path hook.

The cache (or part of it) can be cleared manually if a rescan of *sys.path_hooks* is necessary.

Changed in version 3.3: Updated to be based directly on *importlib* rather than relying on the package internal PEP 302 import emulation.

pkgutil.**get_loader**(*module_or_name*)
Get a *loader* object for *module_or_name*.

If the module or package is accessible via the normal import mechanism, a wrapper around the relevant part of that machinery is returned. Returns `None` if the module cannot be found or imported. If the named module is not already imported, its containing package (if any) is imported, in order to establish the package `__path__`.

Changed in version 3.3: Updated to be based directly on *importlib* rather than relying on the package internal PEP 302 import emulation.

Changed in version 3.4: Updated to be based on **PEP 451**

pkgutil.**iter_importers**(*fullname=''*)
Yield *finder* objects for the given module name.

If fullname contains a '.', the finders will be for the package containing fullname, otherwise they will be all registered top level finders (i.e. those on both sys.meta_path and sys.path_hooks).

If the named module is in a package, that package is imported as a side effect of invoking this function.

If no module name is specified, all top level finders are produced.

Changed in version 3.3: Updated to be based directly on *importlib* rather than relying on the package internal PEP 302 import emulation.

pkgutil.**iter_modules**(*path=None*, *prefix=''*)
Yields *ModuleInfo* for all submodules on *path*, or, if *path* is `None`, all top-level modules on `sys.path`.

path should be either `None` or a list of paths to look for modules in.

prefix is a string to output on the front of every module name on output.

Note: Only works for a *finder* which defines an `iter_modules()` method. This interface is non-standard, so the module also provides implementations for *importlib.machinery.FileFinder* and

zipimport.zipimporter.

Changed in version 3.3: Updated to be based directly on *importlib* rather than relying on the package internal PEP 302 import emulation.

pkgutil.**walk_packages**(*path=None*, *prefix=''*, *onerror=None*)
Yields *ModuleInfo* for all modules recursively on *path*, or, if *path* is `None`, all accessible modules.

path should be either `None` or a list of paths to look for modules in.

prefix is a string to output on the front of every module name on output.

Note that this function must import all *packages* (*not* all modules!) on the given *path*, in order to access the `__path__` attribute to find submodules.

onerror is a function which gets called with one argument (the name of the package which was being imported) if any exception occurs while trying to import a package. If no *onerror* function is supplied, *ImportError*s are caught and ignored, while all other exceptions are propagated, terminating the search.

Examples:

```
# list all modules python can access
walk_packages()

# list all submodules of ctypes
walk_packages(ctypes.__path__, ctypes.__name__ + '.')
```

Note: Only works for a *finder* which defines an `iter_modules()` method. This interface is non-standard, so the module also provides implementations for *importlib.machinery.FileFinder* and *zipimport.zipimporter*.

Changed in version 3.3: Updated to be based directly on *importlib* rather than relying on the package internal PEP 302 import emulation.

pkgutil.**get_data**(*package*, *resource*)
Get a resource from a package.

This is a wrapper for the *loader* *get_data* API. The *package* argument should be the name of a package, in standard module format (`foo.bar`). The *resource* argument should be in the form of a relative filename, using `/` as the path separator. The parent directory name `..` is not allowed, and nor is a rooted name (starting with a `/`).

The function returns a binary string that is the contents of the specified resource.

For packages located in the filesystem, which have already been imported, this is the rough equivalent of:

```
d = os.path.dirname(sys.modules[package].__file__)
data = open(os.path.join(d, resource), 'rb').read()
```

If the package cannot be located or loaded, or it uses a *loader* which does not support *get_data*, then `None` is returned. In particular, the *loader* for *namespace packages* does not support *get_data*.

32.3 `modulefinder` — Find modules used by a script

Source code: Lib/modulefinder.py

This module provides a *ModuleFinder* class that can be used to determine the set of modules imported by a script. `modulefinder.py` can also be run as a script, giving the filename of a Python script as its argument, after which a report of the imported modules will be printed.

`modulefinder.AddPackagePath(pkg_name, path)`
Record that the package named *pkg_name* can be found in the specified *path*.

`modulefinder.ReplacePackage(oldname, newname)`
Allows specifying that the module named *oldname* is in fact the package named *newname*.

`class modulefinder.ModuleFinder(path=None, debug=0, excludes=[], replace_paths=[])`
This class provides *run_script()* and *report()* methods to determine the set of modules imported by a script. *path* can be a list of directories to search for modules; if not specified, `sys.path` is used. *debug* sets the debugging level; higher values make the class print debugging messages about what it's doing. *excludes* is a list of module names to exclude from the analysis. *replace_paths* is a list of `(oldpath, newpath)` tuples that will be replaced in module paths.

`report()`
Print a report to standard output that lists the modules imported by the script and their paths, as well as modules that are missing or seem to be missing.

`run_script(pathname)`
Analyze the contents of the *pathname* file, which must contain Python code.

`modules`
A dictionary mapping module names to modules. See *Example usage of ModuleFinder*.

32.3.1 Example usage of `ModuleFinder`

The script that is going to get analyzed later on (bacon.py):

```
import re, itertools

try:
    import baconhameggs
except ImportError:
    pass

try:
    import guido.python.ham
except ImportError:
    pass
```

The script that will output the report of bacon.py:

```
from modulefinder import ModuleFinder

finder = ModuleFinder()
finder.run_script('bacon.py')

print('Loaded modules:')
for name, mod in finder.modules.items():
    print('%s: ' % name, end='')
    print(','.join(list(mod.globalnames.keys())[:3]))

print('-'*50)
```

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```
print('Modules not imported:')
print('\n'.join(finder.badmodules.keys()))
```

Sample output (may vary depending on the architecture):

```
Loaded modules:
_types:
copyreg:  _inverted_registry,_slotnames,__all__
sre_compile:  isstring,_sre,_optimize_unicode
_sre:
sre_constants:  REPEAT_ONE,makedict,AT_END_LINE
sys:
re:  __module__,finditer,_expand
itertools:
__main__:  re,itertools,baconhameggs
sre_parse:  _PATTERNENDERS,SRE_FLAG_UNICODE
array:
types:  __module__,IntType,TypeType
----------------------------------------------------
Modules not imported:
guido.python.ham
baconhameggs
```

32.4 runpy — Locating and executing Python modules

Source code: Lib/runpy.py

The *runpy* module is used to locate and run Python modules without importing them first. Its main use is to implement the `-m` command line switch that allows scripts to be located using the Python module namespace rather than the filesystem.

Note that this is *not* a sandbox module - all code is executed in the current process, and any side effects (such as cached imports of other modules) will remain in place after the functions have returned.

Furthermore, any functions and classes defined by the executed code are not guaranteed to work correctly after a *runpy* function has returned. If that limitation is not acceptable for a given use case, *importlib* is likely to be a more suitable choice than this module.

The *runpy* module provides two functions:

runpy.run_module(*mod_name*, *init_globals=None*, *run_name=None*, *alter_sys=False*)

Execute the code of the specified module and return the resulting module globals dictionary. The module's code is first located using the standard import mechanism (refer to **PEP 302** for details) and then executed in a fresh module namespace.

The *mod_name* argument should be an absolute module name. If the module name refers to a package rather than a normal module, then that package is imported and the `__main__` submodule within that package is then executed and the resulting module globals dictionary returned.

The optional dictionary argument *init_globals* may be used to pre-populate the module's globals dictionary before the code is executed. The supplied dictionary will not be modified. If any of the special global variables below are defined in the supplied dictionary, those definitions are overridden by *run_module()*.

The special global variables `__name__`, `__spec__`, `__file__`, `__cached__`, `__loader__` and `__package__` are set in the globals dictionary before the module code is executed (Note that this

is a minimal set of variables - other variables may be set implicitly as an interpreter implementation detail).

`__name__` is set to *run_name* if this optional argument is not *None*, to `mod_name + '.__main__'` if the named module is a package and to the *mod_name* argument otherwise.

`__spec__` will be set appropriately for the *actually* imported module (that is, `__spec__.name` will always be *mod_name* or `mod_name + '.__main__'`, never *run_name*).

`__file__`, `__cached__`, `__loader__` and `__package__` are set as normal based on the module spec.

If the argument *alter_sys* is supplied and evaluates to *True*, then `sys.argv[0]` is updated with the value of `__file__` and `sys.modules[__name__]` is updated with a temporary module object for the module being executed. Both `sys.argv[0]` and `sys.modules[__name__]` are restored to their original values before the function returns.

Note that this manipulation of *sys* is not thread-safe. Other threads may see the partially initialised module, as well as the altered list of arguments. It is recommended that the *sys* module be left alone when invoking this function from threaded code.

See also:

The `-m` option offering equivalent functionality from the command line.

Changed in version 3.1: Added ability to execute packages by looking for a `__main__` submodule.

Changed in version 3.2: Added `__cached__` global variable (see **PEP 3147**).

Changed in version 3.4: Updated to take advantage of the module spec feature added by **PEP 451**. This allows `__cached__` to be set correctly for modules run this way, as well as ensuring the real module name is always accessible as `__spec__.name`.

`runpy.run_path`(*file_path*, *init_globals=None*, *run_name=None*)

Execute the code at the named filesystem location and return the resulting module globals dictionary. As with a script name supplied to the CPython command line, the supplied path may refer to a Python source file, a compiled bytecode file or a valid sys.path entry containing a `__main__` module (e.g. a zipfile containing a top-level `__main__.py` file).

For a simple script, the specified code is simply executed in a fresh module namespace. For a valid sys.path entry (typically a zipfile or directory), the entry is first added to the beginning of `sys.path`. The function then looks for and executes a *__main__* module using the updated path. Note that there is no special protection against invoking an existing *__main__* entry located elsewhere on `sys.path` if there is no such module at the specified location.

The optional dictionary argument *init_globals* may be used to pre-populate the module's globals dictionary before the code is executed. The supplied dictionary will not be modified. If any of the special global variables below are defined in the supplied dictionary, those definitions are overridden by *run_path()*.

The special global variables `__name__`, `__spec__`, `__file__`, `__cached__`, `__loader__` and `__package__` are set in the globals dictionary before the module code is executed (Note that this is a minimal set of variables - other variables may be set implicitly as an interpreter implementation detail).

`__name__` is set to *run_name* if this optional argument is not *None* and to `'<run_path>'` otherwise.

If the supplied path directly references a script file (whether as source or as precompiled byte code), then `__file__` will be set to the supplied path, and `__spec__`, `__cached__`, `__loader__` and `__package__` will all be set to *None*.

If the supplied path is a reference to a valid sys.path entry, then `__spec__` will be set appropriately for the imported `__main__` module (that is, `__spec__.name` will always be `__main__`). `__file__`, `__cached__`, `__loader__` and `__package__` will be set as normal based on the module spec.

A number of alterations are also made to the *sys* module. Firstly, `sys.path` may be altered as described above. `sys.argv[0]` is updated with the value of `file_path` and `sys.modules[__name__]` is updated with a temporary module object for the module being executed. All modifications to items in *sys* are reverted before the function returns.

Note that, unlike *run_module()*, the alterations made to *sys* are not optional in this function as these adjustments are essential to allowing the execution of sys.path entries. As the thread-safety limitations still apply, use of this function in threaded code should be either serialised with the import lock or delegated to a separate process.

See also:

using-on-interface-options for equivalent functionality on the command line (`python path/to/script`).

New in version 3.2.

Changed in version 3.4: Updated to take advantage of the module spec feature added by **PEP 451**. This allows `__cached__` to be set correctly in the case where `__main__` is imported from a valid sys.path entry rather than being executed directly.

See also:

PEP 338 – **Executing modules as scripts** PEP written and implemented by Nick Coghlan.

PEP 366 – **Main module explicit relative imports** PEP written and implemented by Nick Coghlan.

PEP 451 – **A ModuleSpec Type for the Import System** PEP written and implemented by Eric Snow

using-on-general - CPython command line details

The *importlib.import_module()* function

32.5 `importlib` — The implementation of `import`

New in version 3.1.

Source code: Lib/importlib/__init__.py

32.5.1 Introduction

The purpose of the *importlib* package is two-fold. One is to provide the implementation of the `import` statement (and thus, by extension, the *__import__()* function) in Python source code. This provides an implementation of `import` which is portable to any Python interpreter. This also provides an implementation which is easier to comprehend than one implemented in a programming language other than Python.

Two, the components to implement `import` are exposed in this package, making it easier for users to create their own custom objects (known generically as an *importer*) to participate in the import process.

See also:

import The language reference for the `import` statement.

Packages specification Original specification of packages. Some semantics have changed since the writing of this document (e.g. redirecting based on `None` in *sys.modules*).

The *__import__()* function The `import` statement is syntactic sugar for this function.

PEP 235 Import on Case-Insensitive Platforms

PEP 263 Defining Python Source Code Encodings

PEP 302 New Import Hooks

PEP 328 Imports: Multi-Line and Absolute/Relative

PEP 366 Main module explicit relative imports

PEP 420 Implicit namespace packages

PEP 451 A ModuleSpec Type for the Import System

PEP 488 Elimination of PYO files

PEP 489 Multi-phase extension module initialization

PEP 552 Deterministic pycs

PEP 3120 Using UTF-8 as the Default Source Encoding

PEP 3147 PYC Repository Directories

32.5.2 Functions

`importlib.__import__`(*name*, *globals=None*, *locals=None*, *fromlist=()*, *level=0*)
An implementation of the built-in *__import__()* function.

Note: Programmatic importing of modules should use *import_module()* instead of this function.

`importlib.import_module`(*name*, *package=None*)
Import a module. The *name* argument specifies what module to import in absolute or relative terms (e.g. either `pkg.mod` or `..mod`). If the name is specified in relative terms, then the *package* argument must be set to the name of the package which is to act as the anchor for resolving the package name (e.g. `import_module('..mod', 'pkg.subpkg')` will import `pkg.mod`).

The *import_module()* function acts as a simplifying wrapper around *importlib.__import__()*. This means all semantics of the function are derived from *importlib.__import__()*. The most important difference between these two functions is that *import_module()* returns the specified package or module (e.g. `pkg.mod`), while *__import__()* returns the top-level package or module (e.g. `pkg`).

If you are dynamically importing a module that was created since the interpreter began execution (e.g., created a Python source file), you may need to call *invalidate_caches()* in order for the new module to be noticed by the import system.

Changed in version 3.3: Parent packages are automatically imported.

`importlib.find_loader`(*name*, *path=None*)
Find the loader for a module, optionally within the specified *path*. If the module is in *sys.modules*, then `sys.modules[name].__loader__` is returned (unless the loader would be `None` or is not set, in which case *ValueError* is raised). Otherwise a search using *sys.meta_path* is done. `None` is returned if no loader is found.

A dotted name does not have its parents implicitly imported as that requires loading them and that may not be desired. To properly import a submodule you will need to import all parent packages of the submodule and use the correct argument to *path*.

New in version 3.3.

Changed in version 3.4: If `__loader__` is not set, raise *ValueError*, just like when the attribute is set to `None`.

Deprecated since version 3.4: Use *importlib.util.find_spec()* instead.

importlib.**invalidate_caches**()

Invalidate the internal caches of finders stored at *sys.meta_path*. If a finder implements `invalidate_caches()` then it will be called to perform the invalidation. This function should be called if any modules are created/installed while your program is running to guarantee all finders will notice the new module's existence.

New in version 3.3.

importlib.**reload**(*module*)

Reload a previously imported *module*. The argument must be a module object, so it must have been successfully imported before. This is useful if you have edited the module source file using an external editor and want to try out the new version without leaving the Python interpreter. The return value is the module object (which can be different if re-importing causes a different object to be placed in *sys.modules*).

When *reload()* is executed:

- Python module's code is recompiled and the module-level code re-executed, defining a new set of objects which are bound to names in the module's dictionary by reusing the *loader* which originally loaded the module. The `init` function of extension modules is not called a second time.
- As with all other objects in Python the old objects are only reclaimed after their reference counts drop to zero.
- The names in the module namespace are updated to point to any new or changed objects.
- Other references to the old objects (such as names external to the module) are not rebound to refer to the new objects and must be updated in each namespace where they occur if that is desired.

There are a number of other caveats:

When a module is reloaded, its dictionary (containing the module's global variables) is retained. Redefinitions of names will override the old definitions, so this is generally not a problem. If the new version of a module does not define a name that was defined by the old version, the old definition remains. This feature can be used to the module's advantage if it maintains a global table or cache of objects — with a `try` statement it can test for the table's presence and skip its initialization if desired:

```
try:
    cache
except NameError:
    cache = {}
```

It is generally not very useful to reload built-in or dynamically loaded modules. Reloading *sys*, *__main__*, *builtins* and other key modules is not recommended. In many cases extension modules are not designed to be initialized more than once, and may fail in arbitrary ways when reloaded.

If a module imports objects from another module using `from` … `import` …, calling *reload()* for the other module does not redefine the objects imported from it — one way around this is to re-execute the `from` statement, another is to use `import` and qualified names (*module.name*) instead.

If a module instantiates instances of a class, reloading the module that defines the class does not affect the method definitions of the instances — they continue to use the old class definition. The same is true for derived classes.

New in version 3.4.

Changed in version 3.7: *ModuleNotFoundError* is raised when the module being reloaded lacks a `ModuleSpec`.

32.5.3 importlib.abc – Abstract base classes related to import

Source code: Lib/importlib/abc.py

The *importlib.abc* module contains all of the core abstract base classes used by `import`. Some subclasses of the core abstract base classes are also provided to help in implementing the core ABCs.

ABC hierarchy:

```
object
 +-- Finder (deprecated)
 |    +-- MetaPathFinder
 |    +-- PathEntryFinder
 +-- Loader
      +-- ResourceLoader --------+
      +-- InspectLoader          |
           +-- ExecutionLoader --+
                                 +-- FileLoader
                                 +-- SourceLoader
```

class importlib.abc.**Finder**

An abstract base class representing a *finder*.

Deprecated since version 3.3: Use *MetaPathFinder* or *PathEntryFinder* instead.

abstractmethod **find_module**(*fullname*, *path=None*)

An abstract method for finding a *loader* for the specified module. Originally specified in **PEP 302**, this method was meant for use in *sys.meta_path* and in the path-based import subsystem.

Changed in version 3.4: Returns `None` when called instead of raising *NotImplementedError*.

class importlib.abc.**MetaPathFinder**

An abstract base class representing a *meta path finder*. For compatibility, this is a subclass of *Finder*.

New in version 3.3.

find_spec(*fullname*, *path*, *target=None*)

An abstract method for finding a *spec* for the specified module. If this is a top-level import, *path* will be `None`. Otherwise, this is a search for a subpackage or module and *path* will be the value of `__path__` from the parent package. If a spec cannot be found, `None` is returned. When passed in, `target` is a module object that the finder may use to make a more educated guess about what spec to return.

New in version 3.4.

find_module(*fullname*, *path*)

A legacy method for finding a *loader* for the specified module. If this is a top-level import, *path* will be `None`. Otherwise, this is a search for a subpackage or module and *path* will be the value of `__path__` from the parent package. If a loader cannot be found, `None` is returned.

If *find_spec()* is defined, backwards-compatible functionality is provided.

Changed in version 3.4: Returns `None` when called instead of raising *NotImplementedError*. Can use *find_spec()* to provide functionality.

Deprecated since version 3.4: Use *find_spec()* instead.

invalidate_caches()

An optional method which, when called, should invalidate any internal cache used by the finder. Used by *importlib.invalidate_caches()* when invalidating the caches of all finders on *sys.meta_path*.

Changed in version 3.4: Returns `None` when called instead of `NotImplemented`.

class importlib.abc.**PathEntryFinder**

An abstract base class representing a *path entry finder*. Though it bears some similarities to *MetaPathFinder*, `PathEntryFinder` is meant for use only within the path-based import subsystem provided by `PathFinder`. This ABC is a subclass of *Finder* for compatibility reasons only.

New in version 3.3.

find_spec(*fullname*, *target=None*)

An abstract method for finding a *spec* for the specified module. The finder will search for the module only within the *path entry* to which it is assigned. If a spec cannot be found, `None` is returned. When passed in, `target` is a module object that the finder may use to make a more educated guess about what spec to return.

New in version 3.4.

find_loader(*fullname*)

A legacy method for finding a *loader* for the specified module. Returns a 2-tuple of `(loader, portion)` where `portion` is a sequence of file system locations contributing to part of a namespace package. The loader may be `None` while specifying `portion` to signify the contribution of the file system locations to a namespace package. An empty list can be used for `portion` to signify the loader is not part of a namespace package. If `loader` is `None` and `portion` is the empty list then no loader or location for a namespace package were found (i.e. failure to find anything for the module).

If *find_spec()* is defined then backwards-compatible functionality is provided.

Changed in version 3.4: Returns `(None, [])` instead of raising *NotImplementedError*. Uses *find_spec()* when available to provide functionality.

Deprecated since version 3.4: Use *find_spec()* instead.

find_module(*fullname*)

A concrete implementation of *Finder.find_module()* which is equivalent to `self.find_loader(fullname)[0]`.

Deprecated since version 3.4: Use *find_spec()* instead.

invalidate_caches()

An optional method which, when called, should invalidate any internal cache used by the finder. Used by `PathFinder.invalidate_caches()` when invalidating the caches of all cached finders.

class importlib.abc.**Loader**

An abstract base class for a *loader*. See **PEP 302** for the exact definition for a loader.

Loaders that wish to support resource reading should implement a `get_resource_reader(fullname)` method as specified by *importlib.abc.ResourceReader*.

Changed in version 3.7: Introduced the optional `get_resource_reader()` method.

create_module(*spec*)

A method that returns the module object to use when importing a module. This method may return `None`, indicating that default module creation semantics should take place.

New in version 3.4.

Changed in version 3.5: Starting in Python 3.6, this method will not be optional when *exec_module()* is defined.

exec_module(*module*)

An abstract method that executes the module in its own namespace when a module is imported or reloaded. The module should already be initialized when `exec_module()` is called. When this method exists, *create_module()* must be defined.

New in version 3.4.

Changed in version 3.6: *create_module()* must also be defined.

load_module(*fullname*)
A legacy method for loading a module. If the module cannot be loaded, *ImportError* is raised, otherwise the loaded module is returned.

If the requested module already exists in *sys.modules*, that module should be used and reloaded. Otherwise the loader should create a new module and insert it into *sys.modules* before any loading begins, to prevent recursion from the import. If the loader inserted a module and the load fails, it must be removed by the loader from *sys.modules*; modules already in *sys.modules* before the loader began execution should be left alone (see *importlib.util.module_for_loader()*).

The loader should set several attributes on the module. (Note that some of these attributes can change when a module is reloaded):

- **__name__** The name of the module.
- **__file__** The path to where the module data is stored (not set for built-in modules).
- **__cached__** The path to where a compiled version of the module is/should be stored (not set when the attribute would be inappropriate).
- **__path__** A list of strings specifying the search path within a package. This attribute is not set on modules.
- **__package__** The parent package for the module/package. If the module is top-level then it has a value of the empty string. The *importlib.util.module_for_loader()* decorator can handle the details for `__package__`.
- **__loader__** The loader used to load the module. The *importlib.util.module_for_loader()* decorator can handle the details for `__package__`.

When *exec_module()* is available then backwards-compatible functionality is provided.

Changed in version 3.4: Raise *ImportError* when called instead of *NotImplementedError*. Functionality provided when *exec_module()* is available.

Deprecated since version 3.4: The recommended API for loading a module is *exec_module()* (and *create_module()*). Loaders should implement it instead of load_module(). The import machinery takes care of all the other responsibilities of load_module() when exec_module() is implemented.

module_repr(*module*)
A legacy method which when implemented calculates and returns the given module's repr, as a string. The module type's default repr() will use the result of this method as appropriate.

New in version 3.3.

Changed in version 3.4: Made optional instead of an abstractmethod.

Deprecated since version 3.4: The import machinery now takes care of this automatically.

class importlib.abc.**ResourceReader**
An *abstract base class* to provide the ability to read *resources*.

From the perspective of this ABC, a *resource* is a binary artifact that is shipped within a package. Typically this is something like a data file that lives next to the `__init__.py` file of the package. The purpose of this class is to help abstract out the accessing of such data files so that it does not matter if the package and its data file(s) are stored in a e.g. zip file versus on the file system.

For any of methods of this class, a *resource* argument is expected to be a *path-like object* which represents conceptually just a file name. This means that no subdirectory paths should be included in the *resource* argument. This is because the location of the package the reader is for, acts as the "directory". Hence the metaphor for directories and file names is packages and resources, respectively.

This is also why instances of this class are expected to directly correlate to a specific package (instead of potentially representing multiple packages or a module).

Loaders that wish to support resource reading are expected to provide a method called `get_resource_loader(fullname)` which returns an object implementing this ABC's interface. If the module specified by fullname is not a package, this method should return *None*. An object compatible with this ABC should only be returned when the specified module is a package.

New in version 3.7.

abstractmethod open_resource(*resource*)
Returns an opened, *file-like object* for binary reading of the *resource*.

If the resource cannot be found, *FileNotFoundError* is raised.

abstractmethod resource_path(*resource*)
Returns the file system path to the *resource*.

If the resource does not concretely exist on the file system, raise *FileNotFoundError*.

abstractmethod is_resource(*name*)
Returns `True` if the named *name* is considered a resource. *FileNotFoundError* is raised if *name* does not exist.

abstractmethod contents()
Returns an *iterable* of strings over the contents of the package. Do note that it is not required that all names returned by the iterator be actual resources, e.g. it is acceptable to return names for which *is_resource()* would be false.

Allowing non-resource names to be returned is to allow for situations where how a package and its resources are stored are known a priori and the non-resource names would be useful. For instance, returning subdirectory names is allowed so that when it is known that the package and resources are stored on the file system then those subdirectory names can be used directly.

The abstract method returns an iterable of no items.

class importlib.abc.**ResourceLoader**
An abstract base class for a *loader* which implements the optional **PEP 302** protocol for loading arbitrary resources from the storage back-end.

Deprecated since version 3.7: This ABC is deprecated in favour of supporting resource loading through *importlib.abc.ResourceReader*.

abstractmethod get_data(*path*)
An abstract method to return the bytes for the data located at *path*. Loaders that have a file-like storage back-end that allows storing arbitrary data can implement this abstract method to give direct access to the data stored. *OSError* is to be raised if the *path* cannot be found. The *path* is expected to be constructed using a module's `__file__` attribute or an item from a package's `__path__`.

Changed in version 3.4: Raises *OSError* instead of *NotImplementedError*.

class importlib.abc.**InspectLoader**
An abstract base class for a *loader* which implements the optional **PEP 302** protocol for loaders that inspect modules.

get_code(*fullname*)
Return the code object for a module, or `None` if the module does not have a code object (as would be the case, for example, for a built-in module). Raise an *ImportError* if loader cannot find the requested module.

Note: While the method has a default implementation, it is suggested that it be overridden if possible for performance.

Changed in version 3.4: No longer abstract and a concrete implementation is provided.

abstractmethod get_source(*fullname*)
An abstract method to return the source of a module. It is returned as a text string using *universal newlines*, translating all recognized line separators into `'\n'` characters. Returns `None` if no source is available (e.g. a built-in module). Raises *ImportError* if the loader cannot find the module specified.

Changed in version 3.4: Raises *ImportError* instead of *NotImplementedError*.

is_package(*fullname*)
An abstract method to return a true value if the module is a package, a false value otherwise. *ImportError* is raised if the *loader* cannot find the module.

Changed in version 3.4: Raises *ImportError* instead of *NotImplementedError*.

static source_to_code(*data*, *path='<string>'*)
Create a code object from Python source.

The *data* argument can be whatever the *compile()* function supports (i.e. string or bytes). The *path* argument should be the "path" to where the source code originated from, which can be an abstract concept (e.g. location in a zip file).

With the subsequent code object one can execute it in a module by running `exec(code, module.__dict__)`.

New in version 3.4.

Changed in version 3.5: Made the method static.

exec_module(*module*)
Implementation of *Loader.exec_module()*.

New in version 3.4.

load_module(*fullname*)
Implementation of *Loader.load_module()*.

Deprecated since version 3.4: use *exec_module()* instead.

class importlib.abc.ExecutionLoader
An abstract base class which inherits from *InspectLoader* that, when implemented, helps a module to be executed as a script. The ABC represents an optional **PEP 302** protocol.

abstractmethod get_filename(*fullname*)
An abstract method that is to return the value of `__file__` for the specified module. If no path is available, *ImportError* is raised.

If source code is available, then the method should return the path to the source file, regardless of whether a bytecode was used to load the module.

Changed in version 3.4: Raises *ImportError* instead of *NotImplementedError*.

class importlib.abc.FileLoader(*fullname*, *path*)
An abstract base class which inherits from *ResourceLoader* and *ExecutionLoader*, providing concrete implementations of *ResourceLoader.get_data()* and *ExecutionLoader.get_filename()*.

The *fullname* argument is a fully resolved name of the module the loader is to handle. The *path* argument is the path to the file for the module.

New in version 3.3.

name
The name of the module the loader can handle.

path
Path to the file of the module.

load_module(*fullname*)
Calls super's `load_module()`.

Deprecated since version 3.4: Use *Loader.exec_module()* instead.

abstractmethod get_filename(*fullname*)
Returns *path*.

abstractmethod get_data(*path*)
Reads *path* as a binary file and returns the bytes from it.

class importlib.abc.**SourceLoader**
An abstract base class for implementing source (and optionally bytecode) file loading. The class inherits from both *ResourceLoader* and *ExecutionLoader*, requiring the implementation of:

- *ResourceLoader.get_data()*
- *ExecutionLoader.get_filename()* Should only return the path to the source file; sourceless loading is not supported.

The abstract methods defined by this class are to add optional bytecode file support. Not implementing these optional methods (or causing them to raise *NotImplementedError*) causes the loader to only work with source code. Implementing the methods allows the loader to work with source *and* bytecode files; it does not allow for *sourceless* loading where only bytecode is provided. Bytecode files are an optimization to speed up loading by removing the parsing step of Python's compiler, and so no bytecode-specific API is exposed.

path_stats(*path*)
Optional abstract method which returns a *dict* containing metadata about the specified path. Supported dictionary keys are:

- `'mtime'` (mandatory): an integer or floating-point number representing the modification time of the source code;
- `'size'` (optional): the size in bytes of the source code.

Any other keys in the dictionary are ignored, to allow for future extensions. If the path cannot be handled, *OSError* is raised.

New in version 3.3.

Changed in version 3.4: Raise *OSError* instead of *NotImplementedError*.

path_mtime(*path*)
Optional abstract method which returns the modification time for the specified path.

Deprecated since version 3.3: This method is deprecated in favour of *path_stats()*. You don't have to implement it, but it is still available for compatibility purposes. Raise *OSError* if the path cannot be handled.

Changed in version 3.4: Raise *OSError* instead of *NotImplementedError*.

set_data(*path*, *data*)
Optional abstract method which writes the specified bytes to a file path. Any intermediate directories which do not exist are to be created automatically.

When writing to the path fails because the path is read-only (*errno.EACCES*/*PermissionError*), do not propagate the exception.

Changed in version 3.4: No longer raises *NotImplementedError* when called.

`get_code`(*fullname*)
Concrete implementation of *InspectLoader.get_code()*.

`exec_module`(*module*)

Concrete implementation of *Loader.exec_module()*.

New in version 3.4.

`load_module`(*fullname*)
Concrete implementation of *Loader.load_module()*.

Deprecated since version 3.4: Use *exec_module()* instead.

`get_source`(*fullname*)
Concrete implementation of *InspectLoader.get_source()*.

`is_package`(*fullname*)
Concrete implementation of *InspectLoader.is_package()*. A module is determined to be a package if its file path (as provided by *ExecutionLoader.get_filename()*) is a file named `__init__` when the file extension is removed **and** the module name itself does not end in `__init__`.

32.5.4 `importlib.resources` – Resources

Source code: Lib/importlib/resources.py

New in version 3.7.

This module leverages Python's import system to provide access to *resources* within *packages*. If you can import a package, you can access resources within that package. Resources can be opened or read, in either binary or text mode.

Resources are roughly akin to files inside directories, though it's important to keep in mind that this is just a metaphor. Resources and packages **do not** have to exist as physical files and directories on the file system.

Note: This module provides functionality similar to pkg_resources Basic Resource Access without the performance overhead of that package. This makes reading resources included in packages easier, with more stable and consistent semantics.

The standalone backport of this module provides more information on using importlib.resources and migrating from pkg_resources to importlib.resources.

Loaders that wish to support resource reading should implement a `get_resource_reader(fullname)` method as specified by *importlib.abc.ResourceReader*.

The following types are defined.

`importlib.resources.Package`
The `Package` type is defined as `Union[str, ModuleType]`. This means that where the function describes accepting a `Package`, you can pass in either a string or a module. Module objects must have a resolvable `__spec__.submodule_search_locations` that is not `None`.

`importlib.resources.Resource`
This type describes the resource names passed into the various functions in this package. This is defined as `Union[str, os.PathLike]`.

The following functions are available.

importlib.resources.**open_binary**(*package*, *resource*)
Open for binary reading the *resource* within *package*.

package is either a name or a module object which conforms to the `Package` requirements. *resource* is the name of the resource to open within *package*; it may not contain path separators and it may not have sub-resources (i.e. it cannot be a directory). This function returns a `typing.BinaryIO` instance, a binary I/O stream open for reading.

importlib.resources.**open_text**(*package*, *resource*, *encoding='utf-8'*, *errors='strict'*)
Open for text reading the *resource* within *package*. By default, the resource is opened for reading as UTF-8.

package is either a name or a module object which conforms to the `Package` requirements. *resource* is the name of the resource to open within *package*; it may not contain path separators and it may not have sub-resources (i.e. it cannot be a directory). *encoding* and *errors* have the same meaning as with built-in *open()*.

This function returns a `typing.TextIO` instance, a text I/O stream open for reading.

importlib.resources.**read_binary**(*package*, *resource*)
Read and return the contents of the *resource* within *package* as `bytes`.

package is either a name or a module object which conforms to the `Package` requirements. *resource* is the name of the resource to open within *package*; it may not contain path separators and it may not have sub-resources (i.e. it cannot be a directory). This function returns the contents of the resource as *bytes*.

importlib.resources.**read_text**(*package*, *resource*, *encoding='utf-8'*, *errors='strict'*)
Read and return the contents of *resource* within *package* as a `str`. By default, the contents are read as strict UTF-8.

package is either a name or a module object which conforms to the `Package` requirements. *resource* is the name of the resource to open within *package*; it may not contain path separators and it may not have sub-resources (i.e. it cannot be a directory). *encoding* and *errors* have the same meaning as with built-in *open()*. This function returns the contents of the resource as *str*.

importlib.resources.**path**(*package*, *resource*)
Return the path to the *resource* as an actual file system path. This function returns a context manager for use in a `with` statement. The context manager provides a *pathlib.Path* object.

Exiting the context manager cleans up any temporary file created when the resource needs to be extracted from e.g. a zip file.

package is either a name or a module object which conforms to the `Package` requirements. *resource* is the name of the resource to open within *package*; it may not contain path separators and it may not have sub-resources (i.e. it cannot be a directory).

importlib.resources.**is_resource**(*package*, *name*)
Return `True` if there is a resource named *name* in the package, otherwise `False`. Remember that directories are *not* resources! *package* is either a name or a module object which conforms to the `Package` requirements.

importlib.resources.**contents**(*package*)
Return an iterable over the named items within the package. The iterable returns *str* resources (e.g. files) and non-resources (e.g. directories). The iterable does not recurse into subdirectories.

package is either a name or a module object which conforms to the `Package` requirements.

32.5.5 `importlib.machinery` – Importers and path hooks

Source code: Lib/importlib/machinery.py

This module contains the various objects that help `import` find and load modules.

`importlib.machinery.SOURCE_SUFFIXES`
A list of strings representing the recognized file suffixes for source modules.

New in version 3.3.

`importlib.machinery.DEBUG_BYTECODE_SUFFIXES`
A list of strings representing the file suffixes for non-optimized bytecode modules.

New in version 3.3.

Deprecated since version 3.5: Use *BYTECODE_SUFFIXES* instead.

`importlib.machinery.OPTIMIZED_BYTECODE_SUFFIXES`
A list of strings representing the file suffixes for optimized bytecode modules.

New in version 3.3.

Deprecated since version 3.5: Use *BYTECODE_SUFFIXES* instead.

`importlib.machinery.BYTECODE_SUFFIXES`
A list of strings representing the recognized file suffixes for bytecode modules (including the leading dot).

New in version 3.3.

Changed in version 3.5: The value is no longer dependent on `__debug__`.

`importlib.machinery.EXTENSION_SUFFIXES`
A list of strings representing the recognized file suffixes for extension modules.

New in version 3.3.

`importlib.machinery.all_suffixes()`
Returns a combined list of strings representing all file suffixes for modules recognized by the standard import machinery. This is a helper for code which simply needs to know if a filesystem path potentially refers to a module without needing any details on the kind of module (for example, *inspect.getmodulename()*).

New in version 3.3.

`class importlib.machinery.BuiltinImporter`
An *importer* for built-in modules. All known built-in modules are listed in *sys.builtin_module_names*. This class implements the *importlib.abc.MetaPathFinder* and *importlib.abc.InspectLoader* ABCs.

Only class methods are defined by this class to alleviate the need for instantiation.

Changed in version 3.5: As part of **PEP 489**, the builtin importer now implements `Loader.create_module()` and `Loader.exec_module()`

`class importlib.machinery.FrozenImporter`
An *importer* for frozen modules. This class implements the *importlib.abc.MetaPathFinder* and *importlib.abc.InspectLoader* ABCs.

Only class methods are defined by this class to alleviate the need for instantiation.

`class importlib.machinery.WindowsRegistryFinder`
Finder for modules declared in the Windows registry. This class implements the *importlib.abc.MetaPathFinder* ABC.

Only class methods are defined by this class to alleviate the need for instantiation.

New in version 3.3.

Deprecated since version 3.6: Use *site* configuration instead. Future versions of Python may not enable this finder by default.

class importlib.machinery.**PathFinder**

A *Finder* for *sys.path* and package `__path__` attributes. This class implements the *importlib.abc.MetaPathFinder* ABC.

Only class methods are defined by this class to alleviate the need for instantiation.

classmethod find_spec(*fullname*, *path=None*, *target=None*)

Class method that attempts to find a *spec* for the module specified by *fullname* on *sys.path* or, if defined, on *path*. For each path entry that is searched, *sys.path_importer_cache* is checked. If a non-false object is found then it is used as the *path entry finder* to look for the module being searched for. If no entry is found in *sys.path_importer_cache*, then *sys.path_hooks* is searched for a finder for the path entry and, if found, is stored in *sys.path_importer_cache* along with being queried about the module. If no finder is ever found then `None` is both stored in the cache and returned.

New in version 3.4.

Changed in version 3.5: If the current working directory – represented by an empty string – is no longer valid then `None` is returned but no value is cached in *sys.path_importer_cache*.

classmethod find_module(*fullname*, *path=None*)

A legacy wrapper around *find_spec()*.

Deprecated since version 3.4: Use *find_spec()* instead.

classmethod invalidate_caches()

Calls *importlib.abc.PathEntryFinder.invalidate_caches()* on all finders stored in *sys.path_importer_cache* that define the method. Otherwise entries in *sys.path_importer_cache* set to `None` are deleted.

Changed in version 3.7: Entries of `None` in *sys.path_importer_cache* are deleted.

Changed in version 3.4: Calls objects in *sys.path_hooks* with the current working directory for `''` (i.e. the empty string).

class importlib.machinery.**FileFinder**(*path*, **loader_details*)

A concrete implementation of *importlib.abc.PathEntryFinder* which caches results from the file system.

The *path* argument is the directory for which the finder is in charge of searching.

The *loader_details* argument is a variable number of 2-item tuples each containing a loader and a sequence of file suffixes the loader recognizes. The loaders are expected to be callables which accept two arguments of the module's name and the path to the file found.

The finder will cache the directory contents as necessary, making stat calls for each module search to verify the cache is not outdated. Because cache staleness relies upon the granularity of the operating system's state information of the file system, there is a potential race condition of searching for a module, creating a new file, and then searching for the module the new file represents. If the operations happen fast enough to fit within the granularity of stat calls, then the module search will fail. To prevent this from happening, when you create a module dynamically, make sure to call *importlib.invalidate_caches()*.

New in version 3.3.

path

The path the finder will search in.

find_spec(*fullname*, *target=None*)

Attempt to find the spec to handle *fullname* within *path*.

New in version 3.4.

find_loader(*fullname*)
Attempt to find the loader to handle *fullname* within *path*.

invalidate_caches()
Clear out the internal cache.

classmethod path_hook(**loader_details*)
A class method which returns a closure for use on *sys.path_hooks*. An instance of *FileFinder* is returned by the closure using the path argument given to the closure directly and *loader_details* indirectly.

If the argument to the closure is not an existing directory, *ImportError* is raised.

class importlib.machinery.SourceFileLoader(*fullname*, *path*)
A concrete implementation of *importlib.abc.SourceLoader* by subclassing *importlib.abc.FileLoader* and providing some concrete implementations of other methods.

New in version 3.3.

name
The name of the module that this loader will handle.

path
The path to the source file.

is_package(*fullname*)
Return true if *path* appears to be for a package.

path_stats(*path*)
Concrete implementation of *importlib.abc.SourceLoader.path_stats()*.

set_data(*path*, *data*)
Concrete implementation of *importlib.abc.SourceLoader.set_data()*.

load_module(*name=None*)
Concrete implementation of *importlib.abc.Loader.load_module()* where specifying the name of the module to load is optional.

Deprecated since version 3.6: Use *importlib.abc.Loader.exec_module()* instead.

class importlib.machinery.SourcelessFileLoader(*fullname*, *path*)
A concrete implementation of *importlib.abc.FileLoader* which can import bytecode files (i.e. no source code files exist).

Please note that direct use of bytecode files (and thus not source code files) inhibits your modules from being usable by all Python implementations or new versions of Python which change the bytecode format.

New in version 3.3.

name
The name of the module the loader will handle.

path
The path to the bytecode file.

is_package(*fullname*)
Determines if the module is a package based on *path*.

get_code(*fullname*)
Returns the code object for *name* created from *path*.

get_source(*fullname*)
Returns `None` as bytecode files have no source when this loader is used.

load_module(*name=None*)

Concrete implementation of *importlib.abc.Loader.load_module()* where specifying the name of the module to load is optional.

Deprecated since version 3.6: Use *importlib.abc.Loader.exec_module()* instead.

class importlib.machinery.**ExtensionFileLoader**(*fullname*, *path*)

A concrete implementation of *importlib.abc.ExecutionLoader* for extension modules.

The *fullname* argument specifies the name of the module the loader is to support. The *path* argument is the path to the extension module's file.

New in version 3.3.

name

Name of the module the loader supports.

path

Path to the extension module.

create_module(*spec*)

Creates the module object from the given specification in accordance with **PEP 489**.

New in version 3.5.

exec_module(*module*)

Initializes the given module object in accordance with **PEP 489**.

New in version 3.5.

is_package(*fullname*)

Returns `True` if the file path points to a package's `__init__` module based on *EXTENSION_SUFFIXES*.

get_code(*fullname*)

Returns `None` as extension modules lack a code object.

get_source(*fullname*)

Returns `None` as extension modules do not have source code.

get_filename(*fullname*)

Returns *path*.

New in version 3.4.

class importlib.machinery.**ModuleSpec**(*name*, *loader*, ***, *origin=None*, *loader_state=None*, *is_package=None*)

A specification for a module's import-system-related state. This is typically exposed as the module's `__spec__` attribute. In the descriptions below, the names in parentheses give the corresponding attribute available directly on the module object. E.g. `module.__spec__.origin == module.__file__`. Note however that while the *values* are usually equivalent, they can differ since there is no synchronization between the two objects. Thus it is possible to update the module's `__path__` at runtime, and this will not be automatically reflected in `__spec__.submodule_search_locations`.

New in version 3.4.

name

(`__name__`)

A string for the fully-qualified name of the module.

loader

(`__loader__`)

The loader to use for loading. For namespace packages this should be set to `None`.

origin

(__file__)

Name of the place from which the module is loaded, e.g. "builtin" for built-in modules and the filename for modules loaded from source. Normally "origin" should be set, but it may be None (the default) which indicates it is unspecified (e.g. for namespace packages).

submodule_search_locations

(__path__)

List of strings for where to find submodules, if a package (None otherwise).

loader_state

Container of extra module-specific data for use during loading (or None).

cached

(__cached__)

String for where the compiled module should be stored (or None).

parent

(__package__)

(Read-only) Fully-qualified name of the package to which the module belongs as a submodule (or None).

has_location

Boolean indicating whether or not the module's "origin" attribute refers to a loadable location.

32.5.6 importlib.util – Utility code for importers

Source code: Lib/importlib/util.py

This module contains the various objects that help in the construction of an *importer*.

importlib.util.**MAGIC_NUMBER**

The bytes which represent the bytecode version number. If you need help with loading/writing bytecode then consider *importlib.abc.SourceLoader*.

New in version 3.4.

importlib.util.**cache_from_source**(*path*, *debug_override=None*, ***, *optimization=None*)

Return the **PEP 3147**/**PEP 488** path to the byte-compiled file associated with the source *path*. For example, if *path* is /foo/bar/baz.py the return value would be /foo/bar/__pycache__/baz.cpython-32.pyc for Python 3.2. The cpython-32 string comes from the current magic tag (see get_tag(); if sys.implementation.cache_tag is not defined then *NotImplementedError* will be raised).

The *optimization* parameter is used to specify the optimization level of the bytecode file. An empty string represents no optimization, so /foo/bar/baz.py with an *optimization* of '' will result in a bytecode path of /foo/bar/__pycache__/baz.cpython-32.pyc. None causes the interpter's optimization level to be used. Any other value's string representation being used, so /foo/bar/baz.py with an *optimization* of 2 will lead to the bytecode path of /foo/bar/__pycache__/baz.cpython-32.opt-2.pyc. The string representation of *optimization* can only be alphanumeric, else *ValueError* is raised.

The *debug_override* parameter is deprecated and can be used to override the system's value for __debug__. A True value is the equivalent of setting *optimization* to the empty string. A False

value is the same as setting *optimization* to `1`. If both *debug_override* an *optimization* are not `None` then *TypeError* is raised.

New in version 3.4.

Changed in version 3.5: The *optimization* parameter was added and the *debug_override* parameter was deprecated.

Changed in version 3.6: Accepts a *path-like object*.

`importlib.util.source_from_cache(path)`
Given the *path* to a **PEP 3147** file name, return the associated source code file path. For example, if *path* is `/foo/bar/__pycache__/baz.cpython-32.pyc` the returned path would be `/foo/bar/baz.py`. *path* need not exist, however if it does not conform to **PEP 3147** or **PEP 488** format, a `ValueError` is raised. If `sys.implementation.cache_tag` is not defined, *NotImplementedError* is raised.

New in version 3.4.

Changed in version 3.6: Accepts a *path-like object*.

`importlib.util.decode_source(source_bytes)`
Decode the given bytes representing source code and return it as a string with universal newlines (as required by *importlib.abc.InspectLoader.get_source()*).

New in version 3.4.

`importlib.util.resolve_name(name, package)`
Resolve a relative module name to an absolute one.

If **name** has no leading dots, then **name** is simply returned. This allows for usage such as `importlib.util.resolve_name('sys', __package__)` without doing a check to see if the **package** argument is needed.

ValueError is raised if **name** is a relative module name but package is a false value (e.g. `None` or the empty string). *ValueError* is also raised a relative name would escape its containing package (e.g. requesting `..bacon` from within the `spam` package).

New in version 3.3.

`importlib.util.find_spec(name, package=None)`
Find the *spec* for a module, optionally relative to the specified **package** name. If the module is in *sys.modules*, then `sys.modules[name].__spec__` is returned (unless the spec would be `None` or is not set, in which case *ValueError* is raised). Otherwise a search using *sys.meta_path* is done. `None` is returned if no spec is found.

If **name** is for a submodule (contains a dot), the parent module is automatically imported.

name and **package** work the same as for `import_module()`.

New in version 3.4.

Changed in version 3.7: Raises *ModuleNotFoundError* instead of *AttributeError* if **package** is in fact not a package (i.e. lacks a `__path__` attribute).

`importlib.util.module_from_spec(spec)`
Create a new module based on **spec** and *spec.loader.create_module*.

If *spec.loader.create_module* does not return `None`, then any pre-existing attributes will not be reset. Also, no *AttributeError* will be raised if triggered while accessing **spec** or setting an attribute on the module.

This function is preferred over using *types.ModuleType* to create a new module as **spec** is used to set as many import-controlled attributes on the module as possible.

New in version 3.5.

`@importlib.util.module_for_loader`

A *decorator* for *importlib.abc.Loader.load_module()* to handle selecting the proper module object to load with. The decorated method is expected to have a call signature taking two positional arguments (e.g. `load_module(self, module)`) for which the second argument will be the module **object** to be used by the loader. Note that the decorator will not work on static methods because of the assumption of two arguments.

The decorated method will take in the **name** of the module to be loaded as expected for a *loader*. If the module is not found in *sys.modules* then a new one is constructed. Regardless of where the module came from, `__loader__` set to **self** and `__package__` is set based on what *importlib.abc.InspectLoader.is_package()* returns (if available). These attributes are set unconditionally to support reloading.

If an exception is raised by the decorated method and a module was added to *sys.modules*, then the module will be removed to prevent a partially initialized module from being in left in *sys.modules*. If the module was already in *sys.modules* then it is left alone.

Changed in version 3.3: `__loader__` and `__package__` are automatically set (when possible).

Changed in version 3.4: Set `__name__`, `__loader__` `__package__` unconditionally to support reloading.

Deprecated since version 3.4: The import machinery now directly performs all the functionality provided by this function.

`@importlib.util.set_loader`

A *decorator* for *importlib.abc.Loader.load_module()* to set the `__loader__` attribute on the returned module. If the attribute is already set the decorator does nothing. It is assumed that the first positional argument to the wrapped method (i.e. `self`) is what `__loader__` should be set to.

Changed in version 3.4: Set `__loader__` if set to `None`, as if the attribute does not exist.

Deprecated since version 3.4: The import machinery takes care of this automatically.

`@importlib.util.set_package`

A *decorator* for *importlib.abc.Loader.load_module()* to set the `__package__` attribute on the returned module. If `__package__` is set and has a value other than `None` it will not be changed.

Deprecated since version 3.4: The import machinery takes care of this automatically.

`importlib.util.spec_from_loader`(*name*, *loader*, ***, *origin=None*, *is_package=None*)

A factory function for creating a `ModuleSpec` instance based on a loader. The parameters have the same meaning as they do for ModuleSpec. The function uses available *loader* APIs, such as `InspectLoader.is_package()`, to fill in any missing information on the spec.

New in version 3.4.

`importlib.util.spec_from_file_location`(*name*, *location*, ***, *loader=None*, *submodule_search_locations=None*)

A factory function for creating a `ModuleSpec` instance based on the path to a file. Missing information will be filled in on the spec by making use of loader APIs and by the implication that the module will be file-based.

New in version 3.4.

Changed in version 3.6: Accepts a *path-like object*.

`importlib.util.source_hash`(*source_bytes*)

Return the hash of *source_bytes* as bytes. A hash-based `.pyc` file embeds the *source_hash()* of the corresponding source file's contents in its header.

New in version 3.7.

`class importlib.util.LazyLoader`(*loader*)

A class which postpones the execution of the loader of a module until the module has an attribute accessed.

This class **only** works with loaders that define *exec_module()* as control over what module type is used for the module is required. For those same reasons, the loader's *create_module()* method must return `None` or a type for which its `__class__` attribute can be mutated along with not using *slots*. Finally, modules which substitute the object placed into *sys.modules* will not work as there is no way to properly replace the module references throughout the interpreter safely; *ValueError* is raised if such a substitution is detected.

Note: For projects where startup time is critical, this class allows for potentially minimizing the cost of loading a module if it is never used. For projects where startup time is not essential then use of this class is **heavily** discouraged due to error messages created during loading being postponed and thus occurring out of context.

New in version 3.5.

Changed in version 3.6: Began calling *create_module()*, removing the compatibility warning for *importlib.machinery.BuiltinImporter* and *importlib.machinery.ExtensionFileLoader*.

classmethod factory(*loader*)

A static method which returns a callable that creates a lazy loader. This is meant to be used in situations where the loader is passed by class instead of by instance.

```
suffixes = importlib.machinery.SOURCE_SUFFIXES
loader = importlib.machinery.SourceFileLoader
lazy_loader = importlib.util.LazyLoader.factory(loader)
finder = importlib.machinery.FileFinder(path, (lazy_loader, suffixes))
```

32.5.7 Examples

Importing programmatically

To programmatically import a module, use *importlib.import_module()*.

```
import importlib

itertools = importlib.import_module('itertools')
```

Checking if a module can be imported

If you need to find out if a module can be imported without actually doing the import, then you should use *importlib.util.find_spec()*.

```
import importlib.util
import sys

# For illustrative purposes.
name = 'itertools'

spec = importlib.util.find_spec(name)
if spec is None:
    print("can't find the itertools module")
else:
    # If you chose to perform the actual import ...
    module = importlib.util.module_from_spec(spec)
```

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```
    spec.loader.exec_module(module)
    # Adding the module to sys.modules is optional.
    sys.modules[name] = module
```

Importing a source file directly

To import a Python source file directly, use the following recipe (Python 3.4 and newer only):

```
import importlib.util
import sys

# For illustrative purposes.
import tokenize
file_path = tokenize.__file__
module_name = tokenize.__name__

spec = importlib.util.spec_from_file_location(module_name, file_path)
module = importlib.util.module_from_spec(spec)
spec.loader.exec_module(module)
# Optional; only necessary if you want to be able to import the module
# by name later.
sys.modules[module_name] = module
```

Setting up an importer

For deep customizations of import, you typically want to implement an *importer*. This means managing both the *finder* and *loader* side of things. For finders there are two flavours to choose from depending on your needs: a *meta path finder* or a *path entry finder*. The former is what you would put on *sys.meta_path* while the latter is what you create using a *path entry hook* on *sys.path_hooks* which works with *sys.path* entries to potentially create a finder. This example will show you how to register your own importers so that import will use them (for creating an importer for yourself, read the documentation for the appropriate classes defined within this package):

```
import importlib.machinery
import sys

# For illustrative purposes only.
SpamMetaPathFinder = importlib.machinery.PathFinder
SpamPathEntryFinder = importlib.machinery.FileFinder
loader_details = (importlib.machinery.SourceFileLoader,
                  importlib.machinery.SOURCE_SUFFIXES)

# Setting up a meta path finder.
# Make sure to put the finder in the proper location in the list in terms of
# priority.
sys.meta_path.append(SpamMetaPathFinder)

# Setting up a path entry finder.
# Make sure to put the path hook in the proper location in the list in terms
# of priority.
sys.path_hooks.append(SpamPathEntryFinder.path_hook(loader_details))
```

Approximating `importlib.import_module()`

Import itself is implemented in Python code, making it possible to expose most of the import machinery through importlib. The following helps illustrate the various APIs that importlib exposes by providing an approximate implementation of *importlib.import_module()* (Python 3.4 and newer for the importlib usage, Python 3.6 and newer for other parts of the code).

```
import importlib.util
import sys

def import_module(name, package=None):
    """An approximate implementation of import."""
    absolute_name = importlib.util.resolve_name(name, package)
    try:
        return sys.modules[absolute_name]
    except KeyError:
        pass

    path = None
    if '.' in absolute_name:
        parent_name, _, child_name = absolute_name.rpartition('.')
        parent_module = import_module(parent_name)
        path = parent_module.spec.submodule_search_locations
    for finder in sys.meta_path:
        spec = finder.find_spec(absolute_name, path)
        if spec is not None:
            break
    else:
        raise ImportError(f'No module named {absolute_name!r}')
    module = importlib.util.module_from_spec(spec)
    spec.loader.exec_module(module)
    sys.modules[absolute_name] = module
    if path is not None:
        setattr(parent_module, child_name, module)
    return module
```

CHAPTER

THIRTYTHREE

PYTHON LANGUAGE SERVICES

Python provides a number of modules to assist in working with the Python language. These modules support tokenizing, parsing, syntax analysis, bytecode disassembly, and various other facilities.

These modules include:

33.1 `parser` — Access Python parse trees

The *parser* module provides an interface to Python's internal parser and byte-code compiler. The primary purpose for this interface is to allow Python code to edit the parse tree of a Python expression and create executable code from this. This is better than trying to parse and modify an arbitrary Python code fragment as a string because parsing is performed in a manner identical to the code forming the application. It is also faster.

Note: From Python 2.5 onward, it's much more convenient to cut in at the Abstract Syntax Tree (AST) generation and compilation stage, using the *ast* module.

There are a few things to note about this module which are important to making use of the data structures created. This is not a tutorial on editing the parse trees for Python code, but some examples of using the *parser* module are presented.

Most importantly, a good understanding of the Python grammar processed by the internal parser is required. For full information on the language syntax, refer to reference-index. The parser itself is created from a grammar specification defined in the file `Grammar/Grammar` in the standard Python distribution. The parse trees stored in the ST objects created by this module are the actual output from the internal parser when created by the *expr()* or *suite()* functions, described below. The ST objects created by *sequence2st()* faithfully simulate those structures. Be aware that the values of the sequences which are considered "correct" will vary from one version of Python to another as the formal grammar for the language is revised. However, transporting code from one Python version to another as source text will always allow correct parse trees to be created in the target version, with the only restriction being that migrating to an older version of the interpreter will not support more recent language constructs. The parse trees are not typically compatible from one version to another, whereas source code has always been forward-compatible.

Each element of the sequences returned by *st2list()* or *st2tuple()* has a simple form. Sequences representing non-terminal elements in the grammar always have a length greater than one. The first element is an integer which identifies a production in the grammar. These integers are given symbolic names in the C header file `Include/graminit.h` and the Python module *symbol*. Each additional element of the sequence represents a component of the production as recognized in the input string: these are always sequences which have the same form as the parent. An important aspect of this structure which should be noted is that keywords used to identify the parent node type, such as the keyword `if` in an `if_stmt`, are included

in the node tree without any special treatment. For example, the `if` keyword is represented by the tuple `(1, 'if')`, where `1` is the numeric value associated with all `NAME` tokens, including variable and function names defined by the user. In an alternate form returned when line number information is requested, the same token might be represented as `(1, 'if', 12)`, where the `12` represents the line number at which the terminal symbol was found.

Terminal elements are represented in much the same way, but without any child elements and the addition of the source text which was identified. The example of the `if` keyword above is representative. The various types of terminal symbols are defined in the C header file `Include/token.h` and the Python module *token*.

The ST objects are not required to support the functionality of this module, but are provided for three purposes: to allow an application to amortize the cost of processing complex parse trees, to provide a parse tree representation which conserves memory space when compared to the Python list or tuple representation, and to ease the creation of additional modules in C which manipulate parse trees. A simple "wrapper" class may be created in Python to hide the use of ST objects.

The *parser* module defines functions for a few distinct purposes. The most important purposes are to create ST objects and to convert ST objects to other representations such as parse trees and compiled code objects, but there are also functions which serve to query the type of parse tree represented by an ST object.

See also:

Module *symbol* Useful constants representing internal nodes of the parse tree.

Module *token* Useful constants representing leaf nodes of the parse tree and functions for testing node values.

33.1.1 Creating ST Objects

ST objects may be created from source code or from a parse tree. When creating an ST object from source, different functions are used to create the `'eval'` and `'exec'` forms.

`parser.expr`(*source*)
: The *expr()* function parses the parameter *source* as if it were an input to `compile(source, 'file.py', 'eval')`. If the parse succeeds, an ST object is created to hold the internal parse tree representation, otherwise an appropriate exception is raised.

`parser.suite`(*source*)
: The *suite()* function parses the parameter *source* as if it were an input to `compile(source, 'file.py', 'exec')`. If the parse succeeds, an ST object is created to hold the internal parse tree representation, otherwise an appropriate exception is raised.

`parser.sequence2st`(*sequence*)
: This function accepts a parse tree represented as a sequence and builds an internal representation if possible. If it can validate that the tree conforms to the Python grammar and all nodes are valid node types in the host version of Python, an ST object is created from the internal representation and returned to the called. If there is a problem creating the internal representation, or if the tree cannot be validated, a *ParserError* exception is raised. An ST object created this way should not be assumed to compile correctly; normal exceptions raised by compilation may still be initiated when the ST object is passed to *compilest()*. This may indicate problems not related to syntax (such as a *MemoryError* exception), but may also be due to constructs such as the result of parsing `del f(0)`, which escapes the Python parser but is checked by the bytecode compiler.

  Sequences representing terminal tokens may be represented as either two-element lists of the form `(1, 'name')` or as three-element lists of the form `(1, 'name', 56)`. If the third element is present, it is assumed to be a valid line number. The line number may be specified for any subset of the terminal symbols in the input tree.

`parser.tuple2st`(*sequence*)
: This is the same function as *sequence2st()*. This entry point is maintained for backward compatibility.

33.1.2 Converting ST Objects

ST objects, regardless of the input used to create them, may be converted to parse trees represented as list- or tuple- trees, or may be compiled into executable code objects. Parse trees may be extracted with or without line numbering information.

`parser.st2list`(*st*, *line_info=False*, *col_info=False*)
This function accepts an ST object from the caller in *st* and returns a Python list representing the equivalent parse tree. The resulting list representation can be used for inspection or the creation of a new parse tree in list form. This function does not fail so long as memory is available to build the list representation. If the parse tree will only be used for inspection, *st2tuple()* should be used instead to reduce memory consumption and fragmentation. When the list representation is required, this function is significantly faster than retrieving a tuple representation and converting that to nested lists.

If *line_info* is true, line number information will be included for all terminal tokens as a third element of the list representing the token. Note that the line number provided specifies the line on which the token *ends*. This information is omitted if the flag is false or omitted.

`parser.st2tuple`(*st*, *line_info=False*, *col_info=False*)
This function accepts an ST object from the caller in *st* and returns a Python tuple representing the equivalent parse tree. Other than returning a tuple instead of a list, this function is identical to *st2list()*.

If *line_info* is true, line number information will be included for all terminal tokens as a third element of the list representing the token. This information is omitted if the flag is false or omitted.

`parser.compilest`(*st*, *filename='<syntax-tree>'*)
The Python byte compiler can be invoked on an ST object to produce code objects which can be used as part of a call to the built-in *exec()* or *eval()* functions. This function provides the interface to the compiler, passing the internal parse tree from *st* to the parser, using the source file name specified by the *filename* parameter. The default value supplied for *filename* indicates that the source was an ST object.

Compiling an ST object may result in exceptions related to compilation; an example would be a *SyntaxError* caused by the parse tree for `del f(0)`: this statement is considered legal within the formal grammar for Python but is not a legal language construct. The *SyntaxError* raised for this condition is actually generated by the Python byte-compiler normally, which is why it can be raised at this point by the *parser* module. Most causes of compilation failure can be diagnosed programmatically by inspection of the parse tree.

33.1.3 Queries on ST Objects

Two functions are provided which allow an application to determine if an ST was created as an expression or a suite. Neither of these functions can be used to determine if an ST was created from source code via *expr()* or *suite()* or from a parse tree via *sequence2st()*.

`parser.isexpr`(*st*)
When *st* represents an `'eval'` form, this function returns true, otherwise it returns false. This is useful, since code objects normally cannot be queried for this information using existing built-in functions. Note that the code objects created by *compilest()* cannot be queried like this either, and are identical to those created by the built-in *compile()* function.

`parser.issuite`(*st*)
This function mirrors *isexpr()* in that it reports whether an ST object represents an `'exec'` form, commonly known as a "suite." It is not safe to assume that this function is equivalent to `not isexpr(st)`, as additional syntactic fragments may be supported in the future.

33.1.4 Exceptions and Error Handling

The parser module defines a single exception, but may also pass other built-in exceptions from other portions of the Python runtime environment. See each function for information about the exceptions it can raise.

exception parser.ParserError
Exception raised when a failure occurs within the parser module. This is generally produced for validation failures rather than the built-in *SyntaxError* raised during normal parsing. The exception argument is either a string describing the reason of the failure or a tuple containing a sequence causing the failure from a parse tree passed to *sequence2st()* and an explanatory string. Calls to *sequence2st()* need to be able to handle either type of exception, while calls to other functions in the module will only need to be aware of the simple string values.

Note that the functions *compilest()*, *expr()*, and *suite()* may raise exceptions which are normally raised by the parsing and compilation process. These include the built in exceptions *MemoryError*, *OverflowError*, *SyntaxError*, and *SystemError*. In these cases, these exceptions carry all the meaning normally associated with them. Refer to the descriptions of each function for detailed information.

33.1.5 ST Objects

Ordered and equality comparisons are supported between ST objects. Pickling of ST objects (using the *pickle* module) is also supported.

parser.STType
The type of the objects returned by *expr()*, *suite()* and *sequence2st()*.

ST objects have the following methods:

ST.compile(*filename='<syntax-tree>'*)
Same as `compilest(st, filename)`.

ST.isexpr()
Same as `isexpr(st)`.

ST.issuite()
Same as `issuite(st)`.

ST.tolist(*line_info=False*, *col_info=False*)
Same as `st2list(st, line_info, col_info)`.

ST.totuple(*line_info=False*, *col_info=False*)
Same as `st2tuple(st, line_info, col_info)`.

33.1.6 Example: Emulation of `compile()`

While many useful operations may take place between parsing and bytecode generation, the simplest operation is to do nothing. For this purpose, using the *parser* module to produce an intermediate data structure is equivalent to the code

```
>>> code = compile('a + 5', 'file.py', 'eval')
>>> a = 5
>>> eval(code)
10
```

The equivalent operation using the *parser* module is somewhat longer, and allows the intermediate internal parse tree to be retained as an ST object:

```
>>> import parser
>>> st = parser.expr('a + 5')
>>> code = st.compile('file.py')
>>> a = 5
>>> eval(code)
10
```

An application which needs both ST and code objects can package this code into readily available functions:

```
import parser

def load_suite(source_string):
    st = parser.suite(source_string)
    return st, st.compile()

def load_expression(source_string):
    st = parser.expr(source_string)
    return st, st.compile()
```

33.2 ast — Abstract Syntax Trees

Source code: Lib/ast.py

The *ast* module helps Python applications to process trees of the Python abstract syntax grammar. The abstract syntax itself might change with each Python release; this module helps to find out programmatically what the current grammar looks like.

An abstract syntax tree can be generated by passing `ast.PyCF_ONLY_AST` as a flag to the *compile()* built-in function, or using the *parse()* helper provided in this module. The result will be a tree of objects whose classes all inherit from *ast.AST*. An abstract syntax tree can be compiled into a Python code object using the built-in *compile()* function.

33.2.1 Node classes

class ast.AST

This is the base of all AST node classes. The actual node classes are derived from the `Parser/Python.asdl` file, which is reproduced *below*. They are defined in the `_ast` C module and re-exported in *ast*.

There is one class defined for each left-hand side symbol in the abstract grammar (for example, `ast.stmt` or `ast.expr`). In addition, there is one class defined for each constructor on the right-hand side; these classes inherit from the classes for the left-hand side trees. For example, `ast.BinOp` inherits from `ast.expr`. For production rules with alternatives (aka "sums"), the left-hand side class is abstract: only instances of specific constructor nodes are ever created.

_fields

Each concrete class has an attribute *_fields* which gives the names of all child nodes.

Each instance of a concrete class has one attribute for each child node, of the type as defined in the grammar. For example, `ast.BinOp` instances have an attribute `left` of type `ast.expr`.

If these attributes are marked as optional in the grammar (using a question mark), the value might be `None`. If the attributes can have zero-or-more values (marked with an asterisk), the

values are represented as Python lists. All possible attributes must be present and have valid values when compiling an AST with *compile()*.

lineno
col_offset
Instances of `ast.expr` and `ast.stmt` subclasses have *lineno* and *col_offset* attributes. The *lineno* is the line number of source text (1-indexed so the first line is line 1) and the *col_offset* is the UTF-8 byte offset of the first token that generated the node. The UTF-8 offset is recorded because the parser uses UTF-8 internally.

The constructor of a class `ast.T` parses its arguments as follows:

- If there are positional arguments, there must be as many as there are items in `T._fields`; they will be assigned as attributes of these names.
- If there are keyword arguments, they will set the attributes of the same names to the given values.

For example, to create and populate an `ast.UnaryOp` node, you could use

```
node = ast.UnaryOp()
node.op = ast.USub()
node.operand = ast.Num()
node.operand.n = 5
node.operand.lineno = 0
node.operand.col_offset = 0
node.lineno = 0
node.col_offset = 0
```

or the more compact

```
node = ast.UnaryOp(ast.USub(), ast.Num(5, lineno=0, col_offset=0),
                   lineno=0, col_offset=0)
```

33.2.2 Abstract Grammar

The abstract grammar is currently defined as follows:

```
-- ASDL's 7 builtin types are:
-- identifier, int, string, bytes, object, singleton, constant
--
-- singleton: None, True or False
-- constant can be None, whereas None means "no value" for object.

module Python
{
    mod = Module(stmt* body)
        | Interactive(stmt* body)
        | Expression(expr body)

        -- not really an actual node but useful in Jython's typesystem.
        | Suite(stmt* body)

    stmt = FunctionDef(identifier name, arguments args,
                       stmt* body, expr* decorator_list, expr? returns)
          | AsyncFunctionDef(identifier name, arguments args,
                             stmt* body, expr* decorator_list, expr? returns)

          | ClassDef(identifier name,
```

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```
           expr* bases,
           keyword* keywords,
           stmt* body,
           expr* decorator_list)
         | Return(expr? value)

         | Delete(expr* targets)
         | Assign(expr* targets, expr value)
         | AugAssign(expr target, operator op, expr value)
         -- 'simple' indicates that we annotate simple name without parens
         | AnnAssign(expr target, expr annotation, expr? value, int simple)

         -- use 'orelse' because else is a keyword in target languages
         | For(expr target, expr iter, stmt* body, stmt* orelse)
         | AsyncFor(expr target, expr iter, stmt* body, stmt* orelse)
         | While(expr test, stmt* body, stmt* orelse)
         | If(expr test, stmt* body, stmt* orelse)
         | With(withitem* items, stmt* body)
         | AsyncWith(withitem* items, stmt* body)

         | Raise(expr? exc, expr? cause)
         | Try(stmt* body, excepthandler* handlers, stmt* orelse, stmt* finalbody)
         | Assert(expr test, expr? msg)

         | Import(alias* names)
         | ImportFrom(identifier? module, alias* names, int? level)

         | Global(identifier* names)
         | Nonlocal(identifier* names)
         | Expr(expr value)
         | Pass | Break | Continue

         -- XXX Jython will be different
         -- col_offset is the byte offset in the utf8 string the parser uses
         attributes (int lineno, int col_offset)

         -- BoolOp() can use left & right?
    expr = BoolOp(boolop op, expr* values)
         | BinOp(expr left, operator op, expr right)
         | UnaryOp(unaryop op, expr operand)
         | Lambda(arguments args, expr body)
         | IfExp(expr test, expr body, expr orelse)
         | Dict(expr* keys, expr* values)
         | Set(expr* elts)
         | ListComp(expr elt, comprehension* generators)
         | SetComp(expr elt, comprehension* generators)
         | DictComp(expr key, expr value, comprehension* generators)
         | GeneratorExp(expr elt, comprehension* generators)
         -- the grammar constrains where yield expressions can occur
         | Await(expr value)
         | Yield(expr? value)
         | YieldFrom(expr value)
         -- need sequences for compare to distinguish between
         -- x < 4 < 3 and (x < 4) < 3
         | Compare(expr left, cmpop* ops, expr* comparators)
         | Call(expr func, expr* args, keyword* keywords)
```

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```
         | Num(object n) -- a number as a PyObject.
         | Str(string s) -- need to specify raw, unicode, etc?
         | FormattedValue(expr value, int? conversion, expr? format_spec)
         | JoinedStr(expr* values)
         | Bytes(bytes s)
         | NameConstant(singleton value)
         | Ellipsis
         | Constant(constant value)

        -- the following expression can appear in assignment context
         | Attribute(expr value, identifier attr, expr_context ctx)
         | Subscript(expr value, slice slice, expr_context ctx)
         | Starred(expr value, expr_context ctx)
         | Name(identifier id, expr_context ctx)
         | List(expr* elts, expr_context ctx)
         | Tuple(expr* elts, expr_context ctx)

          -- col_offset is the byte offset in the utf8 string the parser uses
          attributes (int lineno, int col_offset)

    expr_context = Load | Store | Del | AugLoad | AugStore | Param

    slice = Slice(expr? lower, expr? upper, expr? step)
          | ExtSlice(slice* dims)
          | Index(expr value)

    boolop = And | Or

    operator = Add | Sub | Mult | MatMult | Div | Mod | Pow | LShift
                 | RShift | BitOr | BitXor | BitAnd | FloorDiv

    unaryop = Invert | Not | UAdd | USub

    cmpop = Eq | NotEq | Lt | LtE | Gt | GtE | Is | IsNot | In | NotIn

    comprehension = (expr target, expr iter, expr* ifs, int is_async)

    excepthandler = ExceptHandler(expr? type, identifier? name, stmt* body)
                    attributes (int lineno, int col_offset)

    arguments = (arg* args, arg? vararg, arg* kwonlyargs, expr* kw_defaults,
                 arg? kwarg, expr* defaults)

    arg = (identifier arg, expr? annotation)
           attributes (int lineno, int col_offset)

    -- keyword arguments supplied to call (NULL identifier for **kwargs)
    keyword = (identifier? arg, expr value)

    -- import name with optional 'as' alias.
    alias = (identifier name, identifier? asname)

    withitem = (expr context_expr, expr? optional_vars)
}
```

33.2.3 ast Helpers

Apart from the node classes, the *ast* module defines these utility functions and classes for traversing abstract syntax trees:

ast.parse(*source*, *filename='<unknown>'*, *mode='exec'*)
Parse the source into an AST node. Equivalent to `compile(source, filename, mode, ast.PyCF_ONLY_AST)`.

> **Warning:** It is possible to crash the Python interpreter with a sufficiently large/complex string due to stack depth limitations in Python's AST compiler.

ast.literal_eval(*node_or_string*)
Safely evaluate an expression node or a string containing a Python literal or container display. The string or node provided may only consist of the following Python literal structures: strings, bytes, numbers, tuples, lists, dicts, sets, booleans, and `None`.

This can be used for safely evaluating strings containing Python values from untrusted sources without the need to parse the values oneself. It is not capable of evaluating arbitrarily complex expressions, for example involving operators or indexing.

> **Warning:** It is possible to crash the Python interpreter with a sufficiently large/complex string due to stack depth limitations in Python's AST compiler.

Changed in version 3.2: Now allows bytes and set literals.

ast.get_docstring(*node*, *clean=True*)
Return the docstring of the given *node* (which must be a `FunctionDef`, `AsyncFunctionDef`, `ClassDef`, or `Module` node), or `None` if it has no docstring. If *clean* is true, clean up the docstring's indentation with *inspect.cleandoc()*.

Changed in version 3.5: `AsyncFunctionDef` is now supported.

ast.fix_missing_locations(*node*)
When you compile a node tree with *compile()*, the compiler expects `lineno` and `col_offset` attributes for every node that supports them. This is rather tedious to fill in for generated nodes, so this helper adds these attributes recursively where not already set, by setting them to the values of the parent node. It works recursively starting at *node*.

ast.increment_lineno(*node*, *n=1*)
Increment the line number of each node in the tree starting at *node* by *n*. This is useful to "move code" to a different location in a file.

ast.copy_location(*new_node*, *old_node*)
Copy source location (`lineno` and `col_offset`) from *old_node* to *new_node* if possible, and return *new_node*.

ast.iter_fields(*node*)
Yield a tuple of `(fieldname, value)` for each field in `node._fields` that is present on *node*.

ast.iter_child_nodes(*node*)
Yield all direct child nodes of *node*, that is, all fields that are nodes and all items of fields that are lists of nodes.

ast.walk(*node*)
Recursively yield all descendant nodes in the tree starting at *node* (including *node* itself), in no specified order. This is useful if you only want to modify nodes in place and don't care about the context.

class ast.NodeVisitor

A node visitor base class that walks the abstract syntax tree and calls a visitor function for every node found. This function may return a value which is forwarded by the *visit()* method.

This class is meant to be subclassed, with the subclass adding visitor methods.

visit(*node*)

Visit a node. The default implementation calls the method called `self.visit_`*classname* where *classname* is the name of the node class, or *generic_visit()* if that method doesn't exist.

generic_visit(*node*)

This visitor calls *visit()* on all children of the node.

Note that child nodes of nodes that have a custom visitor method won't be visited unless the visitor calls *generic_visit()* or visits them itself.

Don't use the *NodeVisitor* if you want to apply changes to nodes during traversal. For this a special visitor exists (*NodeTransformer*) that allows modifications.

class ast.NodeTransformer

A *NodeVisitor* subclass that walks the abstract syntax tree and allows modification of nodes.

The *NodeTransformer* will walk the AST and use the return value of the visitor methods to replace or remove the old node. If the return value of the visitor method is `None`, the node will be removed from its location, otherwise it is replaced with the return value. The return value may be the original node in which case no replacement takes place.

Here is an example transformer that rewrites all occurrences of name lookups (`foo`) to `data['foo']`:

```
class RewriteName(NodeTransformer):

    def visit_Name(self, node):
        return copy_location(Subscript(
            value=Name(id='data', ctx=Load()),
            slice=Index(value=Str(s=node.id)),
            ctx=node.ctx
        ), node)
```

Keep in mind that if the node you're operating on has child nodes you must either transform the child nodes yourself or call the `generic_visit()` method for the node first.

For nodes that were part of a collection of statements (that applies to all statement nodes), the visitor may also return a list of nodes rather than just a single node.

Usually you use the transformer like this:

```
node = YourTransformer().visit(node)
```

ast.dump(*node*, *annotate_fields=True*, *include_attributes=False*)

Return a formatted dump of the tree in *node*. This is mainly useful for debugging purposes. The returned string will show the names and the values for fields. This makes the code impossible to evaluate, so if evaluation is wanted *annotate_fields* must be set to `False`. Attributes such as line numbers and column offsets are not dumped by default. If this is wanted, *include_attributes* can be set to `True`.

See also:

Green Tree Snakes, an external documentation resource, has good details on working with Python ASTs.

33.3 symtable — Access to the compiler's symbol tables

Source code: Lib/symtable.py

Symbol tables are generated by the compiler from AST just before bytecode is generated. The symbol table is responsible for calculating the scope of every identifier in the code. *symtable* provides an interface to examine these tables.

33.3.1 Generating Symbol Tables

symtable.symtable(*code*, *filename*, *compile_type*)
Return the toplevel *SymbolTable* for the Python source *code*. *filename* is the name of the file containing the code. *compile_type* is like the *mode* argument to *compile()*.

33.3.2 Examining Symbol Tables

class symtable.SymbolTable
A namespace table for a block. The constructor is not public.

get_type()
Return the type of the symbol table. Possible values are 'class', 'module', and 'function'.

get_id()
Return the table's identifier.

get_name()
Return the table's name. This is the name of the class if the table is for a class, the name of the function if the table is for a function, or 'top' if the table is global (*get_type()* returns 'module').

get_lineno()
Return the number of the first line in the block this table represents.

is_optimized()
Return True if the locals in this table can be optimized.

is_nested()
Return True if the block is a nested class or function.

has_children()
Return True if the block has nested namespaces within it. These can be obtained with *get_children()*.

has_exec()
Return True if the block uses exec.

get_identifiers()
Return a list of names of symbols in this table.

lookup(*name*)
Lookup *name* in the table and return a *Symbol* instance.

get_symbols()
Return a list of *Symbol* instances for names in the table.

get_children()
Return a list of the nested symbol tables.

class symtable.Function
A namespace for a function or method. This class inherits *SymbolTable*.

get_parameters()
Return a tuple containing names of parameters to this function.

get_locals()
Return a tuple containing names of locals in this function.

get_globals()
Return a tuple containing names of globals in this function.

get_frees()
Return a tuple containing names of free variables in this function.

class symtable.Class
A namespace of a class. This class inherits *SymbolTable*.

get_methods()
Return a tuple containing the names of methods declared in the class.

class symtable.Symbol
An entry in a *SymbolTable* corresponding to an identifier in the source. The constructor is not public.

get_name()
Return the symbol's name.

is_referenced()
Return **True** if the symbol is used in its block.

is_imported()
Return **True** if the symbol is created from an import statement.

is_parameter()
Return **True** if the symbol is a parameter.

is_global()
Return **True** if the symbol is global.

is_declared_global()
Return **True** if the symbol is declared global with a global statement.

is_local()
Return **True** if the symbol is local to its block.

is_free()
Return **True** if the symbol is referenced in its block, but not assigned to.

is_assigned()
Return **True** if the symbol is assigned to in its block.

is_namespace()
Return **True** if name binding introduces new namespace.

If the name is used as the target of a function or class statement, this will be true.

For example:

```
>>> table = symtable.symtable("def some_func(): pass", "string", "exec")
>>> table.lookup("some_func").is_namespace()
True
```

Note that a single name can be bound to multiple objects. If the result is **True**, the name may also be bound to other objects, like an int or list, that does not introduce a new namespace.

`get_namespaces()`
Return a list of namespaces bound to this name.

`get_namespace()`
Return the namespace bound to this name. If more than one namespace is bound, *ValueError* is raised.

33.4 `symbol` — Constants used with Python parse trees

Source code: Lib/symbol.py

This module provides constants which represent the numeric values of internal nodes of the parse tree. Unlike most Python constants, these use lower-case names. Refer to the file `Grammar/Grammar` in the Python distribution for the definitions of the names in the context of the language grammar. The specific numeric values which the names map to may change between Python versions.

This module also provides one additional data object:

`symbol.sym_name`
Dictionary mapping the numeric values of the constants defined in this module back to name strings, allowing more human-readable representation of parse trees to be generated.

33.5 `token` — Constants used with Python parse trees

Source code: Lib/token.py

This module provides constants which represent the numeric values of leaf nodes of the parse tree (terminal tokens). Refer to the file `Grammar/Grammar` in the Python distribution for the definitions of the names in the context of the language grammar. The specific numeric values which the names map to may change between Python versions.

The module also provides a mapping from numeric codes to names and some functions. The functions mirror definitions in the Python C header files.

`token.tok_name`
Dictionary mapping the numeric values of the constants defined in this module back to name strings, allowing more human-readable representation of parse trees to be generated.

`token.ISTERMINAL(`x`)`
Return true for terminal token values.

`token.ISNONTERMINAL(`x`)`
Return true for non-terminal token values.

`token.ISEOF(`x`)`
Return true if x is the marker indicating the end of input.

The token constants are:

`token.ENDMARKER`
`token.NAME`
`token.NUMBER`
`token.STRING`
`token.NEWLINE`

```
token.INDENT
token.DEDENT
token.LPAR
token.RPAR
token.LSQB
token.RSQB
token.COLON
token.COMMA
token.SEMI
token.PLUS
token.MINUS
token.STAR
token.SLASH
token.VBAR
token.AMPER
token.LESS
token.GREATER
token.EQUAL
token.DOT
token.PERCENT
token.LBRACE
token.RBRACE
token.EQEQUAL
token.NOTEQUAL
token.LESSEQUAL
token.GREATEREQUAL
token.TILDE
token.CIRCUMFLEX
token.LEFTSHIFT
token.RIGHTSHIFT
token.DOUBLESTAR
token.PLUSEQUAL
token.MINEQUAL
token.STAREQUAL
token.SLASHEQUAL
token.PERCENTEQUAL
token.AMPEREQUAL
token.VBAREQUAL
token.CIRCUMFLEXEQUAL
token.LEFTSHIFTEQUAL
token.RIGHTSHIFTEQUAL
token.DOUBLESTAREQUAL
token.DOUBLESLASH
token.DOUBLESLASHEQUAL
token.AT
token.ATEQUAL
token.RARROW
token.ELLIPSIS
token.OP
token.ERRORTOKEN
token.N_TOKENS
token.NT_OFFSET
```

The following token type values aren't used by the C tokenizer but are needed for the *tokenize* module.

`token.COMMENT`
Token value used to indicate a comment.

`token.NL`
Token value used to indicate a non-terminating newline. The *NEWLINE* token indicates the end of a logical line of Python code; `NL` tokens are generated when a logical line of code is continued over multiple physical lines.

`token.ENCODING`
Token value that indicates the encoding used to decode the source bytes into text. The first token returned by *tokenize.tokenize()* will always be an `ENCODING` token.

Changed in version 3.5: Added `AWAIT` and `ASYNC` tokens.

Changed in version 3.7: Added *COMMENT*, *NL* and *ENCODING* tokens.

Changed in version 3.7: Removed `AWAIT` and `ASYNC` tokens. "async" and "await" are now tokenized as *NAME* tokens.

33.6 `keyword` — Testing for Python keywords

Source code: Lib/keyword.py

This module allows a Python program to determine if a string is a keyword.

`keyword.iskeyword(s)`
Return true if *s* is a Python keyword.

`keyword.kwlist`
Sequence containing all the keywords defined for the interpreter. If any keywords are defined to only be active when particular *__future__* statements are in effect, these will be included as well.

33.7 `tokenize` — Tokenizer for Python source

Source code: Lib/tokenize.py

The *tokenize* module provides a lexical scanner for Python source code, implemented in Python. The scanner in this module returns comments as tokens as well, making it useful for implementing "pretty-printers," including colorizers for on-screen displays.

To simplify token stream handling, all operator and delimiter tokens and *Ellipsis* are returned using the generic *OP* token type. The exact type can be determined by checking the `exact_type` property on the *named tuple* returned from *tokenize.tokenize()*.

33.7.1 Tokenizing Input

The primary entry point is a *generator*:

`tokenize.tokenize(readline)`
The *tokenize()* generator requires one argument, *readline*, which must be a callable object which provides the same interface as the *io.IOBase.readline()* method of file objects. Each call to the function should return one line of input as bytes.

The generator produces 5-tuples with these members: the token type; the token string; a 2-tuple `(srow, scol)` of ints specifying the row and column where the token begins in the source; a 2-tuple `(erow, ecol)` of ints specifying the row and column where the token ends in the source; and the line on which the token was found. The line passed (the last tuple item) is the *logical* line; continuation lines are included. The 5 tuple is returned as a *named tuple* with the field names: `type string start end line`.

The returned *named tuple* has an additional property named `exact_type` that contains the exact operator type for *OP* tokens. For all other token types `exact_type` equals the named tuple `type` field.

Changed in version 3.1: Added support for named tuples.

Changed in version 3.3: Added support for `exact_type`.

tokenize() determines the source encoding of the file by looking for a UTF-8 BOM or encoding cookie, according to **PEP 263**.

All constants from the *token* module are also exported from *tokenize*.

Another function is provided to reverse the tokenization process. This is useful for creating tools that tokenize a script, modify the token stream, and write back the modified script.

`tokenize.untokenize`(*iterable*)
Converts tokens back into Python source code. The *iterable* must return sequences with at least two elements, the token type and the token string. Any additional sequence elements are ignored.

The reconstructed script is returned as a single string. The result is guaranteed to tokenize back to match the input so that the conversion is lossless and round-trips are assured. The guarantee applies only to the token type and token string as the spacing between tokens (column positions) may change.

It returns bytes, encoded using the *ENCODING* token, which is the first token sequence output by *tokenize()*.

tokenize() needs to detect the encoding of source files it tokenizes. The function it uses to do this is available:

`tokenize.detect_encoding`(*readline*)
The *detect_encoding()* function is used to detect the encoding that should be used to decode a Python source file. It requires one argument, readline, in the same way as the *tokenize()* generator.

It will call readline a maximum of twice, and return the encoding used (as a string) and a list of any lines (not decoded from bytes) it has read in.

It detects the encoding from the presence of a UTF-8 BOM or an encoding cookie as specified in **PEP 263**. If both a BOM and a cookie are present, but disagree, a *SyntaxError* will be raised. Note that if the BOM is found, `'utf-8-sig'` will be returned as an encoding.

If no encoding is specified, then the default of `'utf-8'` will be returned.

Use *open()* to open Python source files: it uses *detect_encoding()* to detect the file encoding.

`tokenize.open`(*filename*)
Open a file in read only mode using the encoding detected by *detect_encoding()*.

New in version 3.2.

`exception tokenize.TokenError`
Raised when either a docstring or expression that may be split over several lines is not completed anywhere in the file, for example:

```
"""Beginning of
docstring
```

or:

```
[1,
 2,
 3
```

Note that unclosed single-quoted strings do not cause an error to be raised. They are tokenized as *ERRORTOKEN*, followed by the tokenization of their contents.

33.7.2 Command-Line Usage

New in version 3.3.

The *tokenize* module can be executed as a script from the command line. It is as simple as:

```
python -m tokenize [-e] [filename.py]
```

The following options are accepted:

-h, --help
show this help message and exit

-e, --exact
display token names using the exact type

If `filename.py` is specified its contents are tokenized to stdout. Otherwise, tokenization is performed on stdin.

33.7.3 Examples

Example of a script rewriter that transforms float literals into Decimal objects:

```
from tokenize import tokenize, untokenize, NUMBER, STRING, NAME, OP
from io import BytesIO

def decistmt(s):
    """Substitute Decimals for floats in a string of statements.

    >>> from decimal import Decimal
    >>> s = 'print(+21.3e-5*-.1234/81.7)'
    >>> decistmt(s)
    "print (+Decimal ('21.3e-5')*-Decimal ('.1234')/Decimal ('81.7'))"

    The format of the exponent is inherited from the platform C library.
    Known cases are "e-007" (Windows) and "e-07" (not Windows).  Since
    we're only showing 12 digits, and the 13th isn't close to 5, the
    rest of the output should be platform-independent.

    >>> exec(s)  #doctest: +ELLIPSIS
    -3.21716034272e-0...7

    Output from calculations with Decimal should be identical across all
    platforms.

    >>> exec(decistmt(s))
    -3.217160342717258261933904529E-7
    """
    result = []
    g = tokenize(BytesIO(s.encode('utf-8')).readline)  # tokenize the string
```

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```
    for toknum, tokval, _, _, _ in g:
        if toknum == NUMBER and '.' in tokval:  # replace NUMBER tokens
            result.extend([
                (NAME, 'Decimal'),
                (OP, '('),
                (STRING, repr(tokval)),
                (OP, ')')
            ])
        else:
            result.append((toknum, tokval))
    return untokenize(result).decode('utf-8')
```

Example of tokenizing from the command line. The script:

```
def say_hello():
    print("Hello, World!")

say_hello()
```

will be tokenized to the following output where the first column is the range of the line/column coordinates where the token is found, the second column is the name of the token, and the final column is the value of the token (if any)

```
$ python -m tokenize hello.py
0,0-0,0:            ENCODING       'utf-8'
1,0-1,3:            NAME           'def'
1,4-1,13:           NAME           'say_hello'
1,13-1,14:          OP             '('
1,14-1,15:          OP             ')'
1,15-1,16:          OP             ':'
1,16-1,17:          NEWLINE        '\n'
2,0-2,4:            INDENT         '    '
2,4-2,9:            NAME           'print'
2,9-2,10:           OP             '('
2,10-2,25:          STRING         '"Hello, World!"'
2,25-2,26:          OP             ')'
2,26-2,27:          NEWLINE        '\n'
3,0-3,1:            NL             '\n'
4,0-4,0:            DEDENT         ''
4,0-4,9:            NAME           'say_hello'
4,9-4,10:           OP             '('
4,10-4,11:          OP             ')'
4,11-4,12:          NEWLINE        '\n'
5,0-5,0:            ENDMARKER      ''
```

The exact token type names can be displayed using the *-e* option:

```
$ python -m tokenize -e hello.py
0,0-0,0:            ENCODING       'utf-8'
1,0-1,3:            NAME           'def'
1,4-1,13:           NAME           'say_hello'
1,13-1,14:          LPAR           '('
1,14-1,15:          RPAR           ')'
1,15-1,16:          COLON          ':'
1,16-1,17:          NEWLINE        '\n'
2,0-2,4:            INDENT         '    '
```

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```
2,4-2,9:            NAME           'print'
2,9-2,10:           LPAR           '('
2,10-2,25:          STRING         '"Hello, World!"'
2,25-2,26:          RPAR           ')'
2,26-2,27:          NEWLINE        '\n'
3,0-3,1:            NL             '\n'
4,0-4,0:            DEDENT         ''
4,0-4,9:            NAME           'say_hello'
4,9-4,10:           LPAR           '('
4,10-4,11:          RPAR           ')'
4,11-4,12:          NEWLINE        '\n'
5,0-5,0:            ENDMARKER      ''
```

33.8 tabnanny — Detection of ambiguous indentation

Source code: Lib/tabnanny.py

For the time being this module is intended to be called as a script. However it is possible to import it into an IDE and use the function *check()* described below.

Note: The API provided by this module is likely to change in future releases; such changes may not be backward compatible.

---

tabnanny.**check**(*file_or_dir*)
: If *file_or_dir* is a directory and not a symbolic link, then recursively descend the directory tree named by *file_or_dir*, checking all `.py` files along the way. If *file_or_dir* is an ordinary Python source file, it is checked for whitespace related problems. The diagnostic messages are written to standard output using the *print()* function.

tabnanny.**verbose**
: Flag indicating whether to print verbose messages. This is incremented by the `-v` option if called as a script.

tabnanny.**filename_only**
: Flag indicating whether to print only the filenames of files containing whitespace related problems. This is set to true by the `-q` option if called as a script.

exception tabnanny.**NannyNag**
: Raised by *process_tokens()* if detecting an ambiguous indent. Captured and handled in *check()*.

tabnanny.**process_tokens**(*tokens*)
: This function is used by *check()* to process tokens generated by the *tokenize* module.

See also:

Module *tokenize* Lexical scanner for Python source code.

33.9 pyclbr — Python class browser support

Source code: Lib/pyclbr.py

The *pyclbr* module provides limited information about the functions, classes, and methods defined in a python-coded module. The information is sufficient to implement a module browser. The information is extracted from the python source code rather than by importing the module, so this module is safe to use with untrusted code. This restriction makes it impossible to use this module with modules not implemented in Python, including all standard and optional extension modules.

`pyclbr.readmodule(`*module*, *path=None*`)`
Return a dictionary mapping module-level class names to class descriptors. If possible, descriptors for imported base classes are included. Parameter *module* is a string with the name of the module to read; it may be the name of a module within a package. If given, *path* is a sequence of directory paths prepended to `sys.path`, which is used to locate the module source code.

`pyclbr.readmodule_ex(`*module*, *path=None*`)`
Return a dictionary-based tree containing a function or class descriptors for each function and class defined in the module with a `def` or `class` statement. The returned dictionary maps module-level function and class names to their descriptors. Nested objects are entered into the children dictionary of their parent. As with readmodule, *module* names the module to be read and *path* is prepended to sys.path. If the module being read is a package, the returned dictionary has a key `'__path__'` whose value is a list containing the package search path.

New in version 3.7: Descriptors for nested definitions. They are accessed through the new children attibute. Each has a new parent attribute.

The descriptors returned by these functions are instances of Function and Class classes. Users are not expected to create instances of these classes.

33.9.1 Function Objects

Class `Function` instances describe functions defined by def statements. They have the following attributes:

`Function.file`
Name of the file in which the function is defined.

`Function.module`
The name of the module defining the function described.

`Function.name`
The name of the function.

`Function.lineno`
The line number in the file where the definition starts.

`Function.parent`
For top-level functions, None. For nested functions, the parent.

New in version 3.7.

`Function.children`
A dictionary mapping names to descriptors for nested functions and classes.

New in version 3.7.

33.9.2 Class Objects

Class `Class` instances describe classes defined by class statements. They have the same attributes as Functions and two more.

`Class.file`
Name of the file in which the class is defined.

`Class.module`
The name of the module defining the class described.

`Class.name`
The name of the class.

`Class.lineno`
The line number in the file where the definition starts.

`Class.parent`
For top-level classes, None. For nested classes, the parent.

New in version 3.7.

`Class.children`
A dictionary mapping names to descriptors for nested functions and classes.

New in version 3.7.

`Class.super`
A list of `Class` objects which describe the immediate base classes of the class being described. Classes which are named as superclasses but which are not discoverable by *readmodule_ex()* are listed as a string with the class name instead of as `Class` objects.

`Class.methods`
A dictionary mapping method names to line numbers. This can be derived from the newer children dictionary, but remains for back-compatibility.

33.10 py_compile — Compile Python source files

Source code: Lib/py_compile.py

The *py_compile* module provides a function to generate a byte-code file from a source file, and another function used when the module source file is invoked as a script.

Though not often needed, this function can be useful when installing modules for shared use, especially if some of the users may not have permission to write the byte-code cache files in the directory containing the source code.

exception py_compile.**PyCompileError**
Exception raised when an error occurs while attempting to compile the file.

py_compile.**compile**(*file*, *cfile=None*, *dfile=None*, *doraise=False*, *optimize=-1*, *invalidation_mode=PycInvalidationMode.TIMESTAMP*)
Compile a source file to byte-code and write out the byte-code cache file. The source code is loaded from the file named *file*. The byte-code is written to *cfile*, which defaults to the **PEP 3147**/**PEP 488** path, ending in `.pyc`. For example, if *file* is `/foo/bar/baz.py` *cfile* will default to `/foo/bar/__pycache__/baz.cpython-32.pyc` for Python 3.2. If *dfile* is specified, it is used as the name of the source file in error messages when instead of *file*. If *doraise* is true, a *PyCompileError* is raised when an error is encountered while compiling *file*. If *doraise* is false (the default), an error string is written to `sys.stderr`, but no exception is raised. This function returns the path to byte-compiled file, i.e. whatever *cfile* value was used.

If the path that *cfile* becomes (either explicitly specified or computed) is a symlink or non-regular file, *FileExistsError* will be raised. This is to act as a warning that import will turn those paths into regular files if it is allowed to write byte-compiled files to those paths. This is a side-effect of import using file renaming to place the final byte-compiled file into place to prevent concurrent file writing issues.

optimize controls the optimization level and is passed to the built-in *compile()* function. The default of `-1` selects the optimization level of the current interpreter.

invalidation_mode should be a member of the *PycInvalidationMode* enum and controls how the generated `.pyc` files are invalidated at runtime. If the `SOURCE_DATE_EPOCH` environment variable is set, *invalidation_mode* will be forced to *PycInvalidationMode.CHECKED_HASH*.

Changed in version 3.2: Changed default value of *cfile* to be **PEP 3147**-compliant. Previous default was *file* + `'c'` (`'o'` if optimization was enabled). Also added the *optimize* parameter.

Changed in version 3.4: Changed code to use *importlib* for the byte-code cache file writing. This means file creation/writing semantics now match what *importlib* does, e.g. permissions, write-and-move semantics, etc. Also added the caveat that *FileExistsError* is raised if *cfile* is a symlink or non-regular file.

Changed in version 3.7: The *invalidation_mode* parameter was added as specified in **PEP 552**. If the `SOURCE_DATE_EPOCH` environment variable is set, *invalidation_mode* will be forced to *PycInvalidationMode.CHECKED_HASH*.

class py_compile.**PycInvalidationMode**

A enumeration of possible methods the interpreter can use to determine whether a bytecode file is up to date with a source file. The `.pyc` file indicates the desired invalidation mode in its header. See pyc-invalidation for more information on how Python invalidates `.pyc` files at runtime.

New in version 3.7.

TIMESTAMP

The `.pyc` file includes the timestamp and size of the source file, which Python will compare against the metadata of the source file at runtime to determine if the `.pyc` file needs to be regenerated.

CHECKED_HASH

The `.pyc` file includes a hash of the source file content, which Python will compare against the source at runtime to determine if the `.pyc` file needs to be regenerated.

UNCHECKED_HASH

Like *CHECKED_HASH*, the `.pyc` file includes a hash of the source file content. However, Python will at runtime assume the `.pyc` file is up to date and not validate the `.pyc` against the source file at all.

This option is useful when the `.pycs` are kept up to date by some system external to Python like a build system.

py_compile.**main**(*args=None*)

Compile several source files. The files named in *args* (or on the command line, if *args* is `None`) are compiled and the resulting byte-code is cached in the normal manner. This function does not search a directory structure to locate source files; it only compiles files named explicitly. If `'-'` is the only parameter in args, the list of files is taken from standard input.

Changed in version 3.2: Added support for `'-'`.

When this module is run as a script, the *main()* is used to compile all the files named on the command line. The exit status is nonzero if one of the files could not be compiled.

See also:

Module *compileall* Utilities to compile all Python source files in a directory tree.

33.11 compileall — Byte-compile Python libraries

Source code: Lib/compileall.py

This module provides some utility functions to support installing Python libraries. These functions compile Python source files in a directory tree. This module can be used to create the cached byte-code files at library installation time, which makes them available for use even by users who don't have write permission to the library directories.

33.11.1 Command-line use

This module can work as a script (using **python -m compileall**) to compile Python sources.

directory ...
file ...
Positional arguments are files to compile or directories that contain source files, traversed recursively. If no argument is given, behave as if the command line was **-l <directories from sys.path>**.

-l
Do not recurse into subdirectories, only compile source code files directly contained in the named or implied directories.

-f
Force rebuild even if timestamps are up-to-date.

-q
Do not print the list of files compiled. If passed once, error messages will still be printed. If passed twice (**-qq**), all output is suppressed.

-d destdir
Directory prepended to the path to each file being compiled. This will appear in compilation time tracebacks, and is also compiled in to the byte-code file, where it will be used in tracebacks and other messages in cases where the source file does not exist at the time the byte-code file is executed.

-x regex
regex is used to search the full path to each file considered for compilation, and if the regex produces a match, the file is skipped.

-i list
Read the file **list** and add each line that it contains to the list of files and directories to compile. If **list** is **-**, read lines from **stdin**.

-b
Write the byte-code files to their legacy locations and names, which may overwrite byte-code files created by another version of Python. The default is to write files to their **PEP 3147** locations and names, which allows byte-code files from multiple versions of Python to coexist.

-r
Control the maximum recursion level for subdirectories. If this is given, then **-l** option will not be taken into account. **python -m compileall <directory> -r 0** is equivalent to **python -m compileall <directory> -l**.

-j N
Use *N* workers to compile the files within the given directory. If **0** is used, then the result of *os.cpu_count()* will be used.

--invalidation-mode [timestamp|checked-hash|unchecked-hash]
Control how the generated pycs will be invalidated at runtime. The default setting, **timestamp**, means that **.pyc** files with the source timestamp and size embedded will be generated. The **checked-hash** and **unchecked-hash** values cause hash-based pycs to be generated. Hash-based pycs embed a hash of the source file contents rather than a timestamp. See pyc-invalidation for more information on how Python validates bytecode cache files at runtime.

Changed in version 3.2: Added the `-i`, `-b` and `-h` options.

Changed in version 3.5: Added the `-j`, `-r`, and `-qq` options. `-q` option was changed to a multilevel value. `-b` will always produce a byte-code file ending in `.pyc`, never `.pyo`.

Changed in version 3.7: Added the `--invalidation-mode` parameter.

There is no command-line option to control the optimization level used by the *compile()* function, because the Python interpreter itself already provides the option: `python -O -m compileall`.

33.11.2 Public functions

`compileall.compile_dir`(*dir*, *maxlevels=10*, *ddir=None*, *force=False*, *rx=None*, *quiet=0*, *legacy=False*, *optimize=-1*, *workers=1*, *invalidation_mode=py_compile.PycInvalidationMode.TIMESTAMP*)

Recursively descend the directory tree named by *dir*, compiling all `.py` files along the way. Return a true value if all the files compiled successfully, and a false value otherwise.

The *maxlevels* parameter is used to limit the depth of the recursion; it defaults to `10`.

If *ddir* is given, it is prepended to the path to each file being compiled for use in compilation time tracebacks, and is also compiled in to the byte-code file, where it will be used in tracebacks and other messages in cases where the source file does not exist at the time the byte-code file is executed.

If *force* is true, modules are re-compiled even if the timestamps are up to date.

If *rx* is given, its search method is called on the complete path to each file considered for compilation, and if it returns a true value, the file is skipped.

If *quiet* is `False` or `0` (the default), the filenames and other information are printed to standard out. Set to `1`, only errors are printed. Set to `2`, all output is suppressed.

If *legacy* is true, byte-code files are written to their legacy locations and names, which may overwrite byte-code files created by another version of Python. The default is to write files to their **PEP 3147** locations and names, which allows byte-code files from multiple versions of Python to coexist.

optimize specifies the optimization level for the compiler. It is passed to the built-in *compile()* function.

The argument *workers* specifies how many workers are used to compile files in parallel. The default is to not use multiple workers. If the platform can't use multiple workers and *workers* argument is given, then sequential compilation will be used as a fallback. If *workers* is lower than `0`, a *ValueError* will be raised.

invalidation_mode should be a member of the *py_compile.PycInvalidationMode* enum and controls how the generated pycs are invalidated at runtime.

Changed in version 3.2: Added the *legacy* and *optimize* parameter.

Changed in version 3.5: Added the *workers* parameter.

Changed in version 3.5: *quiet* parameter was changed to a multilevel value.

Changed in version 3.5: The *legacy* parameter only writes out `.pyc` files, not `.pyo` files no matter what the value of *optimize* is.

Changed in version 3.6: Accepts a *path-like object*.

Changed in version 3.7: The *invalidation_mode* parameter was added.

`compileall.compile_file`(*fullname*, *ddir=None*, *force=False*, *rx=None*, *quiet=0*, *legacy=False*, *optimize=-1*, *invalidation_mode=py_compile.PycInvalidationMode.TIMESTAMP*)

Compile the file with path *fullname*. Return a true value if the file compiled successfully, and a false value otherwise.

If *ddir* is given, it is prepended to the path to the file being compiled for use in compilation time tracebacks, and is also compiled in to the byte-code file, where it will be used in tracebacks and other messages in cases where the source file does not exist at the time the byte-code file is executed.

If *rx* is given, its search method is passed the full path name to the file being compiled, and if it returns a true value, the file is not compiled and `True` is returned.

If *quiet* is `False` or `0` (the default), the filenames and other information are printed to standard out. Set to `1`, only errors are printed. Set to `2`, all output is suppressed.

If *legacy* is true, byte-code files are written to their legacy locations and names, which may overwrite byte-code files created by another version of Python. The default is to write files to their **PEP 3147** locations and names, which allows byte-code files from multiple versions of Python to coexist.

optimize specifies the optimization level for the compiler. It is passed to the built-in *compile()* function.

invalidation_mode should be a member of the *py_compile.PycInvalidationMode* enum and controls how the generated pycs are invalidated at runtime.

New in version 3.2.

Changed in version 3.5: *quiet* parameter was changed to a multilevel value.

Changed in version 3.5: The *legacy* parameter only writes out `.pyc` files, not `.pyo` files no matter what the value of *optimize* is.

Changed in version 3.7: The *invalidation_mode* parameter was added.

compileall.compile_path(*skip_curdir=True*, *maxlevels=0*, *force=False*, *quiet=0*, *legacy=False*, *optimize=-1*, *invalidation_mode=py_compile.PycInvalidationMode.TIMESTAMP*)

Byte-compile all the `.py` files found along `sys.path`. Return a true value if all the files compiled successfully, and a false value otherwise.

If *skip_curdir* is true (the default), the current directory is not included in the search. All other parameters are passed to the *compile_dir()* function. Note that unlike the other compile functions, `maxlevels` defaults to `0`.

Changed in version 3.2: Added the *legacy* and *optimize* parameter.

Changed in version 3.5: *quiet* parameter was changed to a multilevel value.

Changed in version 3.5: The *legacy* parameter only writes out `.pyc` files, not `.pyo` files no matter what the value of *optimize* is.

Changed in version 3.7: The *invalidation_mode* parameter was added.

To force a recompile of all the `.py` files in the `Lib/` subdirectory and all its subdirectories:

```
import compileall

compileall.compile_dir('Lib/', force=True)

# Perform same compilation, excluding files in .svn directories.
import re
compileall.compile_dir('Lib/', rx=re.compile(r'[/\\][.]svn'), force=True)

# pathlib.Path objects can also be used.
import pathlib
compileall.compile_dir(pathlib.Path('Lib/'), force=True)
```

See also:

Module *py_compile* Byte-compile a single source file.

33.12 dis — Disassembler for Python bytecode

Source code: Lib/dis.py

The *dis* module supports the analysis of CPython *bytecode* by disassembling it. The CPython bytecode which this module takes as an input is defined in the file `Include/opcode.h` and used by the compiler and the interpreter.

CPython implementation detail: Bytecode is an implementation detail of the CPython interpreter. No guarantees are made that bytecode will not be added, removed, or changed between versions of Python. Use of this module should not be considered to work across Python VMs or Python releases.

Changed in version 3.6: Use 2 bytes for each instruction. Previously the number of bytes varied by instruction.

Example: Given the function `myfunc()`:

```
def myfunc(alist):
    return len(alist)
```

the following command can be used to display the disassembly of `myfunc()`:

```
>>> dis.dis(myfunc)
  2           0 LOAD_GLOBAL              0 (len)
              2 LOAD_FAST                0 (alist)
              4 CALL_FUNCTION            1
              6 RETURN_VALUE
```

(The "2" is a line number).

33.12.1 Bytecode analysis

New in version 3.4.

The bytecode analysis API allows pieces of Python code to be wrapped in a *Bytecode* object that provides easy access to details of the compiled code.

class dis.Bytecode(*x*, ***, *first_line=None*, *current_offset=None*)

Analyse the bytecode corresponding to a function, generator, asynchronous generator, coroutine, method, string of source code, or a code object (as returned by *compile()*).

This is a convenience wrapper around many of the functions listed below, most notably *get_instructions()*, as iterating over a *Bytecode* instance yields the bytecode operations as *Instruction* instances.

If *first_line* is not `None`, it indicates the line number that should be reported for the first source line in the disassembled code. Otherwise, the source line information (if any) is taken directly from the disassembled code object.

If *current_offset* is not `None`, it refers to an instruction offset in the disassembled code. Setting this means *dis()* will display a "current instruction" marker against the specified opcode.

classmethod from_traceback(*tb*)

Construct a *Bytecode* instance from the given traceback, setting *current_offset* to the instruction responsible for the exception.

codeobj

The compiled code object.

first_line
The first source line of the code object (if available)

dis()
Return a formatted view of the bytecode operations (the same as printed by *dis.dis()*, but returned as a multi-line string).

info()
Return a formatted multi-line string with detailed information about the code object, like *code_info()*.

Changed in version 3.7: This can now handle coroutine and asynchronous generator objects.

Example:

```
>>> bytecode = dis.Bytecode(myfunc)
>>> for instr in bytecode:
...     print(instr.opname)
...
LOAD_GLOBAL
LOAD_FAST
CALL_FUNCTION
RETURN_VALUE
```

33.12.2 Analysis functions

The *dis* module also defines the following analysis functions that convert the input directly to the desired output. They can be useful if only a single operation is being performed, so the intermediate analysis object isn't useful:

dis.code_info(*x*)
Return a formatted multi-line string with detailed code object information for the supplied function, generator, asynchronous generator, coroutine, method, source code string or code object.

Note that the exact contents of code info strings are highly implementation dependent and they may change arbitrarily across Python VMs or Python releases.

New in version 3.2.

Changed in version 3.7: This can now handle coroutine and asynchronous generator objects.

dis.show_code(*x*, ***, *file=None*)
Print detailed code object information for the supplied function, method, source code string or code object to *file* (or `sys.stdout` if *file* is not specified).

This is a convenient shorthand for `print(code_info(x), file=file)`, intended for interactive exploration at the interpreter prompt.

New in version 3.2.

Changed in version 3.4: Added *file* parameter.

dis.dis(*x=None*, ***, *file=None*, *depth=None*)
Disassemble the *x* object. *x* can denote either a module, a class, a method, a function, a generator, an asynchronous generator, a couroutine, a code object, a string of source code or a byte sequence of raw bytecode. For a module, it disassembles all functions. For a class, it disassembles all methods (including class and static methods). For a code object or sequence of raw bytecode, it prints one line per bytecode instruction. It also recursively disassembles nested code objects (the code of comprehensions, generator expressions and nested functions, and the code used for building nested classes). Strings are first compiled to code objects with the *compile()* built-in function before being disassembled. If no object is provided, this function disassembles the last traceback.

The disassembly is written as text to the supplied *file* argument if provided and to `sys.stdout` otherwise.

The maximal depth of recursion is limited by *depth* unless it is `None`. `depth=0` means no recursion.

Changed in version 3.4: Added *file* parameter.

Changed in version 3.7: Implemented recursive disassembling and added *depth* parameter.

Changed in version 3.7: This can now handle coroutine and asynchronous generator objects.

`dis.distb`(*tb=None*, ***, *file=None*)

Disassemble the top-of-stack function of a traceback, using the last traceback if none was passed. The instruction causing the exception is indicated.

The disassembly is written as text to the supplied *file* argument if provided and to `sys.stdout` otherwise.

Changed in version 3.4: Added *file* parameter.

`dis.disassemble`(*code*, *lasti=-1*, ***, *file=None*)

`dis.disco`(*code*, *lasti=-1*, ***, *file=None*)

Disassemble a code object, indicating the last instruction if *lasti* was provided. The output is divided in the following columns:

1. the line number, for the first instruction of each line
2. the current instruction, indicated as `-->`,
3. a labelled instruction, indicated with `>>`,
4. the address of the instruction,
5. the operation code name,
6. operation parameters, and
7. interpretation of the parameters in parentheses.

The parameter interpretation recognizes local and global variable names, constant values, branch targets, and compare operators.

The disassembly is written as text to the supplied *file* argument if provided and to `sys.stdout` otherwise.

Changed in version 3.4: Added *file* parameter.

`dis.get_instructions`(*x*, ***, *first_line=None*)

Return an iterator over the instructions in the supplied function, method, source code string or code object.

The iterator generates a series of *Instruction* named tuples giving the details of each operation in the supplied code.

If *first_line* is not `None`, it indicates the line number that should be reported for the first source line in the disassembled code. Otherwise, the source line information (if any) is taken directly from the disassembled code object.

New in version 3.4.

`dis.findlinestarts`(*code*)

This generator function uses the `co_firstlineno` and `co_lnotab` attributes of the code object *code* to find the offsets which are starts of lines in the source code. They are generated as `(offset, lineno)` pairs. See Objects/lnotab_notes.txt for the `co_lnotab` format and how to decode it.

Changed in version 3.6: Line numbers can be decreasing. Before, they were always increasing.

dis.findlabels(*code*)
Detect all offsets in the code object *code* which are jump targets, and return a list of these offsets.

dis.stack_effect(*opcode*[, *oparg*])
Compute the stack effect of *opcode* with argument *oparg*.

New in version 3.4.

33.12.3 Python Bytecode Instructions

The *get_instructions()* function and *Bytecode* class provide details of bytecode instructions as *Instruction* instances:

class dis.Instruction
Details for a bytecode operation

opcode
numeric code for operation, corresponding to the opcode values listed below and the bytecode values in the *Opcode collections*.

opname
human readable name for operation

arg
numeric argument to operation (if any), otherwise None

argval
resolved arg value (if known), otherwise same as arg

argrepr
human readable description of operation argument

offset
start index of operation within bytecode sequence

starts_line
line started by this opcode (if any), otherwise None

is_jump_target
True if other code jumps to here, otherwise False

New in version 3.4.

The Python compiler currently generates the following bytecode instructions.

General instructions

NOP
Do nothing code. Used as a placeholder by the bytecode optimizer.

POP_TOP
Removes the top-of-stack (TOS) item.

ROT_TWO
Swaps the two top-most stack items.

ROT_THREE
Lifts second and third stack item one position up, moves top down to position three.

DUP_TOP
Duplicates the reference on top of the stack.

New in version 3.2.

DUP_TOP_TWO
: Duplicates the two references on top of the stack, leaving them in the same order.

  New in version 3.2.

Unary operations

Unary operations take the top of the stack, apply the operation, and push the result back on the stack.

UNARY_POSITIVE
: Implements `TOS = +TOS`.

UNARY_NEGATIVE
: Implements `TOS = -TOS`.

UNARY_NOT
: Implements `TOS = not TOS`.

UNARY_INVERT
: Implements `TOS = ~TOS`.

GET_ITER
: Implements `TOS = iter(TOS)`.

GET_YIELD_FROM_ITER
: If `TOS` is a *generator iterator* or *coroutine* object it is left as is. Otherwise, implements `TOS = iter(TOS)`.

  New in version 3.5.

Binary operations

Binary operations remove the top of the stack (TOS) and the second top-most stack item (TOS1) from the stack. They perform the operation, and put the result back on the stack.

BINARY_POWER
: Implements `TOS = TOS1 ** TOS`.

BINARY_MULTIPLY
: Implements `TOS = TOS1 * TOS`.

BINARY_MATRIX_MULTIPLY
: Implements `TOS = TOS1 @ TOS`.

  New in version 3.5.

BINARY_FLOOR_DIVIDE
: Implements `TOS = TOS1 // TOS`.

BINARY_TRUE_DIVIDE
: Implements `TOS = TOS1 / TOS`.

BINARY_MODULO
: Implements `TOS = TOS1 % TOS`.

BINARY_ADD
: Implements `TOS = TOS1 + TOS`.

BINARY_SUBTRACT
: Implements `TOS = TOS1 - TOS`.

BINARY_SUBSCR
: Implements `TOS = TOS1[TOS]`.

BINARY_LSHIFT
: Implements `TOS = TOS1 << TOS`.

BINARY_RSHIFT
: Implements `TOS = TOS1 >> TOS`.

BINARY_AND
Implements TOS = TOS1 & TOS.

BINARY_XOR
Implements TOS = TOS1 ^ TOS.

BINARY_OR
Implements TOS = TOS1 | TOS.

In-place operations

In-place operations are like binary operations, in that they remove TOS and TOS1, and push the result back on the stack, but the operation is done in-place when TOS1 supports it, and the resulting TOS may be (but does not have to be) the original TOS1.

INPLACE_POWER
Implements in-place TOS = TOS1 ** TOS.

INPLACE_MULTIPLY
Implements in-place TOS = TOS1 * TOS.

INPLACE_MATRIX_MULTIPLY
Implements in-place TOS = TOS1 @ TOS.

New in version 3.5.

INPLACE_FLOOR_DIVIDE
Implements in-place TOS = TOS1 // TOS.

INPLACE_TRUE_DIVIDE
Implements in-place TOS = TOS1 / TOS.

INPLACE_MODULO
Implements in-place TOS = TOS1 % TOS.

INPLACE_ADD
Implements in-place TOS = TOS1 + TOS.

INPLACE_SUBTRACT
Implements in-place TOS = TOS1 - TOS.

INPLACE_LSHIFT
Implements in-place TOS = TOS1 << TOS.

INPLACE_RSHIFT
Implements in-place TOS = TOS1 >> TOS.

INPLACE_AND
Implements in-place TOS = TOS1 & TOS.

INPLACE_XOR
Implements in-place TOS = TOS1 ^ TOS.

INPLACE_OR
Implements in-place TOS = TOS1 | TOS.

STORE_SUBSCR
Implements TOS1[TOS] = TOS2.

DELETE_SUBSCR
Implements del TOS1[TOS].

Coroutine opcodes

GET_AWAITABLE
Implements TOS = get_awaitable(TOS), where get_awaitable(o) returns o if o is a coroutine object or a generator object with the CO_ITERABLE_COROUTINE flag, or resolves o.__await__.

New in version 3.5.

GET_AITER
Implements TOS = TOS.__aiter__().

New in version 3.5.

Changed in version 3.7: Returning awaitable objects from __aiter__ is no longer supported.

GET_ANEXT
Implements PUSH(get_awaitable(TOS.__anext__())). See GET_AWAITABLE for details about get_awaitable

New in version 3.5.

BEFORE_ASYNC_WITH
Resolves __aenter__ and __aexit__ from the object on top of the stack. Pushes __aexit__ and result of __aenter__() to the stack.

New in version 3.5.

SETUP_ASYNC_WITH
Creates a new frame object.

New in version 3.5.

Miscellaneous opcodes

PRINT_EXPR
Implements the expression statement for the interactive mode. TOS is removed from the stack and printed. In non-interactive mode, an expression statement is terminated with *POP_TOP*.

BREAK_LOOP
Terminates a loop due to a break statement.

CONTINUE_LOOP(*target*)
Continues a loop due to a continue statement. *target* is the address to jump to (which should be a *FOR_ITER* instruction).

SET_ADD(*i*)
Calls set.add(TOS1[-i], TOS). Used to implement set comprehensions.

LIST_APPEND(*i*)
Calls list.append(TOS[-i], TOS). Used to implement list comprehensions.

MAP_ADD(*i*)
Calls dict.setitem(TOS1[-i], TOS, TOS1). Used to implement dict comprehensions.

New in version 3.1.

For all of the *SET_ADD*, *LIST_APPEND* and *MAP_ADD* instructions, while the added value or key/value pair is popped off, the container object remains on the stack so that it is available for further iterations of the loop.

RETURN_VALUE
Returns with TOS to the caller of the function.

YIELD_VALUE
Pops TOS and yields it from a *generator*.

YIELD_FROM
Pops TOS and delegates to it as a subiterator from a *generator*.

New in version 3.3.

SETUP_ANNOTATIONS
: Checks whether `__annotations__` is defined in `locals()`, if not it is set up to an empty `dict`. This opcode is only emitted if a class or module body contains *variable annotations* statically.

  New in version 3.6.

IMPORT_STAR
: Loads all symbols not starting with `'_'` directly from the module TOS to the local namespace. The module is popped after loading all names. This opcode implements `from module import *`.

POP_BLOCK
: Removes one block from the block stack. Per frame, there is a stack of blocks, denoting nested loops, try statements, and such.

POP_EXCEPT
: Removes one block from the block stack. The popped block must be an exception handler block, as implicitly created when entering an except handler. In addition to popping extraneous values from the frame stack, the last three popped values are used to restore the exception state.

END_FINALLY
: Terminates a `finally` clause. The interpreter recalls whether the exception has to be re-raised, or whether the function returns, and continues with the outer-next block.

LOAD_BUILD_CLASS
: Pushes `builtins.__build_class__()` onto the stack. It is later called by *CALL_FUNCTION* to construct a class.

SETUP_WITH(*delta*)
: This opcode performs several operations before a with block starts. First, it loads `__exit__()` from the context manager and pushes it onto the stack for later use by `WITH_CLEANUP`. Then, `__enter__()` is called, and a finally block pointing to *delta* is pushed. Finally, the result of calling the enter method is pushed onto the stack. The next opcode will either ignore it (*POP_TOP*), or store it in (a) variable(s) (*STORE_FAST*, *STORE_NAME*, or *UNPACK_SEQUENCE*).

  New in version 3.2.

WITH_CLEANUP_START
: Cleans up the stack when a `with` statement block exits. TOS is the context manager's `__exit__()` bound method. Below TOS are 1–3 values indicating how/why the finally clause was entered:

  - SECOND = `None`
  - (SECOND, THIRD) = (`WHY_{RETURN,CONTINUE}`), retval
  - SECOND = `WHY_*`; no retval below it
  - (SECOND, THIRD, FOURTH) = exc_info()

  In the last case, `TOS(SECOND, THIRD, FOURTH)` is called, otherwise `TOS(None, None, None)`. Pushes SECOND and result of the call to the stack.

WITH_CLEANUP_FINISH
: Pops exception type and result of 'exit' function call from the stack.

  If the stack represents an exception, *and* the function call returns a 'true' value, this information is "zapped" and replaced with a single `WHY_SILENCED` to prevent *END_FINALLY* from re-raising the exception. (But non-local gotos will still be resumed.)

All of the following opcodes use their arguments.

STORE_NAME(*namei*)
: Implements `name = TOS`. *namei* is the index of *name* in the attribute `co_names` of the code object. The compiler tries to use *STORE_FAST* or *STORE_GLOBAL* if possible.

`DELETE_NAME`(*namei*)
Implements `del name`, where *namei* is the index into `co_names` attribute of the code object.

`UNPACK_SEQUENCE`(*count*)
Unpacks TOS into *count* individual values, which are put onto the stack right-to-left.

`UNPACK_EX`(*counts*)
Implements assignment with a starred target: Unpacks an iterable in TOS into individual values, where the total number of values can be smaller than the number of items in the iterable: one of the new values will be a list of all leftover items.

The low byte of *counts* is the number of values before the list value, the high byte of *counts* the number of values after it. The resulting values are put onto the stack right-to-left.

`STORE_ATTR`(*namei*)
Implements `TOS.name = TOS1`, where *namei* is the index of name in `co_names`.

`DELETE_ATTR`(*namei*)
Implements `del TOS.name`, using *namei* as index into `co_names`.

`STORE_GLOBAL`(*namei*)
Works as *STORE_NAME*, but stores the name as a global.

`DELETE_GLOBAL`(*namei*)
Works as *DELETE_NAME*, but deletes a global name.

`LOAD_CONST`(*consti*)
Pushes `co_consts[consti]` onto the stack.

`LOAD_NAME`(*namei*)
Pushes the value associated with `co_names[namei]` onto the stack.

`BUILD_TUPLE`(*count*)
Creates a tuple consuming *count* items from the stack, and pushes the resulting tuple onto the stack.

`BUILD_LIST`(*count*)
Works as *BUILD_TUPLE*, but creates a list.

`BUILD_SET`(*count*)
Works as *BUILD_TUPLE*, but creates a set.

`BUILD_MAP`(*count*)
Pushes a new dictionary object onto the stack. Pops `2 * count` items so that the dictionary holds *count* entries: `{..., TOS3: TOS2, TOS1: TOS}`.

Changed in version 3.5: The dictionary is created from stack items instead of creating an empty dictionary pre-sized to hold *count* items.

`BUILD_CONST_KEY_MAP`(*count*)
The version of *BUILD_MAP* specialized for constant keys. *count* values are consumed from the stack. The top element on the stack contains a tuple of keys.

New in version 3.6.

`BUILD_STRING`(*count*)
Concatenates *count* strings from the stack and pushes the resulting string onto the stack.

New in version 3.6.

`BUILD_TUPLE_UNPACK`(*count*)
Pops *count* iterables from the stack, joins them in a single tuple, and pushes the result. Implements iterable unpacking in tuple displays `(*x, *y, *z)`.

New in version 3.5.

BUILD_TUPLE_UNPACK_WITH_CALL(*count*)
This is similar to *BUILD_TUPLE_UNPACK*, but is used for `f(*x, *y, *z)` call syntax. The stack item at position `count + 1` should be the corresponding callable `f`.

New in version 3.6.

BUILD_LIST_UNPACK(*count*)
This is similar to *BUILD_TUPLE_UNPACK*, but pushes a list instead of tuple. Implements iterable unpacking in list displays `[*x, *y, *z]`.

New in version 3.5.

BUILD_SET_UNPACK(*count*)
This is similar to *BUILD_TUPLE_UNPACK*, but pushes a set instead of tuple. Implements iterable unpacking in set displays `{*x, *y, *z}`.

New in version 3.5.

BUILD_MAP_UNPACK(*count*)
Pops *count* mappings from the stack, merges them into a single dictionary, and pushes the result. Implements dictionary unpacking in dictionary displays `{**x, **y, **z}`.

New in version 3.5.

BUILD_MAP_UNPACK_WITH_CALL(*count*)
This is similar to *BUILD_MAP_UNPACK*, but is used for `f(**x, **y, **z)` call syntax. The stack item at position `count + 2` should be the corresponding callable `f`.

New in version 3.5.

Changed in version 3.6: The position of the callable is determined by adding 2 to the opcode argument instead of encoding it in the second byte of the argument.

LOAD_ATTR(*namei*)
Replaces TOS with `getattr(TOS, co_names[namei])`.

COMPARE_OP(*opname*)
Performs a Boolean operation. The operation name can be found in `cmp_op[opname]`.

IMPORT_NAME(*namei*)
Imports the module `co_names[namei]`. TOS and TOS1 are popped and provide the *fromlist* and *level* arguments of *__import__()*. The module object is pushed onto the stack. The current namespace is not affected: for a proper import statement, a subsequent *STORE_FAST* instruction modifies the namespace.

IMPORT_FROM(*namei*)
Loads the attribute `co_names[namei]` from the module found in TOS. The resulting object is pushed onto the stack, to be subsequently stored by a *STORE_FAST* instruction.

JUMP_FORWARD(*delta*)
Increments bytecode counter by *delta*.

POP_JUMP_IF_TRUE(*target*)
If TOS is true, sets the bytecode counter to *target*. TOS is popped.

New in version 3.1.

POP_JUMP_IF_FALSE(*target*)
If TOS is false, sets the bytecode counter to *target*. TOS is popped.

New in version 3.1.

JUMP_IF_TRUE_OR_POP(*target*)
If TOS is true, sets the bytecode counter to *target* and leaves TOS on the stack. Otherwise (TOS is false), TOS is popped.

New in version 3.1.

JUMP_IF_FALSE_OR_POP(*target*)
If TOS is false, sets the bytecode counter to *target* and leaves TOS on the stack. Otherwise (TOS is true), TOS is popped.

New in version 3.1.

JUMP_ABSOLUTE(*target*)
Set bytecode counter to *target*.

FOR_ITER(*delta*)
TOS is an *iterator*. Call its *__next__()* method. If this yields a new value, push it on the stack (leaving the iterator below it). If the iterator indicates it is exhausted TOS is popped, and the byte code counter is incremented by *delta*.

LOAD_GLOBAL(*namei*)
Loads the global named `co_names[namei]` onto the stack.

SETUP_LOOP(*delta*)
Pushes a block for a loop onto the block stack. The block spans from the current instruction with a size of *delta* bytes.

SETUP_EXCEPT(*delta*)
Pushes a try block from a try-except clause onto the block stack. *delta* points to the first except block.

SETUP_FINALLY(*delta*)
Pushes a try block from a try-except clause onto the block stack. *delta* points to the finally block.

LOAD_FAST(*var_num*)
Pushes a reference to the local `co_varnames[var_num]` onto the stack.

STORE_FAST(*var_num*)
Stores TOS into the local `co_varnames[var_num]`.

DELETE_FAST(*var_num*)
Deletes local `co_varnames[var_num]`.

LOAD_CLOSURE(*i*)
Pushes a reference to the cell contained in slot *i* of the cell and free variable storage. The name of the variable is `co_cellvars[i]` if *i* is less than the length of *co_cellvars*. Otherwise it is `co_freevars[i - len(co_cellvars)]`.

LOAD_DEREF(*i*)
Loads the cell contained in slot *i* of the cell and free variable storage. Pushes a reference to the object the cell contains on the stack.

LOAD_CLASSDEREF(*i*)
Much like *LOAD_DEREF* but first checks the locals dictionary before consulting the cell. This is used for loading free variables in class bodies.

New in version 3.4.

STORE_DEREF(*i*)
Stores TOS into the cell contained in slot *i* of the cell and free variable storage.

DELETE_DEREF(*i*)
Empties the cell contained in slot *i* of the cell and free variable storage. Used by the `del` statement.

New in version 3.2.

RAISE_VARARGS(*argc*)
Raises an exception. *argc* indicates the number of parameters to the raise statement, ranging from 0 to 3. The handler will find the traceback as TOS2, the parameter as TOS1, and the exception as TOS.

`CALL_FUNCTION`(*argc*)
Calls a function. *argc* indicates the number of positional arguments. The positional arguments are on the stack, with the right-most argument on top. Below the arguments, the function object to call is on the stack. Pops all function arguments, and the function itself off the stack, and pushes the return value.

Changed in version 3.6: This opcode is used only for calls with positional arguments.

`CALL_FUNCTION_KW`(*argc*)
Calls a function. *argc* indicates the number of arguments (positional and keyword). The top element on the stack contains a tuple of keyword argument names. Below the tuple, keyword arguments are on the stack, in the order corresponding to the tuple. Below the keyword arguments, the positional arguments are on the stack, with the right-most parameter on top. Below the arguments, the function object to call is on the stack. Pops all function arguments, and the function itself off the stack, and pushes the return value.

Changed in version 3.6: Keyword arguments are packed in a tuple instead of a dictionary, *argc* indicates the total number of arguments

`CALL_FUNCTION_EX`(*flags*)
Calls a function. The lowest bit of *flags* indicates whether the var-keyword argument is placed at the top of the stack. Below the var-keyword argument, the var-positional argument is on the stack. Below the arguments, the function object to call is placed. Pops all function arguments, and the function itself off the stack, and pushes the return value. Note that this opcode pops at most three items from the stack. Var-positional and var-keyword arguments are packed by *BUILD_TUPLE_UNPACK_WITH_CALL* and *BUILD_MAP_UNPACK_WITH_CALL*.

New in version 3.6.

`LOAD_METHOD`(*namei*)
Loads a method named `co_names[namei]` from TOS object. TOS is popped and method and TOS are pushed when interpreter can call unbound method directly. TOS will be used as the first argument (`self`) by *CALL_METHOD*. Otherwise, `NULL` and method is pushed (method is bound method or something else).

New in version 3.7.

`CALL_METHOD`(*argc*)
Calls a method. *argc* is number of positional arguments. Keyword arguments are not supported. This opcode is designed to be used with *LOAD_METHOD*. Positional arguments are on top of the stack. Below them, two items described in *LOAD_METHOD* on the stack. All of them are popped and return value is pushed.

New in version 3.7.

`MAKE_FUNCTION`(*argc*)
Pushes a new function object on the stack. From bottom to top, the consumed stack must consist of values if the argument carries a specified flag value

- `0x01` a tuple of default argument objects in positional order
- `0x02` a dictionary of keyword-only parameters' default values
- `0x04` an annotation dictionary
- `0x08` a tuple containing cells for free variables, making a closure
- the code associated with the function (at TOS1)
- the *qualified name* of the function (at TOS)

`BUILD_SLICE`(*argc*)
Pushes a slice object on the stack. *argc* must be 2 or 3. If it is 2, `slice(TOS1, TOS)` is pushed; if it is 3, `slice(TOS2, TOS1, TOS)` is pushed. See the *slice()* built-in function for more information.

`EXTENDED_ARG`(*ext*)
Prefixes any opcode which has an argument too big to fit into the default two bytes. *ext* holds two additional bytes which, taken together with the subsequent opcode's argument, comprise a four-byte argument, *ext* being the two most-significant bytes.

`FORMAT_VALUE`(*flags*)
Used for implementing formatted literal strings (f-strings). Pops an optional *fmt_spec* from the stack, then a required *value*. *flags* is interpreted as follows:

- `(flags & 0x03) == 0x00`: *value* is formatted as-is.
- `(flags & 0x03) == 0x01`: call *str()* on *value* before formatting it.
- `(flags & 0x03) == 0x02`: call *repr()* on *value* before formatting it.
- `(flags & 0x03) == 0x03`: call *ascii()* on *value* before formatting it.
- `(flags & 0x04) == 0x04`: pop *fmt_spec* from the stack and use it, else use an empty *fmt_spec*.

Formatting is performed using `PyObject_Format()`. The result is pushed on the stack.

New in version 3.6.

`HAVE_ARGUMENT`
This is not really an opcode. It identifies the dividing line between opcodes which don't use their argument and those that do (`< HAVE_ARGUMENT` and `>= HAVE_ARGUMENT`, respectively).

Changed in version 3.6: Now every instruction has an argument, but opcodes `< HAVE_ARGUMENT` ignore it. Before, only opcodes `>= HAVE_ARGUMENT` had an argument.

33.12.4 Opcode collections

These collections are provided for automatic introspection of bytecode instructions:

`dis.opname`
Sequence of operation names, indexable using the bytecode.

`dis.opmap`
Dictionary mapping operation names to bytecodes.

`dis.cmp_op`
Sequence of all compare operation names.

`dis.hasconst`
Sequence of bytecodes that have a constant parameter.

`dis.hasfree`
Sequence of bytecodes that access a free variable (note that 'free' in this context refers to names in the current scope that are referenced by inner scopes or names in outer scopes that are referenced from this scope. It does *not* include references to global or builtin scopes).

`dis.hasname`
Sequence of bytecodes that access an attribute by name.

`dis.hasjrel`
Sequence of bytecodes that have a relative jump target.

`dis.hasjabs`
Sequence of bytecodes that have an absolute jump target.

`dis.haslocal`
Sequence of bytecodes that access a local variable.

`dis.hascompare`
Sequence of bytecodes of Boolean operations.

33.13 pickletools — Tools for pickle developers

Source code: Lib/pickletools.py

This module contains various constants relating to the intimate details of the *pickle* module, some lengthy comments about the implementation, and a few useful functions for analyzing pickled data. The contents of this module are useful for Python core developers who are working on the *pickle*; ordinary users of the *pickle* module probably won't find the *pickletools* module relevant.

33.13.1 Command line usage

New in version 3.2.

When invoked from the command line, `python -m pickletools` will disassemble the contents of one or more pickle files. Note that if you want to see the Python object stored in the pickle rather than the details of pickle format, you may want to use `-m pickle` instead. However, when the pickle file that you want to examine comes from an untrusted source, `-m pickletools` is a safer option because it does not execute pickle bytecode.

For example, with a tuple `(1, 2)` pickled in file `x.pickle`:

```
$ python -m pickle x.pickle
(1, 2)

$ python -m pickletools x.pickle
    0: \x80 PROTO      3
    2: K    BININT1    1
    4: K    BININT1    2
    6: \x86 TUPLE2
    7: q    BINPUT     0
    9: .    STOP
highest protocol among opcodes = 2
```

Command line options

-a, --annotate
Annotate each line with a short opcode description.

-o, --output=<file>
Name of a file where the output should be written.

-l, --indentlevel=<num>
The number of blanks by which to indent a new MARK level.

-m, --memo
When multiple objects are disassembled, preserve memo between disassemblies.

-p, --preamble=<preamble>
When more than one pickle file are specified, print given preamble before each disassembly.

33.13.2 Programmatic Interface

pickletools.dis(*pickle*, *out=None*, *memo=None*, *indentlevel=4*, *annotate=0*)
Outputs a symbolic disassembly of the pickle to the file-like object *out*, defaulting to `sys.stdout`.

pickle can be a string or a file-like object. *memo* can be a Python dictionary that will be used as the pickle's memo; it can be used to perform disassemblies across multiple pickles created by the same pickler. Successive levels, indicated by `MARK` opcodes in the stream, are indented by *indentlevel* spaces. If a nonzero value is given to *annotate*, each opcode in the output is annotated with a short description. The value of *annotate* is used as a hint for the column where annotation should start.

New in version 3.2: The *annotate* argument.

`pickletools.genops`(*pickle*)
Provides an *iterator* over all of the opcodes in a pickle, returning a sequence of `(opcode, arg, pos)` triples. *opcode* is an instance of an `OpcodeInfo` class; *arg* is the decoded value, as a Python object, of the opcode's argument; *pos* is the position at which this opcode is located. *pickle* can be a string or a file-like object.

`pickletools.optimize`(*picklestring*)
Returns a new equivalent pickle string after eliminating unused `PUT` opcodes. The optimized pickle is shorter, takes less transmission time, requires less storage space, and unpickles more efficiently.

CHAPTER

THIRTYFOUR

MISCELLANEOUS SERVICES

The modules described in this chapter provide miscellaneous services that are available in all Python versions. Here's an overview:

34.1 `formatter` — Generic output formatting

Deprecated since version 3.4: Due to lack of usage, the formatter module has been deprecated.

This module supports two interface definitions, each with multiple implementations: The *formatter* interface, and the *writer* interface which is required by the formatter interface.

Formatter objects transform an abstract flow of formatting events into specific output events on writer objects. Formatters manage several stack structures to allow various properties of a writer object to be changed and restored; writers need not be able to handle relative changes nor any sort of "change back" operation. Specific writer properties which may be controlled via formatter objects are horizontal alignment, font, and left margin indentations. A mechanism is provided which supports providing arbitrary, non-exclusive style settings to a writer as well. Additional interfaces facilitate formatting events which are not reversible, such as paragraph separation.

Writer objects encapsulate device interfaces. Abstract devices, such as file formats, are supported as well as physical devices. The provided implementations all work with abstract devices. The interface makes available mechanisms for setting the properties which formatter objects manage and inserting data into the output.

34.1.1 The Formatter Interface

Interfaces to create formatters are dependent on the specific formatter class being instantiated. The interfaces described below are the required interfaces which all formatters must support once initialized.

One data element is defined at the module level:

`formatter.AS_IS`
: Value which can be used in the font specification passed to the `push_font()` method described below, or as the new value to any other `push_property()` method. Pushing the `AS_IS` value allows the corresponding `pop_property()` method to be called without having to track whether the property was changed.

The following attributes are defined for formatter instance objects:

`formatter.writer`
: The writer instance with which the formatter interacts.

formatter.**end_paragraph**(*blanklines*)
Close any open paragraphs and insert at least *blanklines* before the next paragraph.

formatter.**add_line_break**()
Add a hard line break if one does not already exist. This does not break the logical paragraph.

formatter.**add_hor_rule**(**args*, ***kw*)
Insert a horizontal rule in the output. A hard break is inserted if there is data in the current paragraph, but the logical paragraph is not broken. The arguments and keywords are passed on to the writer's `send_line_break()` method.

formatter.**add_flowing_data**(*data*)
Provide data which should be formatted with collapsed whitespace. Whitespace from preceding and successive calls to *add_flowing_data()* is considered as well when the whitespace collapse is performed. The data which is passed to this method is expected to be word-wrapped by the output device. Note that any word-wrapping still must be performed by the writer object due to the need to rely on device and font information.

formatter.**add_literal_data**(*data*)
Provide data which should be passed to the writer unchanged. Whitespace, including newline and tab characters, are considered legal in the value of *data*.

formatter.**add_label_data**(*format*, *counter*)
Insert a label which should be placed to the left of the current left margin. This should be used for constructing bulleted or numbered lists. If the *format* value is a string, it is interpreted as a format specification for *counter*, which should be an integer. The result of this formatting becomes the value of the label; if *format* is not a string it is used as the label value directly. The label value is passed as the only argument to the writer's `send_label_data()` method. Interpretation of non-string label values is dependent on the associated writer.

Format specifications are strings which, in combination with a counter value, are used to compute label values. Each character in the format string is copied to the label value, with some characters recognized to indicate a transform on the counter value. Specifically, the character `'1'` represents the counter value formatter as an Arabic number, the characters `'A'` and `'a'` represent alphabetic representations of the counter value in upper and lower case, respectively, and `'I'` and `'i'` represent the counter value in Roman numerals, in upper and lower case. Note that the alphabetic and roman transforms require that the counter value be greater than zero.

formatter.**flush_softspace**()
Send any pending whitespace buffered from a previous call to *add_flowing_data()* to the associated writer object. This should be called before any direct manipulation of the writer object.

formatter.**push_alignment**(*align*)
Push a new alignment setting onto the alignment stack. This may be *AS_IS* if no change is desired. If the alignment value is changed from the previous setting, the writer's `new_alignment()` method is called with the *align* value.

formatter.**pop_alignment**()
Restore the previous alignment.

formatter.**push_font**(*(size*, *italic*, *bold*, *teletype)*)
Change some or all font properties of the writer object. Properties which are not set to *AS_IS* are set to the values passed in while others are maintained at their current settings. The writer's `new_font()` method is called with the fully resolved font specification.

formatter.**pop_font**()
Restore the previous font.

formatter.**push_margin**(*margin*)
Increase the number of left margin indentations by one, associating the logical tag *margin* with the

new indentation. The initial margin level is `0`. Changed values of the logical tag must be true values; false values other than *AS_IS* are not sufficient to change the margin.

`formatter.pop_margin()`
Restore the previous margin.

`formatter.push_style(`**styles*`)`
Push any number of arbitrary style specifications. All styles are pushed onto the styles stack in order. A tuple representing the entire stack, including *AS_IS* values, is passed to the writer's `new_styles()` method.

`formatter.pop_style(`*n=1*`)`
Pop the last *n* style specifications passed to *push_style()*. A tuple representing the revised stack, including *AS_IS* values, is passed to the writer's `new_styles()` method.

`formatter.set_spacing(`*spacing*`)`
Set the spacing style for the writer.

`formatter.assert_line_data(`*flag=1*`)`
Inform the formatter that data has been added to the current paragraph out-of-band. This should be used when the writer has been manipulated directly. The optional *flag* argument can be set to false if the writer manipulations produced a hard line break at the end of the output.

34.1.2 Formatter Implementations

Two implementations of formatter objects are provided by this module. Most applications may use one of these classes without modification or subclassing.

`class formatter.NullFormatter(`*writer=None*`)`
A formatter which does nothing. If *writer* is omitted, a *NullWriter* instance is created. No methods of the writer are called by *NullFormatter* instances. Implementations should inherit from this class if implementing a writer interface but don't need to inherit any implementation.

`class formatter.AbstractFormatter(`*writer*`)`
The standard formatter. This implementation has demonstrated wide applicability to many writers, and may be used directly in most circumstances. It has been used to implement a full-featured World Wide Web browser.

34.1.3 The Writer Interface

Interfaces to create writers are dependent on the specific writer class being instantiated. The interfaces described below are the required interfaces which all writers must support once initialized. Note that while most applications can use the *AbstractFormatter* class as a formatter, the writer must typically be provided by the application.

`writer.flush()`
Flush any buffered output or device control events.

`writer.new_alignment(`*align*`)`
Set the alignment style. The *align* value can be any object, but by convention is a string or `None`, where `None` indicates that the writer's "preferred" alignment should be used. Conventional *align* values are `'left'`, `'center'`, `'right'`, and `'justify'`.

`writer.new_font(`*font*`)`
Set the font style. The value of *font* will be `None`, indicating that the device's default font should be used, or a tuple of the form `(size, italic, bold, teletype)`. Size will be a string indicating the size of font that should be used; specific strings and their interpretation must be defined by the application.

The *italic*, *bold*, and *teletype* values are Boolean values specifying which of those font attributes should be used.

writer.new_margin(*margin*, *level*)
Set the margin level to the integer *level* and the logical tag to *margin*. Interpretation of the logical tag is at the writer's discretion; the only restriction on the value of the logical tag is that it not be a false value for non-zero values of *level*.

writer.new_spacing(*spacing*)
Set the spacing style to *spacing*.

writer.new_styles(*styles*)
Set additional styles. The *styles* value is a tuple of arbitrary values; the value *AS_IS* should be ignored. The *styles* tuple may be interpreted either as a set or as a stack depending on the requirements of the application and writer implementation.

writer.send_line_break()
Break the current line.

writer.send_paragraph(*blankline*)
Produce a paragraph separation of at least *blankline* blank lines, or the equivalent. The *blankline* value will be an integer. Note that the implementation will receive a call to *send_line_break()* before this call if a line break is needed; this method should not include ending the last line of the paragraph. It is only responsible for vertical spacing between paragraphs.

writer.send_hor_rule(**args*, ***kw*)
Display a horizontal rule on the output device. The arguments to this method are entirely application- and writer-specific, and should be interpreted with care. The method implementation may assume that a line break has already been issued via *send_line_break()*.

writer.send_flowing_data(*data*)
Output character data which may be word-wrapped and re-flowed as needed. Within any sequence of calls to this method, the writer may assume that spans of multiple whitespace characters have been collapsed to single space characters.

writer.send_literal_data(*data*)
Output character data which has already been formatted for display. Generally, this should be interpreted to mean that line breaks indicated by newline characters should be preserved and no new line breaks should be introduced. The data may contain embedded newline and tab characters, unlike data provided to the `send_formatted_data()` interface.

writer.send_label_data(*data*)
Set *data* to the left of the current left margin, if possible. The value of *data* is not restricted; treatment of non-string values is entirely application- and writer-dependent. This method will only be called at the beginning of a line.

34.1.4 Writer Implementations

Three implementations of the writer object interface are provided as examples by this module. Most applications will need to derive new writer classes from the *NullWriter* class.

class formatter.NullWriter
A writer which only provides the interface definition; no actions are taken on any methods. This should be the base class for all writers which do not need to inherit any implementation methods.

class formatter.AbstractWriter
A writer which can be used in debugging formatters, but not much else. Each method simply announces itself by printing its name and arguments on standard output.

`class formatter.DumbWriter(`*file=None*, *maxcol=72*`)`

Simple writer class which writes output on the *file object* passed in as *file* or, if *file* is omitted, on standard output. The output is simply word-wrapped to the number of columns specified by *maxcol*. This class is suitable for reflowing a sequence of paragraphs.

CHAPTER

THIRTYFIVE

MS WINDOWS SPECIFIC SERVICES

This chapter describes modules that are only available on MS Windows platforms.

35.1 `msilib` — Read and write Microsoft Installer files

Source code: Lib/msilib/__init__.py

The *msilib* supports the creation of Microsoft Installer (`.msi`) files. Because these files often contain an embedded "cabinet" file (`.cab`), it also exposes an API to create CAB files. Support for reading `.cab` files is currently not implemented; read support for the `.msi` database is possible.

This package aims to provide complete access to all tables in an `.msi` file, therefore, it is a fairly low-level API. Two primary applications of this package are the *distutils* command `bdist_msi`, and the creation of Python installer package itself (although that currently uses a different version of `msilib`).

The package contents can be roughly split into four parts: low-level CAB routines, low-level MSI routines, higher-level MSI routines, and standard table structures.

`msilib.FCICreate`(*cabname*, *files*)
: Create a new CAB file named *cabname*. *files* must be a list of tuples, each containing the name of the file on disk, and the name of the file inside the CAB file.

  The files are added to the CAB file in the order they appear in the list. All files are added into a single CAB file, using the MSZIP compression algorithm.

  Callbacks to Python for the various steps of MSI creation are currently not exposed.

`msilib.UuidCreate`()
: Return the string representation of a new unique identifier. This wraps the Windows API functions `UuidCreate()` and `UuidToString()`.

`msilib.OpenDatabase`(*path*, *persist*)
: Return a new database object by calling MsiOpenDatabase. *path* is the file name of the MSI file; *persist* can be one of the constants `MSIDBOPEN_CREATEDIRECT`, `MSIDBOPEN_CREATE`, `MSIDBOPEN_DIRECT`, `MSIDBOPEN_READONLY`, or `MSIDBOPEN_TRANSACT`, and may include the flag `MSIDBOPEN_PATCHFILE`. See the Microsoft documentation for the meaning of these flags; depending on the flags, an existing database is opened, or a new one created.

`msilib.CreateRecord`(*count*)
: Return a new record object by calling `MSICreateRecord()`. *count* is the number of fields of the record.

`msilib.init_database`(*name*, *schema*, *ProductName*, *ProductCode*, *ProductVersion*, *Manufacturer*)
: Create and return a new database *name*, initialize it with *schema*, and set the properties *ProductName*, *ProductCode*, *ProductVersion*, and *Manufacturer*.

schema must be a module object containing `tables` and `_Validation_records` attributes; typically, *msilib.schema* should be used.

The database will contain just the schema and the validation records when this function returns.

msilib.add_data(*database*, *table*, *records*)
Add all *records* to the table named *table* in *database*.

The *table* argument must be one of the predefined tables in the MSI schema, e.g. `'Feature'`, `'File'`, `'Component'`, `'Dialog'`, `'Control'`, etc.

records should be a list of tuples, each one containing all fields of a record according to the schema of the table. For optional fields, `None` can be passed.

Field values can be ints, strings, or instances of the Binary class.

class msilib.Binary(*filename*)
Represents entries in the Binary table; inserting such an object using *add_data()* reads the file named *filename* into the table.

msilib.add_tables(*database*, *module*)
Add all table content from *module* to *database*. *module* must contain an attribute *tables* listing all tables for which content should be added, and one attribute per table that has the actual content.

This is typically used to install the sequence tables.

msilib.add_stream(*database*, *name*, *path*)
Add the file *path* into the `_Stream` table of *database*, with the stream name *name*.

msilib.gen_uuid()
Return a new UUID, in the format that MSI typically requires (i.e. in curly braces, and with all hexdigits in upper-case).

See also:

FCICreate UuidCreate UuidToString

35.1.1 Database Objects

Database.OpenView(*sql*)
Return a view object, by calling `MSIDatabaseOpenView()`. *sql* is the SQL statement to execute.

Database.Commit()
Commit the changes pending in the current transaction, by calling `MSIDatabaseCommit()`.

Database.GetSummaryInformation(*count*)
Return a new summary information object, by calling `MsiGetSummaryInformation()`. *count* is the maximum number of updated values.

Database.Close()
Close the database object, through `MsiCloseHandle()`.

New in version 3.7.

See also:

MSIDatabaseOpenView MSIDatabaseCommit MSIGetSummaryInformation MsiCloseHandle

35.1.2 View Objects

View.Execute(*params*)
Execute the SQL query of the view, through `MSIViewExecute()`. If *params* is not `None`, it is a record describing actual values of the parameter tokens in the query.

View.**GetColumnInfo**(*kind*)
Return a record describing the columns of the view, through calling `MsiViewGetColumnInfo()`. *kind* can be either `MSICOLINFO_NAMES` or `MSICOLINFO_TYPES`.

View.**Fetch**()
Return a result record of the query, through calling `MsiViewFetch()`.

View.**Modify**(*kind*, *data*)
Modify the view, by calling `MsiViewModify()`. *kind* can be one of `MSIMODIFY_SEEK`, `MSIMODIFY_REFRESH`, `MSIMODIFY_INSERT`, `MSIMODIFY_UPDATE`, `MSIMODIFY_ASSIGN`, `MSIMODIFY_REPLACE`, `MSIMODIFY_MERGE`, `MSIMODIFY_DELETE`, `MSIMODIFY_INSERT_TEMPORARY`, `MSIMODIFY_VALIDATE`, `MSIMODIFY_VALIDATE_NEW`, `MSIMODIFY_VALIDATE_FIELD`, or `MSIMODIFY_VALIDATE_DELETE`.

data must be a record describing the new data.

View.**Close**()
Close the view, through `MsiViewClose()`.

See also:

MsiViewExecute MSIViewGetColumnInfo MsiViewFetch MsiViewModify MsiViewClose

35.1.3 Summary Information Objects

SummaryInformation.**GetProperty**(*field*)
Return a property of the summary, through `MsiSummaryInfoGetProperty()`. *field* is the name of the property, and can be one of the constants `PID_CODEPAGE`, `PID_TITLE`, `PID_SUBJECT`, `PID_AUTHOR`, `PID_KEYWORDS`, `PID_COMMENTS`, `PID_TEMPLATE`, `PID_LASTAUTHOR`, `PID_REVNUMBER`, `PID_LASTPRINTED`, `PID_CREATE_DTM`, `PID_LASTSAVE_DTM`, `PID_PAGECOUNT`, `PID_WORDCOUNT`, `PID_CHARCOUNT`, `PID_APPNAME`, or `PID_SECURITY`.

SummaryInformation.**GetPropertyCount**()
Return the number of summary properties, through `MsiSummaryInfoGetPropertyCount()`.

SummaryInformation.**SetProperty**(*field*, *value*)
Set a property through `MsiSummaryInfoSetProperty()`. *field* can have the same values as in *GetProperty()*, *value* is the new value of the property. Possible value types are integer and string.

SummaryInformation.**Persist**()
Write the modified properties to the summary information stream, using `MsiSummaryInfoPersist()`.

See also:

MsiSummaryInfoGetProperty MsiSummaryInfoGetPropertyCount MsiSummaryInfoSetProperty MsiSummaryInfoPersist

35.1.4 Record Objects

Record.**GetFieldCount**()
Return the number of fields of the record, through `MsiRecordGetFieldCount()`.

Record.**GetInteger**(*field*)
Return the value of *field* as an integer where possible. *field* must be an integer.

Record.**GetString**(*field*)
Return the value of *field* as a string where possible. *field* must be an integer.

Record.**SetString**(*field*, *value*)
Set *field* to *value* through `MsiRecordSetString()`. *field* must be an integer; *value* a string.

`Record.SetStream`(*field*, *value*)
Set *field* to the contents of the file named *value*, through `MsiRecordSetStream()`. *field* must be an integer; *value* a string.

`Record.SetInteger`(*field*, *value*)
Set *field* to *value* through `MsiRecordSetInteger()`. Both *field* and *value* must be an integer.

`Record.ClearData`()
Set all fields of the record to 0, through `MsiRecordClearData()`.

See also:

MsiRecordGetFieldCount MsiRecordSetString MsiRecordSetStream MsiRecordSetInteger MsiRecordClearData

35.1.5 Errors

All wrappers around MSI functions raise `MSIError`; the string inside the exception will contain more detail.

35.1.6 CAB Objects

`class msilib.CAB`(*name*)
The class *CAB* represents a CAB file. During MSI construction, files will be added simultaneously to the `Files` table, and to a CAB file. Then, when all files have been added, the CAB file can be written, then added to the MSI file.

name is the name of the CAB file in the MSI file.

`append`(*full*, *file*, *logical*)
Add the file with the pathname *full* to the CAB file, under the name *logical*. If there is already a file named *logical*, a new file name is created.

Return the index of the file in the CAB file, and the new name of the file inside the CAB file.

`commit`(*database*)
Generate a CAB file, add it as a stream to the MSI file, put it into the `Media` table, and remove the generated file from the disk.

35.1.7 Directory Objects

`class msilib.Directory`(*database*, *cab*, *basedir*, *physical*, *logical*, *default*[, *componentflags*])
Create a new directory in the Directory table. There is a current component at each point in time for the directory, which is either explicitly created through *start_component()*, or implicitly when files are added for the first time. Files are added into the current component, and into the cab file. To create a directory, a base directory object needs to be specified (can be `None`), the path to the physical directory, and a logical directory name. *default* specifies the DefaultDir slot in the directory table. *componentflags* specifies the default flags that new components get.

`start_component`(*component=None*, *feature=None*, *flags=None*, *keyfile=None*, *uuid=None*)
Add an entry to the Component table, and make this component the current component for this directory. If no component name is given, the directory name is used. If no *feature* is given, the current feature is used. If no *flags* are given, the directory's default flags are used. If no *keyfile* is given, the KeyPath is left null in the Component table.

`add_file`(*file*, *src=None*, *version=None*, *language=None*)
Add a file to the current component of the directory, starting a new one if there is no current component. By default, the file name in the source and the file table will be identical. If the

src file is specified, it is interpreted relative to the current directory. Optionally, a *version* and a *language* can be specified for the entry in the File table.

glob(*pattern*, *exclude=None*)
Add a list of files to the current component as specified in the glob pattern. Individual files can be excluded in the *exclude* list.

remove_pyc()
Remove `.pyc` files on uninstall.

See also:

Directory Table File Table Component Table FeatureComponents Table

35.1.8 Features

class msilib.Feature(*db*, *id*, *title*, *desc*, *display*, *level=1*, *parent=None*, *directory=None*, *attributes=0*)
Add a new record to the `Feature` table, using the values *id*, *parent.id*, *title*, *desc*, *display*, *level*, *directory*, and *attributes*. The resulting feature object can be passed to the `start_component()` method of *Directory*.

set_current()
Make this feature the current feature of *msilib*. New components are automatically added to the default feature, unless a feature is explicitly specified.

See also:

Feature Table

35.1.9 GUI classes

msilib provides several classes that wrap the GUI tables in an MSI database. However, no standard user interface is provided; use `bdist_msi` to create MSI files with a user-interface for installing Python packages.

class msilib.Control(*dlg*, *name*)
Base class of the dialog controls. *dlg* is the dialog object the control belongs to, and *name* is the control's name.

event(*event*, *argument*, *condition=1*, *ordering=None*)
Make an entry into the `ControlEvent` table for this control.

mapping(*event*, *attribute*)
Make an entry into the `EventMapping` table for this control.

condition(*action*, *condition*)
Make an entry into the `ControlCondition` table for this control.

class msilib.RadioButtonGroup(*dlg*, *name*, *property*)
Create a radio button control named *name*. *property* is the installer property that gets set when a radio button is selected.

add(*name*, *x*, *y*, *width*, *height*, *text*, *value=None*)
Add a radio button named *name* to the group, at the coordinates *x*, *y*, *width*, *height*, and with the label *text*. If *value* is `None`, it defaults to *name*.

class msilib.Dialog(*db*, *name*, *x*, *y*, *w*, *h*, *attr*, *title*, *first*, *default*, *cancel*)
Return a new *Dialog* object. An entry in the `Dialog` table is made, with the specified coordinates, dialog attributes, title, name of the first, default, and cancel controls.

control(*name*, *type*, *x*, *y*, *width*, *height*, *attributes*, *property*, *text*, *control_next*, *help*)
Return a new *Control* object. An entry in the `Control` table is made with the specified parameters.

This is a generic method; for specific types, specialized methods are provided.

text(*name*, *x*, *y*, *width*, *height*, *attributes*, *text*)
Add and return a `Text` control.

bitmap(*name*, *x*, *y*, *width*, *height*, *text*)
Add and return a `Bitmap` control.

line(*name*, *x*, *y*, *width*, *height*)
Add and return a `Line` control.

pushbutton(*name*, *x*, *y*, *width*, *height*, *attributes*, *text*, *next_control*)
Add and return a `PushButton` control.

radiogroup(*name*, *x*, *y*, *width*, *height*, *attributes*, *property*, *text*, *next_control*)
Add and return a `RadioButtonGroup` control.

checkbox(*name*, *x*, *y*, *width*, *height*, *attributes*, *property*, *text*, *next_control*)
Add and return a `CheckBox` control.

See also:

Dialog Table Control Table Control Types ControlCondition Table ControlEvent Table EventMapping Table RadioButton Table

35.1.10 Precomputed tables

msilib provides a few subpackages that contain only schema and table definitions. Currently, these definitions are based on MSI version 2.0.

msilib.schema
This is the standard MSI schema for MSI 2.0, with the *tables* variable providing a list of table definitions, and *_Validation_records* providing the data for MSI validation.

msilib.sequence
This module contains table contents for the standard sequence tables: *AdminExecuteSequence*, *AdminUISequence*, *AdvtExecuteSequence*, *InstallExecuteSequence*, and *InstallUISequence*.

msilib.text
This module contains definitions for the UIText and ActionText tables, for the standard installer actions.

35.2 msvcrt — Useful routines from the MS VC++ runtime

These functions provide access to some useful capabilities on Windows platforms. Some higher-level modules use these functions to build the Windows implementations of their services. For example, the *getpass* module uses this in the implementation of the *getpass()* function.

Further documentation on these functions can be found in the Platform API documentation.

The module implements both the normal and wide char variants of the console I/O api. The normal API deals only with ASCII characters and is of limited use for internationalized applications. The wide char API should be used where ever possible.

Changed in version 3.3: Operations in this module now raise *OSError* where *IOError* was raised.

35.2.1 File Operations

msvcrt.locking(*fd*, *mode*, *nbytes*)
Lock part of a file based on file descriptor *fd* from the C runtime. Raises *OSError* on failure. The locked region of the file extends from the current file position for *nbytes* bytes, and may continue beyond the end of the file. *mode* must be one of the `LK_*` constants listed below. Multiple regions in a file may be locked at the same time, but may not overlap. Adjacent regions are not merged; they must be unlocked individually.

msvcrt.LK_LOCK
msvcrt.LK_RLCK
Locks the specified bytes. If the bytes cannot be locked, the program immediately tries again after 1 second. If, after 10 attempts, the bytes cannot be locked, *OSError* is raised.

msvcrt.LK_NBLCK
msvcrt.LK_NBRLCK
Locks the specified bytes. If the bytes cannot be locked, *OSError* is raised.

msvcrt.LK_UNLCK
Unlocks the specified bytes, which must have been previously locked.

msvcrt.setmode(*fd*, *flags*)
Set the line-end translation mode for the file descriptor *fd*. To set it to text mode, *flags* should be *os.O_TEXT*; for binary, it should be *os.O_BINARY*.

msvcrt.open_osfhandle(*handle*, *flags*)
Create a C runtime file descriptor from the file handle *handle*. The *flags* parameter should be a bitwise OR of *os.O_APPEND*, *os.O_RDONLY*, and *os.O_TEXT*. The returned file descriptor may be used as a parameter to *os.fdopen()* to create a file object.

msvcrt.get_osfhandle(*fd*)
Return the file handle for the file descriptor *fd*. Raises *OSError* if *fd* is not recognized.

35.2.2 Console I/O

msvcrt.kbhit()
Return true if a keypress is waiting to be read.

msvcrt.getch()
Read a keypress and return the resulting character as a byte string. Nothing is echoed to the console. This call will block if a keypress is not already available, but will not wait for `Enter` to be pressed. If the pressed key was a special function key, this will return `'\000'` or `'\xe0'`; the next call will return the keycode. The `Control-C` keypress cannot be read with this function.

msvcrt.getwch()
Wide char variant of *getch()*, returning a Unicode value.

msvcrt.getche()
Similar to *getch()*, but the keypress will be echoed if it represents a printable character.

msvcrt.getwche()
Wide char variant of *getche()*, returning a Unicode value.

msvcrt.putch(*char*)
Print the byte string *char* to the console without buffering.

msvcrt.putwch(*unicode_char*)
Wide char variant of *putch()*, accepting a Unicode value.

msvcrt.ungetch(*char*)
Cause the byte string *char* to be "pushed back" into the console buffer; it will be the next character read by *getch()* or *getche()*.

msvcrt.ungetwch(*unicode_char*)
Wide char variant of *ungetch()*, accepting a Unicode value.

35.2.3 Other Functions

msvcrt.heapmin()
Force the `malloc()` heap to clean itself up and return unused blocks to the operating system. On failure, this raises *OSError*.

35.3 `winreg` — Windows registry access

These functions expose the Windows registry API to Python. Instead of using an integer as the registry handle, a *handle object* is used to ensure that the handles are closed correctly, even if the programmer neglects to explicitly close them.

Changed in version 3.3: Several functions in this module used to raise a *WindowsError*, which is now an alias of *OSError*.

35.3.1 Functions

This module offers the following functions:

winreg.CloseKey(*hkey*)
Closes a previously opened registry key. The *hkey* argument specifies a previously opened key.

Note: If *hkey* is not closed using this method (or via *hkey.Close()*), it is closed when the *hkey* object is destroyed by Python.

winreg.ConnectRegistry(*computer_name*, *key*)
Establishes a connection to a predefined registry handle on another computer, and returns a *handle object*.

computer_name is the name of the remote computer, of the form `r"\\computername"`. If `None`, the local computer is used.

key is the predefined handle to connect to.

The return value is the handle of the opened key. If the function fails, an *OSError* exception is raised.

Changed in version 3.3: See *above*.

winreg.CreateKey(*key*, *sub_key*)
Creates or opens the specified key, returning a *handle object*.

key is an already open key, or one of the predefined *HKEY_* constants*.

sub_key is a string that names the key this method opens or creates.

If *key* is one of the predefined keys, *sub_key* may be `None`. In that case, the handle returned is the same key handle passed in to the function.

If the key already exists, this function opens the existing key.

The return value is the handle of the opened key. If the function fails, an *OSError* exception is raised.

Changed in version 3.3: See *above*.

winreg.CreateKeyEx(*key*, *sub_key*, *reserved=0*, *access=KEY_WRITE*)
Creates or opens the specified key, returning a *handle object*.

key is an already open key, or one of the predefined *HKEY_* constants*.

sub_key is a string that names the key this method opens or creates.

reserved is a reserved integer, and must be zero. The default is zero.

access is an integer that specifies an access mask that describes the desired security access for the key. Default is *KEY_WRITE*. See *Access Rights* for other allowed values.

If *key* is one of the predefined keys, *sub_key* may be `None`. In that case, the handle returned is the same key handle passed in to the function.

If the key already exists, this function opens the existing key.

The return value is the handle of the opened key. If the function fails, an *OSError* exception is raised.

New in version 3.2.

Changed in version 3.3: See *above*.

winreg.DeleteKey(*key*, *sub_key*)
Deletes the specified key.

key is an already open key, or one of the predefined *HKEY_* constants*.

sub_key is a string that must be a subkey of the key identified by the *key* parameter. This value must not be `None`, and the key may not have subkeys.

This method can not delete keys with subkeys.

If the method succeeds, the entire key, including all of its values, is removed. If the method fails, an *OSError* exception is raised.

Changed in version 3.3: See *above*.

winreg.DeleteKeyEx(*key*, *sub_key*, *access=KEY_WOW64_64KEY*, *reserved=0*)
Deletes the specified key.

Note: The *DeleteKeyEx()* function is implemented with the RegDeleteKeyEx Windows API function, which is specific to 64-bit versions of Windows. See the RegDeleteKeyEx documentation.

---

key is an already open key, or one of the predefined *HKEY_* constants*.

sub_key is a string that must be a subkey of the key identified by the *key* parameter. This value must not be `None`, and the key may not have subkeys.

reserved is a reserved integer, and must be zero. The default is zero.

access is an integer that specifies an access mask that describes the desired security access for the key. Default is *KEY_WOW64_64KEY*. See *Access Rights* for other allowed values.

This method can not delete keys with subkeys.

If the method succeeds, the entire key, including all of its values, is removed. If the method fails, an *OSError* exception is raised.

On unsupported Windows versions, *NotImplementedError* is raised.

New in version 3.2.

Changed in version 3.3: See *above*.

winreg.DeleteValue(*key*, *value*)
Removes a named value from a registry key.

key is an already open key, or one of the predefined *HKEY_* constants*.

value is a string that identifies the value to remove.

winreg.EnumKey(*key*, *index*)
Enumerates subkeys of an open registry key, returning a string.

key is an already open key, or one of the predefined *HKEY_* constants*.

index is an integer that identifies the index of the key to retrieve.

The function retrieves the name of one subkey each time it is called. It is typically called repeatedly until an *OSError* exception is raised, indicating, no more values are available.

Changed in version 3.3: See *above*.

winreg.EnumValue(*key*, *index*)
Enumerates values of an open registry key, returning a tuple.

key is an already open key, or one of the predefined *HKEY_* constants*.

index is an integer that identifies the index of the value to retrieve.

The function retrieves the name of one subkey each time it is called. It is typically called repeatedly, until an *OSError* exception is raised, indicating no more values.

The result is a tuple of 3 items:

Index	Meaning
0	A string that identifies the value name
1	An object that holds the value data, and whose type depends on the underlying registry type
2	An integer that identifies the type of the value data (see table in docs for *SetValueEx()*)

Changed in version 3.3: See *above*.

winreg.ExpandEnvironmentStrings(*str*)
Expands environment variable placeholders **%NAME%** in strings like *REG_EXPAND_SZ*:

```
>>> ExpandEnvironmentStrings('%windir%')
'C:\\Windows'
```

winreg.FlushKey(*key*)
Writes all the attributes of a key to the registry.

key is an already open key, or one of the predefined *HKEY_* constants*.

It is not necessary to call *FlushKey()* to change a key. Registry changes are flushed to disk by the registry using its lazy flusher. Registry changes are also flushed to disk at system shutdown. Unlike *CloseKey()*, the *FlushKey()* method returns only when all the data has been written to the registry. An application should only call *FlushKey()* if it requires absolute certainty that registry changes are on disk.

Note: If you don't know whether a *FlushKey()* call is required, it probably isn't.

winreg.**LoadKey**(*key*, *sub_key*, *file_name*)
Creates a subkey under the specified key and stores registration information from a specified file into that subkey.

key is a handle returned by *ConnectRegistry()* or one of the constants *HKEY_USERS* or *HKEY_LOCAL_MACHINE*.

sub_key is a string that identifies the subkey to load.

file_name is the name of the file to load registry data from. This file must have been created with the *SaveKey()* function. Under the file allocation table (FAT) file system, the filename may not have an extension.

A call to *LoadKey()* fails if the calling process does not have the SE_RESTORE_PRIVILEGE privilege. Note that privileges are different from permissions – see the RegLoadKey documentation for more details.

If *key* is a handle returned by *ConnectRegistry()*, then the path specified in *file_name* is relative to the remote computer.

winreg.**OpenKey**(*key*, *sub_key*, *reserved=0*, *access=KEY_READ*)
winreg.**OpenKeyEx**(*key*, *sub_key*, *reserved=0*, *access=KEY_READ*)
Opens the specified key, returning a *handle object*.

key is an already open key, or one of the predefined *HKEY_* constants*.

sub_key is a string that identifies the sub_key to open.

reserved is a reserved integer, and must be zero. The default is zero.

access is an integer that specifies an access mask that describes the desired security access for the key. Default is *KEY_READ*. See *Access Rights* for other allowed values.

The result is a new handle to the specified key.

If the function fails, *OSError* is raised.

Changed in version 3.2: Allow the use of named arguments.

Changed in version 3.3: See *above*.

winreg.**QueryInfoKey**(*key*)
Returns information about a key, as a tuple.

key is an already open key, or one of the predefined *HKEY_* constants*.

The result is a tuple of 3 items:

Index	Meaning
0	An integer giving the number of sub keys this key has.
1	An integer giving the number of values this key has.
2	An integer giving when the key was last modified (if available) as 100's of nanoseconds since Jan 1, 1601.

winreg.**QueryValue**(*key*, *sub_key*)
Retrieves the unnamed value for a key, as a string.

key is an already open key, or one of the predefined *HKEY_* constants*.

sub_key is a string that holds the name of the subkey with which the value is associated. If this parameter is None or empty, the function retrieves the value set by the *SetValue()* method for the key identified by *key*.

Values in the registry have name, type, and data components. This method retrieves the data for a key's first value that has a NULL name. But the underlying API call doesn't return the type, so always use *QueryValueEx()* if possible.

winreg.QueryValueEx(*key*, *value_name*)
Retrieves the type and data for a specified value name associated with an open registry key.

key is an already open key, or one of the predefined *HKEY_* constants*.

value_name is a string indicating the value to query.

The result is a tuple of 2 items:

Index	Meaning
0	The value of the registry item.
1	An integer giving the registry type for this value (see table in docs for *SetValueEx()*)

winreg.SaveKey(*key*, *file_name*)
Saves the specified key, and all its subkeys to the specified file.

key is an already open key, or one of the predefined *HKEY_* constants*.

file_name is the name of the file to save registry data to. This file cannot already exist. If this filename includes an extension, it cannot be used on file allocation table (FAT) file systems by the *LoadKey()* method.

If *key* represents a key on a remote computer, the path described by *file_name* is relative to the remote computer. The caller of this method must possess the `SeBackupPrivilege` security privilege. Note that privileges are different than permissions – see the Conflicts Between User Rights and Permissions documentation for more details.

This function passes NULL for *security_attributes* to the API.

winreg.SetValue(*key*, *sub_key*, *type*, *value*)
Associates a value with a specified key.

key is an already open key, or one of the predefined *HKEY_* constants*.

sub_key is a string that names the subkey with which the value is associated.

type is an integer that specifies the type of the data. Currently this must be *REG_SZ*, meaning only strings are supported. Use the *SetValueEx()* function for support for other data types.

value is a string that specifies the new value.

If the key specified by the *sub_key* parameter does not exist, the SetValue function creates it.

Value lengths are limited by available memory. Long values (more than 2048 bytes) should be stored as files with the filenames stored in the configuration registry. This helps the registry perform efficiently.

The key identified by the *key* parameter must have been opened with *KEY_SET_VALUE* access.

winreg.SetValueEx(*key*, *value_name*, *reserved*, *type*, *value*)
Stores data in the value field of an open registry key.

key is an already open key, or one of the predefined *HKEY_* constants*.

value_name is a string that names the subkey with which the value is associated.

reserved can be anything – zero is always passed to the API.

type is an integer that specifies the type of the data. See *Value Types* for the available types.

value is a string that specifies the new value.

This method can also set additional value and type information for the specified key. The key identified by the key parameter must have been opened with *KEY_SET_VALUE* access.

To open the key, use the *CreateKey()* or *OpenKey()* methods.

Value lengths are limited by available memory. Long values (more than 2048 bytes) should be stored as files with the filenames stored in the configuration registry. This helps the registry perform efficiently.

winreg.DisableReflectionKey(*key*)
Disables registry reflection for 32-bit processes running on a 64-bit operating system.

key is an already open key, or one of the predefined *HKEY_* constants*.

Will generally raise *NotImplemented* if executed on a 32-bit operating system.

If the key is not on the reflection list, the function succeeds but has no effect. Disabling reflection for a key does not affect reflection of any subkeys.

winreg.EnableReflectionKey(*key*)
Restores registry reflection for the specified disabled key.

key is an already open key, or one of the predefined *HKEY_* constants*.

Will generally raise *NotImplemented* if executed on a 32-bit operating system.

Restoring reflection for a key does not affect reflection of any subkeys.

winreg.QueryReflectionKey(*key*)
Determines the reflection state for the specified key.

key is an already open key, or one of the predefined *HKEY_* constants*.

Returns `True` if reflection is disabled.

Will generally raise *NotImplemented* if executed on a 32-bit operating system.

35.3.2 Constants

The following constants are defined for use in many `_winreg` functions.

HKEY_* Constants

winreg.HKEY_CLASSES_ROOT
Registry entries subordinate to this key define types (or classes) of documents and the properties associated with those types. Shell and COM applications use the information stored under this key.

winreg.HKEY_CURRENT_USER
Registry entries subordinate to this key define the preferences of the current user. These preferences include the settings of environment variables, data about program groups, colors, printers, network connections, and application preferences.

winreg.HKEY_LOCAL_MACHINE
Registry entries subordinate to this key define the physical state of the computer, including data about the bus type, system memory, and installed hardware and software.

winreg.HKEY_USERS
Registry entries subordinate to this key define the default user configuration for new users on the local computer and the user configuration for the current user.

winreg.HKEY_PERFORMANCE_DATA
Registry entries subordinate to this key allow you to access performance data. The data is not actually stored in the registry; the registry functions cause the system to collect the data from its source.

winreg.HKEY_CURRENT_CONFIG
Contains information about the current hardware profile of the local computer system.

winreg.HKEY_DYN_DATA
: This key is not used in versions of Windows after 98.

Access Rights

For more information, see Registry Key Security and Access.

winreg.KEY_ALL_ACCESS
: Combines the STANDARD_RIGHTS_REQUIRED, *KEY_QUERY_VALUE*, *KEY_SET_VALUE*, *KEY_CREATE_SUB_KEY*, *KEY_ENUMERATE_SUB_KEYS*, *KEY_NOTIFY*, and *KEY_CREATE_LINK* access rights.

winreg.KEY_WRITE
: Combines the STANDARD_RIGHTS_WRITE, *KEY_SET_VALUE*, and *KEY_CREATE_SUB_KEY* access rights.

winreg.KEY_READ
: Combines the STANDARD_RIGHTS_READ, *KEY_QUERY_VALUE*, *KEY_ENUMERATE_SUB_KEYS*, and *KEY_NOTIFY* values.

winreg.KEY_EXECUTE
: Equivalent to *KEY_READ*.

winreg.KEY_QUERY_VALUE
: Required to query the values of a registry key.

winreg.KEY_SET_VALUE
: Required to create, delete, or set a registry value.

winreg.KEY_CREATE_SUB_KEY
: Required to create a subkey of a registry key.

winreg.KEY_ENUMERATE_SUB_KEYS
: Required to enumerate the subkeys of a registry key.

winreg.KEY_NOTIFY
: Required to request change notifications for a registry key or for subkeys of a registry key.

winreg.KEY_CREATE_LINK
: Reserved for system use.

64-bit Specific

For more information, see Accessing an Alternate Registry View.

winreg.KEY_WOW64_64KEY
: Indicates that an application on 64-bit Windows should operate on the 64-bit registry view.

winreg.KEY_WOW64_32KEY
: Indicates that an application on 64-bit Windows should operate on the 32-bit registry view.

Value Types

For more information, see Registry Value Types.

winreg.REG_BINARY
: Binary data in any form.

winreg.REG_DWORD
: 32-bit number.

winreg.REG_DWORD_LITTLE_ENDIAN
: A 32-bit number in little-endian format. Equivalent to *REG_DWORD*.

winreg.REG_DWORD_BIG_ENDIAN
: A 32-bit number in big-endian format.

winreg.REG_EXPAND_SZ
: Null-terminated string containing references to environment variables (%PATH%).

winreg.REG_LINK
: A Unicode symbolic link.

winreg.REG_MULTI_SZ
: A sequence of null-terminated strings, terminated by two null characters. (Python handles this termination automatically.)

winreg.REG_NONE
: No defined value type.

winreg.REG_QWORD
: A 64-bit number.

  New in version 3.6.

winreg.REG_QWORD_LITTLE_ENDIAN
: A 64-bit number in little-endian format. Equivalent to *REG_QWORD*.

  New in version 3.6.

winreg.REG_RESOURCE_LIST
: A device-driver resource list.

winreg.REG_FULL_RESOURCE_DESCRIPTOR
: A hardware setting.

winreg.REG_RESOURCE_REQUIREMENTS_LIST
: A hardware resource list.

winreg.REG_SZ
: A null-terminated string.

35.3.3 Registry Handle Objects

This object wraps a Windows HKEY object, automatically closing it when the object is destroyed. To guarantee cleanup, you can call either the *Close()* method on the object, or the *CloseKey()* function.

All registry functions in this module return one of these objects.

All registry functions in this module which accept a handle object also accept an integer, however, use of the handle object is encouraged.

Handle objects provide semantics for `__bool__()` – thus

```
if handle:
    print("Yes")
```

will print `Yes` if the handle is currently valid (has not been closed or detached).

The object also support comparison semantics, so handle objects will compare true if they both reference the same underlying Windows handle value.

Handle objects can be converted to an integer (e.g., using the built-in *int()* function), in which case the underlying Windows handle value is returned. You can also use the *Detach()* method to return the integer handle, and also disconnect the Windows handle from the handle object.

PyHKEY.Close()
Closes the underlying Windows handle.

If the handle is already closed, no error is raised.

PyHKEY.Detach()
Detaches the Windows handle from the handle object.

The result is an integer that holds the value of the handle before it is detached. If the handle is already detached or closed, this will return zero.

After calling this function, the handle is effectively invalidated, but the handle is not closed. You would call this function when you need the underlying Win32 handle to exist beyond the lifetime of the handle object.

PyHKEY.__enter__()
PyHKEY.__exit__(*exc_info*)
The HKEY object implements __enter__() and __exit__() and thus supports the context protocol for the with statement:

```
with OpenKey(HKEY_LOCAL_MACHINE, "foo") as key:
    ...  # work with key
```

will automatically close *key* when control leaves the with block.

35.4 winsound — Sound-playing interface for Windows

The *winsound* module provides access to the basic sound-playing machinery provided by Windows platforms. It includes functions and several constants.

winsound.Beep(*frequency*, *duration*)
Beep the PC's speaker. The *frequency* parameter specifies frequency, in hertz, of the sound, and must be in the range 37 through 32,767. The *duration* parameter specifies the number of milliseconds the sound should last. If the system is not able to beep the speaker, *RuntimeError* is raised.

winsound.PlaySound(*sound*, *flags*)
Call the underlying PlaySound() function from the Platform API. The *sound* parameter may be a filename, a system sound alias, audio data as a *bytes-like object*, or None. Its interpretation depends on the value of *flags*, which can be a bitwise ORed combination of the constants described below. If the *sound* parameter is None, any currently playing waveform sound is stopped. If the system indicates an error, *RuntimeError* is raised.

winsound.MessageBeep(*type=MB_OK*)
Call the underlying MessageBeep() function from the Platform API. This plays a sound as specified in the registry. The *type* argument specifies which sound to play; possible values are -1, MB_ICONASTERISK, MB_ICONEXCLAMATION, MB_ICONHAND, MB_ICONQUESTION, and MB_OK, all described below. The value -1 produces a "simple beep"; this is the final fallback if a sound cannot be played otherwise. If the system indicates an error, *RuntimeError* is raised.

winsound.SND_FILENAME
The *sound* parameter is the name of a WAV file. Do not use with *SND_ALIAS*.

winsound.SND_ALIAS
The *sound* parameter is a sound association name from the registry. If the registry contains no such name, play the system default sound unless *SND_NODEFAULT* is also specified. If no default sound is registered, raise *RuntimeError*. Do not use with *SND_FILENAME*.

All Win32 systems support at least the following; most systems support many more:

PlaySound() name	Corresponding Control Panel Sound name
'SystemAsterisk'	Asterisk
'SystemExclamation'	Exclamation
'SystemExit'	Exit Windows
'SystemHand'	Critical Stop
'SystemQuestion'	Question

For example:

```
import winsound
# Play Windows exit sound.
winsound.PlaySound("SystemExit", winsound.SND_ALIAS)

# Probably play Windows default sound, if any is registered (because
# "*" probably isn't the registered name of any sound).
winsound.PlaySound("*", winsound.SND_ALIAS)
```

winsound.SND_LOOP
Play the sound repeatedly. The *SND_ASYNC* flag must also be used to avoid blocking. Cannot be used with *SND_MEMORY*.

winsound.SND_MEMORY
The *sound* parameter to *PlaySound()* is a memory image of a WAV file, as a *bytes-like object*.

Note: This module does not support playing from a memory image asynchronously, so a combination of this flag and *SND_ASYNC* will raise *RuntimeError*.

---

winsound.SND_PURGE
Stop playing all instances of the specified sound.

Note: This flag is not supported on modern Windows platforms.

---

winsound.SND_ASYNC
Return immediately, allowing sounds to play asynchronously.

winsound.SND_NODEFAULT
If the specified sound cannot be found, do not play the system default sound.

winsound.SND_NOSTOP
Do not interrupt sounds currently playing.

winsound.SND_NOWAIT
Return immediately if the sound driver is busy.

Note: This flag is not supported on modern Windows platforms.

---

winsound.MB_ICONASTERISK
Play the `SystemDefault` sound.

winsound.MB_ICONEXCLAMATION
Play the `SystemExclamation` sound.

winsound.MB_ICONHAND
Play the `SystemHand` sound.

`winsound.MB_ICONQUESTION`
: Play the `SystemQuestion` sound.

`winsound.MB_OK`
: Play the `SystemDefault` sound.

CHAPTER

THIRTYSIX

UNIX SPECIFIC SERVICES

The modules described in this chapter provide interfaces to features that are unique to the Unix operating system, or in some cases to some or many variants of it. Here's an overview:

36.1 `posix` — The most common POSIX system calls

This module provides access to operating system functionality that is standardized by the C Standard and the POSIX standard (a thinly disguised Unix interface).

Do not import this module directly. Instead, import the module *os*, which provides a *portable* version of this interface. On Unix, the *os* module provides a superset of the *posix* interface. On non-Unix operating systems the *posix* module is not available, but a subset is always available through the *os* interface. Once *os* is imported, there is *no* performance penalty in using it instead of *posix*. In addition, *os* provides some additional functionality, such as automatically calling *putenv()* when an entry in `os.environ` is changed.

Errors are reported as exceptions; the usual exceptions are given for type errors, while errors reported by the system calls raise *OSError*.

36.1.1 Large File Support

Several operating systems (including AIX, HP-UX, Irix and Solaris) provide support for files that are larger than 2 GiB from a C programming model where `int` and `long` are 32-bit values. This is typically accomplished by defining the relevant size and offset types as 64-bit values. Such files are sometimes referred to as *large files*.

Large file support is enabled in Python when the size of an `off_t` is larger than a `long` and the `long long` type is available and is at least as large as an `off_t`. It may be necessary to configure and compile Python with certain compiler flags to enable this mode. For example, it is enabled by default with recent versions of Irix, but with Solaris 2.6 and 2.7 you need to do something like:

```
CFLAGS="`getconf LFS_CFLAGS`" OPT="-g -O2 $CFLAGS" \
        ./configure
```

On large-file-capable Linux systems, this might work:

```
CFLAGS='-D_LARGEFILE64_SOURCE -D_FILE_OFFSET_BITS=64' OPT="-g -O2 $CFLAGS" \
        ./configure
```

36.1.2 Notable Module Contents

In addition to many functions described in the *os* module documentation, *posix* defines the following data item:

`posix.environ`
A dictionary representing the string environment at the time the interpreter was started. Keys and values are bytes on Unix and str on Windows. For example, `environ[b'HOME']` (`environ['HOME']` on Windows) is the pathname of your home directory, equivalent to `getenv("HOME")` in C.

Modifying this dictionary does not affect the string environment passed on by *execv()*, *popen()* or *system()*; if you need to change the environment, pass `environ` to *execve()* or add variable assignments and export statements to the command string for *system()* or *popen()*.

Changed in version 3.2: On Unix, keys and values are bytes.

Note: The *os* module provides an alternate implementation of `environ` which updates the environment on modification. Note also that updating *os.environ* will render this dictionary obsolete. Use of the *os* module version of this is recommended over direct access to the *posix* module.

36.2 `pwd` — The password database

This module provides access to the Unix user account and password database. It is available on all Unix versions.

Password database entries are reported as a tuple-like object, whose attributes correspond to the members of the `passwd` structure (Attribute field below, see `<pwd.h>`):

Index	Attribute	Meaning
0	`pw_name`	Login name
1	`pw_passwd`	Optional encrypted password
2	`pw_uid`	Numerical user ID
3	`pw_gid`	Numerical group ID
4	`pw_gecos`	User name or comment field
5	`pw_dir`	User home directory
6	`pw_shell`	User command interpreter

The uid and gid items are integers, all others are strings. *KeyError* is raised if the entry asked for cannot be found.

Note: In traditional Unix the field `pw_passwd` usually contains a password encrypted with a DES derived algorithm (see module *crypt*). However most modern unices use a so-called *shadow password* system. On those unices the *pw_passwd* field only contains an asterisk (`'*'`) or the letter `'x'` where the encrypted password is stored in a file `/etc/shadow` which is not world readable. Whether the *pw_passwd* field contains anything useful is system-dependent. If available, the *spwd* module should be used where access to the encrypted password is required.

It defines the following items:

`pwd.getpwuid(`*uid*`)`
Return the password database entry for the given numeric user ID.

pwd.getpwnam(*name*)
Return the password database entry for the given user name.

pwd.getpwall()
Return a list of all available password database entries, in arbitrary order.

See also:

Module *grp* An interface to the group database, similar to this.

Module *spwd* An interface to the shadow password database, similar to this.

36.3 spwd — The shadow password database

This module provides access to the Unix shadow password database. It is available on various Unix versions.

You must have enough privileges to access the shadow password database (this usually means you have to be root).

Shadow password database entries are reported as a tuple-like object, whose attributes correspond to the members of the spwd structure (Attribute field below, see <shadow.h>):

Index	Attribute	Meaning
0	sp_namp	Login name
1	sp_pwdp	Encrypted password
2	sp_lstchg	Date of last change
3	sp_min	Minimal number of days between changes
4	sp_max	Maximum number of days between changes
5	sp_warn	Number of days before password expires to warn user about it
6	sp_inact	Number of days after password expires until account is disabled
7	sp_expire	Number of days since 1970-01-01 when account expires
8	sp_flag	Reserved

The sp_namp and sp_pwdp items are strings, all others are integers. *KeyError* is raised if the entry asked for cannot be found.

The following functions are defined:

spwd.getspnam(*name*)
Return the shadow password database entry for the given user name.

Changed in version 3.6: Raises a *PermissionError* instead of *KeyError* if the user doesn't have privileges.

spwd.getspall()
Return a list of all available shadow password database entries, in arbitrary order.

See also:

Module *grp* An interface to the group database, similar to this.

Module *pwd* An interface to the normal password database, similar to this.

36.4 grp — The group database

This module provides access to the Unix group database. It is available on all Unix versions.

Group database entries are reported as a tuple-like object, whose attributes correspond to the members of the `group` structure (Attribute field below, see `<pwd.h>`):

Index	Attribute	Meaning
0	gr_name	the name of the group
1	gr_passwd	the (encrypted) group password; often empty
2	gr_gid	the numerical group ID
3	gr_mem	all the group member's user names

The gid is an integer, name and password are strings, and the member list is a list of strings. (Note that most users are not explicitly listed as members of the group they are in according to the password database. Check both databases to get complete membership information. Also note that a `gr_name` that starts with a `+` or `-` is likely to be a YP/NIS reference and may not be accessible via *getgrnam()* or *getgrgid()*.)

It defines the following items:

`grp.getgrgid(`*gid*`)`
: Return the group database entry for the given numeric group ID. *KeyError* is raised if the entry asked for cannot be found.

  Deprecated since version 3.6: Since Python 3.6 the support of non-integer arguments like floats or strings in *getgrgid()* is deprecated.

`grp.getgrnam(`*name*`)`
: Return the group database entry for the given group name. *KeyError* is raised if the entry asked for cannot be found.

`grp.getgrall()`
: Return a list of all available group entries, in arbitrary order.

See also:

Module *pwd* An interface to the user database, similar to this.

Module *spwd* An interface to the shadow password database, similar to this.

36.5 crypt — Function to check Unix passwords

Source code: Lib/crypt.py

This module implements an interface to the *crypt(3)* routine, which is a one-way hash function based upon a modified DES algorithm; see the Unix man page for further details. Possible uses include storing hashed passwords so you can check passwords without storing the actual password, or attempting to crack Unix passwords with a dictionary.

Notice that the behavior of this module depends on the actual implementation of the *crypt(3)* routine in the running system. Therefore, any extensions available on the current implementation will also be available on this module.

36.5.1 Hashing Methods

New in version 3.3.

The *crypt* module defines the list of hashing methods (not all methods are available on all platforms):

`crypt.METHOD_SHA512`
A Modular Crypt Format method with 16 character salt and 86 character hash based on the SHA-512 hash function. This is the strongest method.

`crypt.METHOD_SHA256`
Another Modular Crypt Format method with 16 character salt and 43 character hash based on the SHA-256 hash function.

`crypt.METHOD_BLOWFISH`
Another Modular Crypt Format method with 22 character salt and 31 character hash based on the Blowfish cipher.

New in version 3.7.

`crypt.METHOD_MD5`
Another Modular Crypt Format method with 8 character salt and 22 character hash based on the MD5 hash function.

`crypt.METHOD_CRYPT`
The traditional method with a 2 character salt and 13 characters of hash. This is the weakest method.

36.5.2 Module Attributes

New in version 3.3.

`crypt.methods`
A list of available password hashing algorithms, as `crypt.METHOD_*` objects. This list is sorted from strongest to weakest.

36.5.3 Module Functions

The *crypt* module defines the following functions:

`crypt.crypt(`*word*, *salt=None*`)`
word will usually be a user's password as typed at a prompt or in a graphical interface. The optional *salt* is either a string as returned from *mksalt()*, one of the `crypt.METHOD_*` values (though not all may be available on all platforms), or a full encrypted password including salt, as returned by this function. If *salt* is not provided, the strongest method will be used (as returned by *methods()*.

Checking a password is usually done by passing the plain-text password as *word* and the full results of a previous *crypt()* call, which should be the same as the results of this call.

salt (either a random 2 or 16 character string, possibly prefixed with `$digit$` to indicate the method) which will be used to perturb the encryption algorithm. The characters in *salt* must be in the set `[./a-zA-Z0-9]`, with the exception of Modular Crypt Format which prefixes a `$digit$`.

Returns the hashed password as a string, which will be composed of characters from the same alphabet as the salt.

Since a few *crypt(3)* extensions allow different values, with different sizes in the *salt*, it is recommended to use the full crypted password as salt when checking for a password.

Changed in version 3.3: Accept `crypt.METHOD_*` values in addition to strings for *salt*.

crypt.**mksalt**(*method=None*, ***, *rounds=None*)

Return a randomly generated salt of the specified method. If no *method* is given, the strongest method available as returned by *methods()* is used.

The return value is a string suitable for passing as the *salt* argument to *crypt()*.

rounds specifies the number of rounds for METHOD_SHA256, METHOD_SHA512 and METHOD_BLOWFISH. For METHOD_SHA256 and METHOD_SHA512 it must be an integer between 1000 and 999_999_999, the default is 5000. For METHOD_BLOWFISH it must be a power of two between 16 (2^4) and 2_147_483_648 (2^{31}), the default is 4096 (2^{12}).

New in version 3.3.

Changed in version 3.7: Added the *rounds* parameter.

36.5.4 Examples

A simple example illustrating typical use (a constant-time comparison operation is needed to limit exposure to timing attacks. *hmac.compare_digest()* is suitable for this purpose):

```
import pwd
import crypt
import getpass
from hmac import compare_digest as compare_hash

def login():
    username = input('Python login: ')
    cryptedpasswd = pwd.getpwnam(username)[1]
    if cryptedpasswd:
        if cryptedpasswd == 'x' or cryptedpasswd == '*':
            raise ValueError('no support for shadow passwords')
        cleartext = getpass.getpass()
        return compare_hash(crypt.crypt(cleartext, cryptedpasswd), cryptedpasswd)
    else:
        return True
```

To generate a hash of a password using the strongest available method and check it against the original:

```
import crypt
from hmac import compare_digest as compare_hash

hashed = crypt.crypt(plaintext)
if not compare_hash(hashed, crypt.crypt(plaintext, hashed)):
    raise ValueError("hashed version doesn't validate against original")
```

36.6 termios — POSIX style tty control

This module provides an interface to the POSIX calls for tty I/O control. For a complete description of these calls, see *termios(3)* Unix manual page. It is only available for those Unix versions that support POSIX *termios* style tty I/O control configured during installation.

All functions in this module take a file descriptor *fd* as their first argument. This can be an integer file descriptor, such as returned by sys.stdin.fileno(), or a *file object*, such as sys.stdin itself.

This module also defines all the constants needed to work with the functions provided here; these have the same name as their counterparts in C. Please refer to your system documentation for more information on using these terminal control interfaces.

The module defines the following functions:

termios.tcgetattr(*fd*)
Return a list containing the tty attributes for file descriptor *fd*, as follows: `[iflag, oflag, cflag, lflag, ispeed, ospeed, cc]` where *cc* is a list of the tty special characters (each a string of length 1, except the items with indices `VMIN` and `VTIME`, which are integers when these fields are defined). The interpretation of the flags and the speeds as well as the indexing in the *cc* array must be done using the symbolic constants defined in the *termios* module.

termios.tcsetattr(*fd*, *when*, *attributes*)
Set the tty attributes for file descriptor *fd* from the *attributes*, which is a list like the one returned by *tcgetattr()*. The *when* argument determines when the attributes are changed: `TCSANOW` to change immediately, `TCSADRAIN` to change after transmitting all queued output, or `TCSAFLUSH` to change after transmitting all queued output and discarding all queued input.

termios.tcsendbreak(*fd*, *duration*)
Send a break on file descriptor *fd*. A zero *duration* sends a break for 0.25 –0.5 seconds; a nonzero *duration* has a system dependent meaning.

termios.tcdrain(*fd*)
Wait until all output written to file descriptor *fd* has been transmitted.

termios.tcflush(*fd*, *queue*)
Discard queued data on file descriptor *fd*. The *queue* selector specifies which queue: `TCIFLUSH` for the input queue, `TCOFLUSH` for the output queue, or `TCIOFLUSH` for both queues.

termios.tcflow(*fd*, *action*)
Suspend or resume input or output on file descriptor *fd*. The *action* argument can be `TCOOFF` to suspend output, `TCOON` to restart output, `TCIOFF` to suspend input, or `TCION` to restart input.

See also:

Module *tty* Convenience functions for common terminal control operations.

36.6.1 Example

Here's a function that prompts for a password with echoing turned off. Note the technique using a separate *tcgetattr()* call and a `try` … `finally` statement to ensure that the old tty attributes are restored exactly no matter what happens:

```
def getpass(prompt="Password: "):
    import termios, sys
    fd = sys.stdin.fileno()
    old = termios.tcgetattr(fd)
    new = termios.tcgetattr(fd)
    new[3] = new[3] & ~termios.ECHO          # lflags
    try:
        termios.tcsetattr(fd, termios.TCSADRAIN, new)
        passwd = input(prompt)
    finally:
        termios.tcsetattr(fd, termios.TCSADRAIN, old)
    return passwd
```

36.7 tty — Terminal control functions

Source code: Lib/tty.py

The *tty* module defines functions for putting the tty into cbreak and raw modes.

Because it requires the *termios* module, it will work only on Unix.

The *tty* module defines the following functions:

`tty.setraw`(*fd*, *when=termios.TCSAFLUSH*)
Change the mode of the file descriptor *fd* to raw. If *when* is omitted, it defaults to `termios.TCSAFLUSH`, and is passed to *termios.tcsetattr()*.

`tty.setcbreak`(*fd*, *when=termios.TCSAFLUSH*)
Change the mode of file descriptor *fd* to cbreak. If *when* is omitted, it defaults to `termios.TCSAFLUSH`, and is passed to *termios.tcsetattr()*.

See also:

Module *termios* Low-level terminal control interface.

36.8 pty — Pseudo-terminal utilities

Source code: Lib/pty.py

The *pty* module defines operations for handling the pseudo-terminal concept: starting another process and being able to write to and read from its controlling terminal programmatically.

Because pseudo-terminal handling is highly platform dependent, there is code to do it only for Linux. (The Linux code is supposed to work on other platforms, but hasn't been tested yet.)

The *pty* module defines the following functions:

`pty.fork`()
Fork. Connect the child's controlling terminal to a pseudo-terminal. Return value is `(pid, fd)`. Note that the child gets *pid* 0, and the *fd* is *invalid*. The parent's return value is the *pid* of the child, and *fd* is a file descriptor connected to the child's controlling terminal (and also to the child's standard input and output).

`pty.openpty`()
Open a new pseudo-terminal pair, using *os.openpty()* if possible, or emulation code for generic Unix systems. Return a pair of file descriptors `(master, slave)`, for the master and the slave end, respectively.

`pty.spawn`(*argv*[, *master_read*[, *stdin_read*]])
Spawn a process, and connect its controlling terminal with the current process's standard io. This is often used to baffle programs which insist on reading from the controlling terminal.

The functions *master_read* and *stdin_read* should be functions which read from a file descriptor. The defaults try to read 1024 bytes each time they are called.

Changed in version 3.4: *spawn()* now returns the status value from *os.waitpid()* on the child process.

36.8.1 Example

The following program acts like the Unix command *script(1)*, using a pseudo-terminal to record all input and output of a terminal session in a "typescript".

```
import argparse
import os
import pty
import sys
import time

parser = argparse.ArgumentParser()
parser.add_argument('-a', dest='append', action='store_true')
parser.add_argument('-p', dest='use_python', action='store_true')
parser.add_argument('filename', nargs='?', default='typescript')
options = parser.parse_args()

shell = sys.executable if options.use_python else os.environ.get('SHELL', 'sh')
filename = options.filename
mode = 'ab' if options.append else 'wb'

with open(filename, mode) as script:
    def read(fd):
        data = os.read(fd, 1024)
        script.write(data)
        return data

    print('Script started, file is', filename)
    script.write(('Script started on %s\n' % time.asctime()).encode())

    pty.spawn(shell, read)

    script.write(('Script done on %s\n' % time.asctime()).encode())
    print('Script done, file is', filename)
```

36.9 fcntl — The fcntl and ioctl system calls

This module performs file control and I/O control on file descriptors. It is an interface to the `fcntl()` and `ioctl()` Unix routines. For a complete description of these calls, see *fcntl(2)* and *ioctl(2)* Unix manual pages.

All functions in this module take a file descriptor *fd* as their first argument. This can be an integer file descriptor, such as returned by `sys.stdin.fileno()`, or an *io.IOBase* object, such as `sys.stdin` itself, which provides a *fileno()* that returns a genuine file descriptor.

Changed in version 3.3: Operations in this module used to raise an *IOError* where they now raise an *OSError*.

The module defines the following functions:

`fcntl.fcntl`(*fd*, *cmd*, *arg=0*)

Perform the operation *cmd* on file descriptor *fd* (file objects providing a *fileno()* method are accepted as well). The values used for *cmd* are operating system dependent, and are available as constants in the *fcntl* module, using the same names as used in the relevant C header files. The argument *arg* can either be an integer value, or a *bytes* object. With an integer value, the return value of this function

is the integer return value of the C `fcntl()` call. When the argument is bytes it represents a binary structure, e.g. created by *struct.pack()*. The binary data is copied to a buffer whose address is passed to the C `fcntl()` call. The return value after a successful call is the contents of the buffer, converted to a *bytes* object. The length of the returned object will be the same as the length of the *arg* argument. This is limited to 1024 bytes. If the information returned in the buffer by the operating system is larger than 1024 bytes, this is most likely to result in a segmentation violation or a more subtle data corruption.

If the `fcntl()` fails, an *OSError* is raised.

`fcntl.ioctl`(*fd*, *request*, *arg=0*, *mutate_flag=True*)

This function is identical to the *fcntl()* function, except that the argument handling is even more complicated.

The *request* parameter is limited to values that can fit in 32-bits. Additional constants of interest for use as the *request* argument can be found in the *termios* module, under the same names as used in the relevant C header files.

The parameter *arg* can be one of an integer, an object supporting the read-only buffer interface (like *bytes*) or an object supporting the read-write buffer interface (like *bytearray*).

In all but the last case, behaviour is as for the *fcntl()* function.

If a mutable buffer is passed, then the behaviour is determined by the value of the *mutate_flag* parameter.

If it is false, the buffer's mutability is ignored and behaviour is as for a read-only buffer, except that the 1024 byte limit mentioned above is avoided – so long as the buffer you pass is at least as long as what the operating system wants to put there, things should work.

If *mutate_flag* is true (the default), then the buffer is (in effect) passed to the underlying *ioctl()* system call, the latter's return code is passed back to the calling Python, and the buffer's new contents reflect the action of the *ioctl()*. This is a slight simplification, because if the supplied buffer is less than 1024 bytes long it is first copied into a static buffer 1024 bytes long which is then passed to *ioctl()* and copied back into the supplied buffer.

If the `ioctl()` fails, an *OSError* exception is raised.

An example:

```
>>> import array, fcntl, struct, termios, os
>>> os.getpgrp()
13341
>>> struct.unpack('h', fcntl.ioctl(0, termios.TIOCGPGRP, "  "))[0]
13341
>>> buf = array.array('h', [0])
>>> fcntl.ioctl(0, termios.TIOCGPGRP, buf, 1)
0
>>> buf
array('h', [13341])
```

`fcntl.flock`(*fd*, *operation*)

Perform the lock operation *operation* on file descriptor *fd* (file objects providing a *fileno()* method are accepted as well). See the Unix manual *flock(2)* for details. (On some systems, this function is emulated using `fcntl()`.)

If the `flock()` fails, an *OSError* exception is raised.

`fcntl.lockf`(*fd*, *cmd*, *len=0*, *start=0*, *whence=0*)

This is essentially a wrapper around the *fcntl()* locking calls. *fd* is the file descriptor of the file to lock or unlock, and *cmd* is one of the following values:

- `LOCK_UN` – unlock

- LOCK_SH – acquire a shared lock
- LOCK_EX – acquire an exclusive lock

When *cmd* is LOCK_SH or LOCK_EX, it can also be bitwise ORed with LOCK_NB to avoid blocking on lock acquisition. If LOCK_NB is used and the lock cannot be acquired, an *OSError* will be raised and the exception will have an *errno* attribute set to EACCES or EAGAIN (depending on the operating system; for portability, check for both values). On at least some systems, LOCK_EX can only be used if the file descriptor refers to a file opened for writing.

len is the number of bytes to lock, *start* is the byte offset at which the lock starts, relative to *whence*, and *whence* is as with *io.IOBase.seek()*, specifically:

- 0 – relative to the start of the file (*os.SEEK_SET*)
- 1 – relative to the current buffer position (*os.SEEK_CUR*)
- 2 – relative to the end of the file (*os.SEEK_END*)

The default for *start* is 0, which means to start at the beginning of the file. The default for *len* is 0 which means to lock to the end of the file. The default for *whence* is also 0.

Examples (all on a SVR4 compliant system):

```
import struct, fcntl, os

f = open(...)
rv = fcntl.fcntl(f, fcntl.F_SETFL, os.O_NDELAY)

lockdata = struct.pack('hhllhh', fcntl.F_WRLCK, 0, 0, 0, 0, 0)
rv = fcntl.fcntl(f, fcntl.F_SETLKW, lockdata)
```

Note that in the first example the return value variable *rv* will hold an integer value; in the second example it will hold a *bytes* object. The structure lay-out for the *lockdata* variable is system dependent — therefore using the *flock()* call may be better.

See also:

Module *os* If the locking flags *O_SHLOCK* and *O_EXLOCK* are present in the *os* module (on BSD only), the *os.open()* function provides an alternative to the *lockf()* and *flock()* functions.

36.10 pipes — Interface to shell pipelines

Source code: Lib/pipes.py

The *pipes* module defines a class to abstract the concept of a *pipeline* — a sequence of converters from one file to another.

Because the module uses **/bin/sh** command lines, a POSIX or compatible shell for *os.system()* and *os.popen()* is required.

The *pipes* module defines the following class:

class pipes.Template
An abstraction of a pipeline.

Example:

```
>>> import pipes
>>> t = pipes.Template()
>>> t.append('tr a-z A-Z', '--')
>>> f = t.open('pipefile', 'w')
>>> f.write('hello world')
>>> f.close()
>>> open('pipefile').read()
'HELLO WORLD'
```

36.10.1 Template Objects

Template objects following methods:

Template.reset()
Restore a pipeline template to its initial state.

Template.clone()
Return a new, equivalent, pipeline template.

Template.debug(*flag*)
If *flag* is true, turn debugging on. Otherwise, turn debugging off. When debugging is on, commands to be executed are printed, and the shell is given `set -x` command to be more verbose.

Template.append(*cmd*, *kind*)
Append a new action at the end. The *cmd* variable must be a valid bourne shell command. The *kind* variable consists of two letters.

The first letter can be either of `'-'` (which means the command reads its standard input), `'f'` (which means the commands reads a given file on the command line) or `'.'` (which means the commands reads no input, and hence must be first.)

Similarly, the second letter can be either of `'-'` (which means the command writes to standard output), `'f'` (which means the command writes a file on the command line) or `'.'` (which means the command does not write anything, and hence must be last.)

Template.prepend(*cmd*, *kind*)
Add a new action at the beginning. See *append()* for explanations of the arguments.

Template.open(*file*, *mode*)
Return a file-like object, open to *file*, but read from or written to by the pipeline. Note that only one of `'r'`, `'w'` may be given.

Template.copy(*infile*, *outfile*)
Copy *infile* to *outfile* through the pipe.

36.11 `resource` — Resource usage information

This module provides basic mechanisms for measuring and controlling system resources utilized by a program.

Symbolic constants are used to specify particular system resources and to request usage information about either the current process or its children.

An *OSError* is raised on syscall failure.

exception resource.error
A deprecated alias of *OSError*.

Changed in version 3.3: Following **PEP 3151**, this class was made an alias of *OSError*.

36.11.1 Resource Limits

Resources usage can be limited using the *setrlimit()* function described below. Each resource is controlled by a pair of limits: a soft limit and a hard limit. The soft limit is the current limit, and may be lowered or raised by a process over time. The soft limit can never exceed the hard limit. The hard limit can be lowered to any value greater than the soft limit, but not raised. (Only processes with the effective UID of the super-user can raise a hard limit.)

The specific resources that can be limited are system dependent. They are described in the *getrlimit(2)* man page. The resources listed below are supported when the underlying operating system supports them; resources which cannot be checked or controlled by the operating system are not defined in this module for those platforms.

`resource.RLIM_INFINITY`
Constant used to represent the limit for an unlimited resource.

`resource.getrlimit`(*resource*)
Returns a tuple `(soft, hard)` with the current soft and hard limits of *resource*. Raises *ValueError* if an invalid resource is specified, or *error* if the underlying system call fails unexpectedly.

`resource.setrlimit`(*resource*, *limits*)
Sets new limits of consumption of *resource*. The *limits* argument must be a tuple `(soft, hard)` of two integers describing the new limits. A value of *RLIM_INFINITY* can be used to request a limit that is unlimited.

Raises *ValueError* if an invalid resource is specified, if the new soft limit exceeds the hard limit, or if a process tries to raise its hard limit. Specifying a limit of *RLIM_INFINITY* when the hard or system limit for that resource is not unlimited will result in a *ValueError*. A process with the effective UID of super-user can request any valid limit value, including unlimited, but *ValueError* will still be raised if the requested limit exceeds the system imposed limit.

`setrlimit` may also raise *error* if the underlying system call fails.

`resource.prlimit`(*pid*, *resource*[, *limits*])
Combines *setrlimit()* and *getrlimit()* in one function and supports to get and set the resources limits of an arbitrary process. If *pid* is 0, then the call applies to the current process. *resource* and *limits* have the same meaning as in *setrlimit()*, except that *limits* is optional.

When *limits* is not given the function returns the *resource* limit of the process *pid*. When *limits* is given the *resource* limit of the process is set and the former resource limit is returned.

Raises *ProcessLookupError* when *pid* can't be found and *PermissionError* when the user doesn't have `CAP_SYS_RESOURCE` for the process.

Availability: Linux 2.6.36 or later with glibc 2.13 or later

New in version 3.4.

These symbols define resources whose consumption can be controlled using the *setrlimit()* and *getrlimit()* functions described below. The values of these symbols are exactly the constants used by C programs.

The Unix man page for *getrlimit(2)* lists the available resources. Note that not all systems use the same symbol or same value to denote the same resource. This module does not attempt to mask platform differences — symbols not defined for a platform will not be available from this module on that platform.

`resource.RLIMIT_CORE`
The maximum size (in bytes) of a core file that the current process can create. This may result in the creation of a partial core file if a larger core would be required to contain the entire process image.

`resource.RLIMIT_CPU`
The maximum amount of processor time (in seconds) that a process can use. If this limit is exceeded,

a SIGXCPU signal is sent to the process. (See the *signal* module documentation for information about how to catch this signal and do something useful, e.g. flush open files to disk.)

resource.RLIMIT_FSIZE
The maximum size of a file which the process may create.

resource.RLIMIT_DATA
The maximum size (in bytes) of the process's heap.

resource.RLIMIT_STACK
The maximum size (in bytes) of the call stack for the current process. This only affects the stack of the main thread in a multi-threaded process.

resource.RLIMIT_RSS
The maximum resident set size that should be made available to the process.

resource.RLIMIT_NPROC
The maximum number of processes the current process may create.

resource.RLIMIT_NOFILE
The maximum number of open file descriptors for the current process.

resource.RLIMIT_OFILE
The BSD name for *RLIMIT_NOFILE*.

resource.RLIMIT_MEMLOCK
The maximum address space which may be locked in memory.

resource.RLIMIT_VMEM
The largest area of mapped memory which the process may occupy.

resource.RLIMIT_AS
The maximum area (in bytes) of address space which may be taken by the process.

resource.RLIMIT_MSGQUEUE
The number of bytes that can be allocated for POSIX message queues.

Availability: Linux 2.6.8 or later.

New in version 3.4.

resource.RLIMIT_NICE
The ceiling for the process's nice level (calculated as 20 - rlim_cur).

Availability: Linux 2.6.12 or later.

New in version 3.4.

resource.RLIMIT_RTPRIO
The ceiling of the real-time priority.

Availability: Linux 2.6.12 or later.

New in version 3.4.

resource.RLIMIT_RTTIME
The time limit (in microseconds) on CPU time that a process can spend under real-time scheduling without making a blocking syscall.

Availability: Linux 2.6.25 or later.

New in version 3.4.

resource.RLIMIT_SIGPENDING
The number of signals which the process may queue.

Availability: Linux 2.6.8 or later.

New in version 3.4.

`resource.RLIMIT_SBSIZE`
The maximum size (in bytes) of socket buffer usage for this user. This limits the amount of network memory, and hence the amount of mbufs, that this user may hold at any time.

Availability: FreeBSD 9 or later.

New in version 3.4.

`resource.RLIMIT_SWAP`
The maximum size (in bytes) of the swap space that may be reserved or used by all of this user id's processes. This limit is enforced only if bit 1 of the vm.overcommit sysctl is set. Please see *tuning(7)* for a complete description of this sysctl.

Availability: FreeBSD 9 or later.

New in version 3.4.

`resource.RLIMIT_NPTS`
The maximum number of pseudo-terminals created by this user id.

Availability: FreeBSD 9 or later.

New in version 3.4.

36.11.2 Resource Usage

These functions are used to retrieve resource usage information:

`resource.getrusage(`*who*`)`
This function returns an object that describes the resources consumed by either the current process or its children, as specified by the *who* parameter. The *who* parameter should be specified using one of the `RUSAGE_*` constants described below.

The fields of the return value each describe how a particular system resource has been used, e.g. amount of time spent running is user mode or number of times the process was swapped out of main memory. Some values are dependent on the clock tick internal, e.g. the amount of memory the process is using.

For backward compatibility, the return value is also accessible as a tuple of 16 elements.

The fields `ru_utime` and `ru_stime` of the return value are floating point values representing the amount of time spent executing in user mode and the amount of time spent executing in system mode, respectively. The remaining values are integers. Consult the *getrusage(2)* man page for detailed information about these values. A brief summary is presented here:

Index	Field	Resource
0	ru_utime	time in user mode (float)
1	ru_stime	time in system mode (float)
2	ru_maxrss	maximum resident set size
3	ru_ixrss	shared memory size
4	ru_idrss	unshared memory size
5	ru_isrss	unshared stack size
6	ru_minflt	page faults not requiring I/O
7	ru_majflt	page faults requiring I/O
8	ru_nswap	number of swap outs
9	ru_inblock	block input operations
10	ru_oublock	block output operations
11	ru_msgsnd	messages sent
12	ru_msgrcv	messages received
13	ru_nsignals	signals received
14	ru_nvcsw	voluntary context switches
15	ru_nivcsw	involuntary context switches

This function will raise a *ValueError* if an invalid *who* parameter is specified. It may also raise *error* exception in unusual circumstances.

resource.getpagesize()
Returns the number of bytes in a system page. (This need not be the same as the hardware page size.)

The following RUSAGE_* symbols are passed to the *getrusage()* function to specify which processes information should be provided for.

resource.RUSAGE_SELF
Pass to *getrusage()* to request resources consumed by the calling process, which is the sum of resources used by all threads in the process.

resource.RUSAGE_CHILDREN
Pass to *getrusage()* to request resources consumed by child processes of the calling process which have been terminated and waited for.

resource.RUSAGE_BOTH
Pass to *getrusage()* to request resources consumed by both the current process and child processes. May not be available on all systems.

resource.RUSAGE_THREAD
Pass to *getrusage()* to request resources consumed by the current thread. May not be available on all systems.

New in version 3.2.

36.12 nis — Interface to Sun's NIS (Yellow Pages)

The *nis* module gives a thin wrapper around the NIS library, useful for central administration of several hosts.

Because NIS exists only on Unix systems, this module is only available for Unix.

The *nis* module defines the following functions:

nis.match(*key*, *mapname*, *domain=default_domain*)
Return the match for *key* in map *mapname*, or raise an error (*nis.error*) if there is none. Both should be strings, *key* is 8-bit clean. Return value is an arbitrary array of bytes (may contain NULL and other joys).

Note that *mapname* is first checked if it is an alias to another name.

The *domain* argument allows overriding the NIS domain used for the lookup. If unspecified, lookup is in the default NIS domain.

nis.cat(*mapname*, *domain=default_domain*)
Return a dictionary mapping *key* to *value* such that `match(key, mapname)==value`. Note that both keys and values of the dictionary are arbitrary arrays of bytes.

Note that *mapname* is first checked if it is an alias to another name.

The *domain* argument allows overriding the NIS domain used for the lookup. If unspecified, lookup is in the default NIS domain.

nis.maps(*domain=default_domain*)
Return a list of all valid maps.

The *domain* argument allows overriding the NIS domain used for the lookup. If unspecified, lookup is in the default NIS domain.

nis.get_default_domain()
Return the system default NIS domain.

The *nis* module defines the following exception:

exception nis.error
An error raised when a NIS function returns an error code.

36.13 syslog — Unix syslog library routines

This module provides an interface to the Unix `syslog` library routines. Refer to the Unix manual pages for a detailed description of the `syslog` facility.

This module wraps the system `syslog` family of routines. A pure Python library that can speak to a syslog server is available in the *logging.handlers* module as `SysLogHandler`.

The module defines the following functions:

syslog.syslog(*message*)
syslog.syslog(*priority*, *message*)
Send the string *message* to the system logger. A trailing newline is added if necessary. Each message is tagged with a priority composed of a *facility* and a *level*. The optional *priority* argument, which defaults to `LOG_INFO`, determines the message priority. If the facility is not encoded in *priority* using logical-or (`LOG_INFO | LOG_USER`), the value given in the *openlog()* call is used.

If *openlog()* has not been called prior to the call to *syslog()*, `openlog()` will be called with no arguments.

syslog.openlog(\[*ident*\[, *logoption*\[, *facility*\]\]\])
Logging options of subsequent *syslog()* calls can be set by calling *openlog()*. *syslog()* will call *openlog()* with no arguments if the log is not currently open.

The optional *ident* keyword argument is a string which is prepended to every message, and defaults to `sys.argv[0]` with leading path components stripped. The optional *logoption* keyword argument (default is 0) is a bit field – see below for possible values to combine. The optional *facility* keyword

argument (default is `LOG_USER`) sets the default facility for messages which do not have a facility explicitly encoded.

Changed in version 3.2: In previous versions, keyword arguments were not allowed, and *ident* was required. The default for *ident* was dependent on the system libraries, and often was `python` instead of the name of the python program file.

`syslog.closelog()`
Reset the syslog module values and call the system library `closelog()`.

This causes the module to behave as it does when initially imported. For example, *openlog()* will be called on the first *syslog()* call (if *openlog()* hasn't already been called), and *ident* and other *openlog()* parameters are reset to defaults.

`syslog.setlogmask(`*maskpri*`)`
Set the priority mask to *maskpri* and return the previous mask value. Calls to *syslog()* with a priority level not set in *maskpri* are ignored. The default is to log all priorities. The function `LOG_MASK(pri)` calculates the mask for the individual priority *pri*. The function `LOG_UPTO(pri)` calculates the mask for all priorities up to and including *pri*.

The module defines the following constants:

Priority levels (high to low): `LOG_EMERG`, `LOG_ALERT`, `LOG_CRIT`, `LOG_ERR`, `LOG_WARNING`, `LOG_NOTICE`, `LOG_INFO`, `LOG_DEBUG`.

Facilities: `LOG_KERN`, `LOG_USER`, `LOG_MAIL`, `LOG_DAEMON`, `LOG_AUTH`, `LOG_LPR`, `LOG_NEWS`, `LOG_UUCP`, `LOG_CRON`, `LOG_SYSLOG`, `LOG_LOCAL0` to `LOG_LOCAL7`, and, if defined in `<syslog.h>`, `LOG_AUTHPRIV`.

Log options: `LOG_PID`, `LOG_CONS`, `LOG_NDELAY`, and, if defined in `<syslog.h>`, `LOG_ODELAY`, `LOG_NOWAIT`, and `LOG_PERROR`.

36.13.1 Examples

Simple example

A simple set of examples:

```
import syslog

syslog.syslog('Processing started')
if error:
    syslog.syslog(syslog.LOG_ERR, 'Processing started')
```

An example of setting some log options, these would include the process ID in logged messages, and write the messages to the destination facility used for mail logging:

```
syslog.openlog(logoption=syslog.LOG_PID, facility=syslog.LOG_MAIL)
syslog.syslog('E-mail processing initiated...')
```

CHAPTER

THIRTYSEVEN

SUPERSEDED MODULES

The modules described in this chapter are deprecated and only kept for backwards compatibility. They have been superseded by other modules.

37.1 optparse — Parser for command line options

Source code: Lib/optparse.py

Deprecated since version 3.2: The *optparse* module is deprecated and will not be developed further; development will continue with the *argparse* module.

---

optparse is a more convenient, flexible, and powerful library for parsing command-line options than the old *getopt* module. *optparse* uses a more declarative style of command-line parsing: you create an instance of *OptionParser*, populate it with options, and parse the command line. *optparse* allows users to specify options in the conventional GNU/POSIX syntax, and additionally generates usage and help messages for you.

Here's an example of using *optparse* in a simple script:

```
from optparse import OptionParser
...
parser = OptionParser()
parser.add_option("-f", "--file", dest="filename",
                  help="write report to FILE", metavar="FILE")
parser.add_option("-q", "--quiet",
                  action="store_false", dest="verbose", default=True,
                  help="don't print status messages to stdout")

(options, args) = parser.parse_args()
```

With these few lines of code, users of your script can now do the "usual thing" on the command-line, for example:

```
<yourscript> --file=outfile -q
```

As it parses the command line, *optparse* sets attributes of the `options` object returned by `parse_args()` based on user-supplied command-line values. When `parse_args()` returns from parsing this command line, `options.filename` will be `"outfile"` and `options.verbose` will be `False`. *optparse* supports both long and short options, allows short options to be merged together, and allows options to be associated with their arguments in a variety of ways. Thus, the following command lines are all equivalent to the above example:

```
<yourscript> -f outfile --quiet
<yourscript> --quiet --file outfile
<yourscript> -q -foutfile
<yourscript> -qfoutfile
```

Additionally, users can run one of

```
<yourscript> -h
<yourscript> --help
```

and *optparse* will print out a brief summary of your script's options:

```
Usage: <yourscript> [options]

Options:
  -h, --help            show this help message and exit
  -f FILE, --file=FILE  write report to FILE
  -q, --quiet           don't print status messages to stdout
```

where the value of *yourscript* is determined at runtime (normally from `sys.argv[0]`).

37.1.1 Background

optparse was explicitly designed to encourage the creation of programs with straightforward, conventional command-line interfaces. To that end, it supports only the most common command-line syntax and semantics conventionally used under Unix. If you are unfamiliar with these conventions, read this section to acquaint yourself with them.

Terminology

argument a string entered on the command-line, and passed by the shell to `execl()` or `execv()`. In Python, arguments are elements of `sys.argv[1:]` (`sys.argv[0]` is the name of the program being executed). Unix shells also use the term "word".

It is occasionally desirable to substitute an argument list other than `sys.argv[1:]`, so you should read "argument" as "an element of `sys.argv[1:]`, or of some other list provided as a substitute for `sys.argv[1:]`".

option an argument used to supply extra information to guide or customize the execution of a program. There are many different syntaxes for options; the traditional Unix syntax is a hyphen ("-") followed by a single letter, e.g. `-x` or `-F`. Also, traditional Unix syntax allows multiple options to be merged into a single argument, e.g. `-x -F` is equivalent to `-xF`. The GNU project introduced `--` followed by a series of hyphen-separated words, e.g. `--file` or `--dry-run`. These are the only two option syntaxes provided by *optparse*.

Some other option syntaxes that the world has seen include:

- a hyphen followed by a few letters, e.g. `-pf` (this is *not* the same as multiple options merged into a single argument)
- a hyphen followed by a whole word, e.g. `-file` (this is technically equivalent to the previous syntax, but they aren't usually seen in the same program)
- a plus sign followed by a single letter, or a few letters, or a word, e.g. `+f`, `+rgb`
- a slash followed by a letter, or a few letters, or a word, e.g. `/f`, `/file`

These option syntaxes are not supported by *optparse*, and they never will be. This is deliberate: the first three are non-standard on any environment, and the last only makes sense if you're exclusively targeting VMS, MS-DOS, and/or Windows.

option argument an argument that follows an option, is closely associated with that option, and is consumed from the argument list when that option is. With *optparse*, option arguments may either be in a separate argument from their option:

```
-f foo
--file foo
```

or included in the same argument:

```
-ffoo
--file=foo
```

Typically, a given option either takes an argument or it doesn't. Lots of people want an "optional option arguments" feature, meaning that some options will take an argument if they see it, and won't if they don't. This is somewhat controversial, because it makes parsing ambiguous: if `-a` takes an optional argument and `-b` is another option entirely, how do we interpret `-ab`? Because of this ambiguity, *optparse* does not support this feature.

positional argument something leftover in the argument list after options have been parsed, i.e. after options and their arguments have been parsed and removed from the argument list.

required option an option that must be supplied on the command-line; note that the phrase "required option" is self-contradictory in English. *optparse* doesn't prevent you from implementing required options, but doesn't give you much help at it either.

For example, consider this hypothetical command-line:

```
prog -v --report report.txt foo bar
```

`-v` and `--report` are both options. Assuming that `--report` takes one argument, `report.txt` is an option argument. `foo` and `bar` are positional arguments.

What are options for?

Options are used to provide extra information to tune or customize the execution of a program. In case it wasn't clear, options are usually *optional*. A program should be able to run just fine with no options whatsoever. (Pick a random program from the Unix or GNU toolsets. Can it run without any options at all and still make sense? The main exceptions are `find`, `tar`, and `dd`—all of which are mutant oddballs that have been rightly criticized for their non-standard syntax and confusing interfaces.)

Lots of people want their programs to have "required options". Think about it. If it's required, then it's *not optional*! If there is a piece of information that your program absolutely requires in order to run successfully, that's what positional arguments are for.

As an example of good command-line interface design, consider the humble `cp` utility, for copying files. It doesn't make much sense to try to copy files without supplying a destination and at least one source. Hence, `cp` fails if you run it with no arguments. However, it has a flexible, useful syntax that does not require any options at all:

```
cp SOURCE DEST
cp SOURCE ... DEST-DIR
```

You can get pretty far with just that. Most `cp` implementations provide a bunch of options to tweak exactly how the files are copied: you can preserve mode and modification time, avoid following symlinks, ask before

clobbering existing files, etc. But none of this distracts from the core mission of `cp`, which is to copy either one file to another, or several files to another directory.

What are positional arguments for?

Positional arguments are for those pieces of information that your program absolutely, positively requires to run.

A good user interface should have as few absolute requirements as possible. If your program requires 17 distinct pieces of information in order to run successfully, it doesn't much matter *how* you get that information from the user—most people will give up and walk away before they successfully run the program. This applies whether the user interface is a command-line, a configuration file, or a GUI: if you make that many demands on your users, most of them will simply give up.

In short, try to minimize the amount of information that users are absolutely required to supply—use sensible defaults whenever possible. Of course, you also want to make your programs reasonably flexible. That's what options are for. Again, it doesn't matter if they are entries in a config file, widgets in the "Preferences" dialog of a GUI, or command-line options—the more options you implement, the more flexible your program is, and the more complicated its implementation becomes. Too much flexibility has drawbacks as well, of course; too many options can overwhelm users and make your code much harder to maintain.

37.1.2 Tutorial

While *optparse* is quite flexible and powerful, it's also straightforward to use in most cases. This section covers the code patterns that are common to any *optparse*-based program.

First, you need to import the OptionParser class; then, early in the main program, create an OptionParser instance:

```
from optparse import OptionParser
...
parser = OptionParser()
```

Then you can start defining options. The basic syntax is:

```
parser.add_option(opt_str, ...,
                  attr=value, ...)
```

Each option has one or more option strings, such as `-f` or `--file`, and several option attributes that tell *optparse* what to expect and what to do when it encounters that option on the command line.

Typically, each option will have one short option string and one long option string, e.g.:

```
parser.add_option("-f", "--file", ...)
```

You're free to define as many short option strings and as many long option strings as you like (including zero), as long as there is at least one option string overall.

The option strings passed to *OptionParser.add_option()* are effectively labels for the option defined by that call. For brevity, we will frequently refer to *encountering an option* on the command line; in reality, *optparse* encounters *option strings* and looks up options from them.

Once all of your options are defined, instruct *optparse* to parse your program's command line:

```
(options, args) = parser.parse_args()
```

(If you like, you can pass a custom argument list to `parse_args()`, but that's rarely necessary: by default it uses `sys.argv[1:]`.)

`parse_args()` returns two values:

- `options`, an object containing values for all of your options—e.g. if `--file` takes a single string argument, then `options.file` will be the filename supplied by the user, or `None` if the user did not supply that option
- `args`, the list of positional arguments leftover after parsing options

This tutorial section only covers the four most important option attributes: *action*, *type*, *dest* (destination), and *help*. Of these, *action* is the most fundamental.

Understanding option actions

Actions tell *optparse* what to do when it encounters an option on the command line. There is a fixed set of actions hard-coded into *optparse*; adding new actions is an advanced topic covered in section *Extending optparse*. Most actions tell *optparse* to store a value in some variable—for example, take a string from the command line and store it in an attribute of `options`.

If you don't specify an option action, *optparse* defaults to `store`.

The store action

The most common option action is `store`, which tells *optparse* to take the next argument (or the remainder of the current argument), ensure that it is of the correct type, and store it to your chosen destination.

For example:

```
parser.add_option("-f", "--file",
                  action="store", type="string", dest="filename")
```

Now let's make up a fake command line and ask *optparse* to parse it:

```
args = ["-f", "foo.txt"]
(options, args) = parser.parse_args(args)
```

When *optparse* sees the option string `-f`, it consumes the next argument, `foo.txt`, and stores it in `options.filename`. So, after this call to `parse_args()`, `options.filename` is `"foo.txt"`.

Some other option types supported by *optparse* are `int` and `float`. Here's an option that expects an integer argument:

```
parser.add_option("-n", type="int", dest="num")
```

Note that this option has no long option string, which is perfectly acceptable. Also, there's no explicit action, since the default is `store`.

Let's parse another fake command-line. This time, we'll jam the option argument right up against the option: since `-n42` (one argument) is equivalent to `-n 42` (two arguments), the code

```
(options, args) = parser.parse_args(["-n42"])
print(options.num)
```

will print `42`.

If you don't specify a type, *optparse* assumes `string`. Combined with the fact that the default action is `store`, that means our first example can be a lot shorter:

```
parser.add_option("-f", "--file", dest="filename")
```

If you don't supply a destination, *optparse* figures out a sensible default from the option strings: if the first long option string is `--foo-bar`, then the default destination is `foo_bar`. If there are no long option strings, *optparse* looks at the first short option string: the default destination for `-f` is `f`.

optparse also includes the built-in `complex` type. Adding types is covered in section *Extending optparse*.

Handling boolean (flag) options

Flag options—set a variable to true or false when a particular option is seen —are quite common. *optparse* supports them with two separate actions, `store_true` and `store_false`. For example, you might have a `verbose` flag that is turned on with `-v` and off with `-q`:

```
parser.add_option("-v", action="store_true", dest="verbose")
parser.add_option("-q", action="store_false", dest="verbose")
```

Here we have two different options with the same destination, which is perfectly OK. (It just means you have to be a bit careful when setting default values— see below.)

When *optparse* encounters `-v` on the command line, it sets `options.verbose` to `True`; when it encounters `-q`, `options.verbose` is set to `False`.

Other actions

Some other actions supported by *optparse* are:

`"store_const"` store a constant value

`"append"` append this option's argument to a list

`"count"` increment a counter by one

`"callback"` call a specified function

These are covered in section *Reference Guide*, Reference Guide and section *Option Callbacks*.

Default values

All of the above examples involve setting some variable (the "destination") when certain command-line options are seen. What happens if those options are never seen? Since we didn't supply any defaults, they are all set to `None`. This is usually fine, but sometimes you want more control. *optparse* lets you supply a default value for each destination, which is assigned before the command line is parsed.

First, consider the verbose/quiet example. If we want *optparse* to set `verbose` to `True` unless `-q` is seen, then we can do this:

```
parser.add_option("-v", action="store_true", dest="verbose", default=True)
parser.add_option("-q", action="store_false", dest="verbose")
```

Since default values apply to the *destination* rather than to any particular option, and these two options happen to have the same destination, this is exactly equivalent:

```
parser.add_option("-v", action="store_true", dest="verbose")
parser.add_option("-q", action="store_false", dest="verbose", default=True)
```

Consider this:

```
parser.add_option("-v", action="store_true", dest="verbose", default=False)
parser.add_option("-q", action="store_false", dest="verbose", default=True)
```

Again, the default value for `verbose` will be `True`: the last default value supplied for any particular destination is the one that counts.

A clearer way to specify default values is the `set_defaults()` method of OptionParser, which you can call at any time before calling `parse_args()`:

```
parser.set_defaults(verbose=True)
parser.add_option(...)
(options, args) = parser.parse_args()
```

As before, the last value specified for a given option destination is the one that counts. For clarity, try to use one method or the other of setting default values, not both.

Generating help

optparse's ability to generate help and usage text automatically is useful for creating user-friendly command-line interfaces. All you have to do is supply a *help* value for each option, and optionally a short usage message for your whole program. Here's an OptionParser populated with user-friendly (documented) options:

```
usage = "usage: %prog [options] arg1 arg2"
parser = OptionParser(usage=usage)
parser.add_option("-v", "--verbose",
                  action="store_true", dest="verbose", default=True,
                  help="make lots of noise [default]")
parser.add_option("-q", "--quiet",
                  action="store_false", dest="verbose",
                  help="be vewwy quiet (I'm hunting wabbits)")
parser.add_option("-f", "--filename",
                  metavar="FILE", help="write output to FILE")
parser.add_option("-m", "--mode",
                  default="intermediate",
                  help="interaction mode: novice, intermediate, "
                       "or expert [default: %default]")
```

If *optparse* encounters either `-h` or `--help` on the command-line, or if you just call `parser.print_help()`, it prints the following to standard output:

```
Usage: <yourscript> [options] arg1 arg2

Options:
  -h, --help            show this help message and exit
  -v, --verbose         make lots of noise [default]
  -q, --quiet           be vewwy quiet (I'm hunting wabbits)
  -f FILE, --filename=FILE
                        write output to FILE
  -m MODE, --mode=MODE  interaction mode: novice, intermediate, or
                        expert [default: intermediate]
```

(If the help output is triggered by a help option, *optparse* exits after printing the help text.)

There's a lot going on here to help *optparse* generate the best possible help message:

- the script defines its own usage message:

  ```
  usage = "usage: %prog [options] arg1 arg2"
  ```

  optparse expands `%prog` in the usage string to the name of the current program, i.e. `os.path.basename(sys.argv[0])`. The expanded string is then printed before the detailed option help.

If you don't supply a usage string, *optparse* uses a bland but sensible default: `"Usage: %prog [options]"`, which is fine if your script doesn't take any positional arguments.

- every option defines a help string, and doesn't worry about line-wrapping— *optparse* takes care of wrapping lines and making the help output look good.
- options that take a value indicate this fact in their automatically-generated help message, e.g. for the "mode" option:

```
-m MODE, --mode=MODE
```

Here, "MODE" is called the meta-variable: it stands for the argument that the user is expected to supply to `-m`/`--mode`. By default, *optparse* converts the destination variable name to uppercase and uses that for the meta-variable. Sometimes, that's not what you want—for example, the `--filename` option explicitly sets `metavar="FILE"`, resulting in this automatically-generated option description:

```
-f FILE, --filename=FILE
```

This is important for more than just saving space, though: the manually written help text uses the meta-variable `FILE` to clue the user in that there's a connection between the semi-formal syntax `-f FILE` and the informal semantic description "write output to FILE". This is a simple but effective way to make your help text a lot clearer and more useful for end users.

- options that have a default value can include `%default` in the help string—*optparse* will replace it with *str()* of the option's default value. If an option has no default value (or the default value is `None`), `%default` expands to `none`.

Grouping Options

When dealing with many options, it is convenient to group these options for better help output. An *OptionParser* can contain several option groups, each of which can contain several options.

An option group is obtained using the class *OptionGroup*:

class optparse.**OptionGroup**(*parser*, *title*, *description=None*)

where

- parser is the *OptionParser* instance the group will be inserted in to
- title is the group title
- description, optional, is a long description of the group

OptionGroup inherits from `OptionContainer` (like *OptionParser*) and so the `add_option()` method can be used to add an option to the group.

Once all the options are declared, using the *OptionParser* method `add_option_group()` the group is added to the previously defined parser.

Continuing with the parser defined in the previous section, adding an *OptionGroup* to a parser is easy:

```
group = OptionGroup(parser, "Dangerous Options",
                    "Caution: use these options at your own risk.  "
                    "It is believed that some of them bite.")
group.add_option("-g", action="store_true", help="Group option.")
parser.add_option_group(group)
```

This would result in the following help output:

```
Usage: <yourscript> [options] arg1 arg2

Options:
  -h, --help            show this help message and exit
  -v, --verbose         make lots of noise [default]
  -q, --quiet           be vewwy quiet (I'm hunting wabbits)
  -f FILE, --filename=FILE
                        write output to FILE
  -m MODE, --mode=MODE  interaction mode: novice, intermediate, or
                        expert [default: intermediate]

  Dangerous Options:
    Caution: use these options at your own risk.  It is believed that some
    of them bite.

    -g                  Group option.
```

A bit more complete example might involve using more than one group: still extending the previous example:

```
group = OptionGroup(parser, "Dangerous Options",
                    "Caution: use these options at your own risk.  "
                    "It is believed that some of them bite.")
group.add_option("-g", action="store_true", help="Group option.")
parser.add_option_group(group)

group = OptionGroup(parser, "Debug Options")
group.add_option("-d", "--debug", action="store_true",
                 help="Print debug information")
group.add_option("-s", "--sql", action="store_true",
                 help="Print all SQL statements executed")
group.add_option("-e", action="store_true", help="Print every action done")
parser.add_option_group(group)
```

that results in the following output:

```
Usage: <yourscript> [options] arg1 arg2

Options:
  -h, --help            show this help message and exit
  -v, --verbose         make lots of noise [default]
  -q, --quiet           be vewwy quiet (I'm hunting wabbits)
  -f FILE, --filename=FILE
                        write output to FILE
  -m MODE, --mode=MODE  interaction mode: novice, intermediate, or expert
                        [default: intermediate]

  Dangerous Options:
    Caution: use these options at your own risk.  It is believed that some
    of them bite.

    -g                  Group option.

  Debug Options:
    -d, --debug         Print debug information
    -s, --sql           Print all SQL statements executed
    -e                  Print every action done
```

Another interesting method, in particular when working programmatically with option groups is:

OptionParser.get_option_group(*opt_str*)
: Return the *OptionGroup* to which the short or long option string *opt_str* (e.g. `'-o'` or `'--option'`) belongs. If there's no such *OptionGroup*, return `None`.

Printing a version string

Similar to the brief usage string, *optparse* can also print a version string for your program. You have to supply the string as the `version` argument to OptionParser:

```
parser = OptionParser(usage="%prog [-f] [-q]", version="%prog 1.0")
```

`%prog` is expanded just like it is in `usage`. Apart from that, `version` can contain anything you like. When you supply it, *optparse* automatically adds a `--version` option to your parser. If it encounters this option on the command line, it expands your `version` string (by replacing `%prog`), prints it to stdout, and exits.

For example, if your script is called `/usr/bin/foo`:

```
$ /usr/bin/foo --version
foo 1.0
```

The following two methods can be used to print and get the `version` string:

OptionParser.print_version(*file=None*)
: Print the version message for the current program (`self.version`) to *file* (default stdout). As with *print_usage()*, any occurrence of `%prog` in `self.version` is replaced with the name of the current program. Does nothing if `self.version` is empty or undefined.

OptionParser.get_version()
: Same as *print_version()* but returns the version string instead of printing it.

How optparse handles errors

There are two broad classes of errors that *optparse* has to worry about: programmer errors and user errors. Programmer errors are usually erroneous calls to *OptionParser.add_option()*, e.g. invalid option strings, unknown option attributes, missing option attributes, etc. These are dealt with in the usual way: raise an exception (either `optparse.OptionError` or *TypeError*) and let the program crash.

Handling user errors is much more important, since they are guaranteed to happen no matter how stable your code is. *optparse* can automatically detect some user errors, such as bad option arguments (passing `-n 4x` where `-n` takes an integer argument), missing arguments (`-n` at the end of the command line, where `-n` takes an argument of any type). Also, you can call `OptionParser.error()` to signal an application-defined error condition:

```
(options, args) = parser.parse_args()
...
if options.a and options.b:
    parser.error("options -a and -b are mutually exclusive")
```

In either case, *optparse* handles the error the same way: it prints the program's usage message and an error message to standard error and exits with error status 2.

Consider the first example above, where the user passes `4x` to an option that takes an integer:

```
$ /usr/bin/foo -n 4x
Usage: foo [options]

foo: error: option -n: invalid integer value: '4x'
```

Or, where the user fails to pass a value at all:

```
$ /usr/bin/foo -n
Usage: foo [options]

foo: error: -n option requires an argument
```

optparse-generated error messages take care always to mention the option involved in the error; be sure to do the same when calling `OptionParser.error()` from your application code.

If *optparse*'s default error-handling behaviour does not suit your needs, you'll need to subclass OptionParser and override its `exit()` and/or `error()` methods.

Putting it all together

Here's what *optparse*-based scripts usually look like:

```
from optparse import OptionParser
...
def main():
    usage = "usage: %prog [options] arg"
    parser = OptionParser(usage)
    parser.add_option("-f", "--file", dest="filename",
                      help="read data from FILENAME")
    parser.add_option("-v", "--verbose",
                      action="store_true", dest="verbose")
    parser.add_option("-q", "--quiet",
                      action="store_false", dest="verbose")
    ...
    (options, args) = parser.parse_args()
    if len(args) != 1:
        parser.error("incorrect number of arguments")
    if options.verbose:
        print("reading %s..." % options.filename)
    ...

if __name__ == "__main__":
    main()
```

37.1.3 Reference Guide

Creating the parser

The first step in using *optparse* is to create an OptionParser instance.

class optparse.**OptionParser**(...)

The OptionParser constructor has no required arguments, but a number of optional keyword arguments. You should always pass them as keyword arguments, i.e. do not rely on the order in which the arguments are declared.

usage (default: "%prog [options]") The usage summary to print when your program is run incorrectly or with a help option. When *optparse* prints the usage string, it expands `%prog` to `os.path.basename(sys.argv[0])` (or to `prog` if you passed that keyword argument). To suppress a usage message, pass the special value `optparse.SUPPRESS_USAGE`.

option_list (default: []) A list of Option objects to populate the parser with. The options in `option_list` are added after any options in `standard_option_list` (a class attribute that may

be set by OptionParser subclasses), but before any version or help options. Deprecated; use *add_option()* after creating the parser instead.

option_class (default: optparse.Option) Class to use when adding options to the parser in *add_option()*.

version (default: None) A version string to print when the user supplies a version option. If you supply a true value for `version`, *optparse* automatically adds a version option with the single option string `--version`. The substring `%prog` is expanded the same as for `usage`.

conflict_handler (default: "error") Specifies what to do when options with conflicting option strings are added to the parser; see section *Conflicts between options*.

description (default: None) A paragraph of text giving a brief overview of your program. *optparse* reformats this paragraph to fit the current terminal width and prints it when the user requests help (after `usage`, but before the list of options).

formatter (default: a new IndentedHelpFormatter) An instance of optparse.HelpFormatter that will be used for printing help text. *optparse* provides two concrete classes for this purpose: IndentedHelpFormatter and TitledHelpFormatter.

add_help_option (default: True) If true, *optparse* will add a help option (with option strings `-h` and `--help`) to the parser.

prog The string to use when expanding `%prog` in `usage` and `version` instead of `os.path.basename(sys.argv[0])`.

epilog (default: None) A paragraph of help text to print after the option help.

Populating the parser

There are several ways to populate the parser with options. The preferred way is by using *OptionParser.add_option()*, as shown in section *Tutorial*. `add_option()` can be called in one of two ways:

- pass it an Option instance (as returned by `make_option()`)
- pass it any combination of positional and keyword arguments that are acceptable to `make_option()` (i.e., to the Option constructor), and it will create the Option instance for you

The other alternative is to pass a list of pre-constructed Option instances to the OptionParser constructor, as in:

```
option_list = [
    make_option("-f", "--filename",
                action="store", type="string", dest="filename"),
    make_option("-q", "--quiet",
                action="store_false", dest="verbose"),
    ]
parser = OptionParser(option_list=option_list)
```

(`make_option()` is a factory function for creating Option instances; currently it is an alias for the Option constructor. A future version of *optparse* may split Option into several classes, and `make_option()` will pick the right class to instantiate. Do not instantiate Option directly.)

Defining options

Each Option instance represents a set of synonymous command-line option strings, e.g. `-f` and `--file`. You can specify any number of short or long option strings, but you must specify at least one overall option string.

The canonical way to create an `Option` instance is with the `add_option()` method of *OptionParser*.

OptionParser.add_option(*option*)
OptionParser.add_option(**opt_str*, *attr=value*, *...*)

To define an option with only a short option string:

```
parser.add_option("-f", attr=value, ...)
```

And to define an option with only a long option string:

```
parser.add_option("--foo", attr=value, ...)
```

The keyword arguments define attributes of the new Option object. The most important option attribute is *action*, and it largely determines which other attributes are relevant or required. If you pass irrelevant option attributes, or fail to pass required ones, *optparse* raises an OptionError exception explaining your mistake.

An option's *action* determines what *optparse* does when it encounters this option on the command-line. The standard option actions hard-coded into *optparse* are:

"store" store this option's argument (default)

"store_const" store a constant value

"store_true" store a true value

"store_false" store a false value

"append" append this option's argument to a list

"append_const" append a constant value to a list

"count" increment a counter by one

"callback" call a specified function

"help" print a usage message including all options and the documentation for them

(If you don't supply an action, the default is "store". For this action, you may also supply *type* and *dest* option attributes; see *Standard option actions*.)

As you can see, most actions involve storing or updating a value somewhere. *optparse* always creates a special object for this, conventionally called options (it happens to be an instance of optparse.Values). Option arguments (and various other values) are stored as attributes of this object, according to the *dest* (destination) option attribute.

For example, when you call

```
parser.parse_args()
```

one of the first things *optparse* does is create the options object:

```
options = Values()
```

If one of the options in this parser is defined with

```
parser.add_option("-f", "--file", action="store", type="string", dest="filename")
```

and the command-line being parsed includes any of the following:

```
-ffoo
-f foo
--file=foo
--file foo
```

then *optparse*, on seeing this option, will do the equivalent of

```
options.filename = "foo"
```

The *type* and *dest* option attributes are almost as important as *action*, but *action* is the only one that makes sense for *all* options.

Option attributes

The following option attributes may be passed as keyword arguments to *OptionParser.add_option()*. If you pass an option attribute that is not relevant to a particular option, or fail to pass a required option attribute, *optparse* raises `OptionError`.

`Option.action`
(default: `"store"`)

Determines *optparse*'s behaviour when this option is seen on the command line; the available options are documented *here*.

`Option.type`
(default: `"string"`)

The argument type expected by this option (e.g., `"string"` or `"int"`); the available option types are documented *here*.

`Option.dest`
(default: derived from option strings)

If the option's action implies writing or modifying a value somewhere, this tells *optparse* where to write it: *dest* names an attribute of the `options` object that *optparse* builds as it parses the command line.

`Option.default`
The value to use for this option's destination if the option is not seen on the command line. See also *OptionParser.set_defaults()*.

`Option.nargs`
(default: 1)

How many arguments of type *type* should be consumed when this option is seen. If > 1, *optparse* will store a tuple of values to *dest*.

`Option.const`
For actions that store a constant value, the constant value to store.

`Option.choices`
For options of type `"choice"`, the list of strings the user may choose from.

`Option.callback`
For options with action `"callback"`, the callable to call when this option is seen. See section *Option Callbacks* for detail on the arguments passed to the callable.

`Option.callback_args`
`Option.callback_kwargs`
Additional positional and keyword arguments to pass to `callback` after the four standard callback arguments.

`Option.help`
Help text to print for this option when listing all available options after the user supplies a *help* option (such as `--help`). If no help text is supplied, the option will be listed without help text. To hide this option, use the special value `optparse.SUPPRESS_HELP`.

`Option.metavar`
(default: derived from option strings)

Stand-in for the option argument(s) to use when printing help text. See section *Tutorial* for an example.

Standard option actions

The various option actions all have slightly different requirements and effects. Most actions have several relevant option attributes which you may specify to guide *optparse*'s behaviour; a few have required attributes, which you must specify for any option using that action.

- `"store"` [relevant: *type*, *dest*, *nargs*, *choices*]

  The option must be followed by an argument, which is converted to a value according to *type* and stored in *dest*. If *nargs* > 1, multiple arguments will be consumed from the command line; all will be converted according to *type* and stored to *dest* as a tuple. See the *Standard option types* section.

  If *choices* is supplied (a list or tuple of strings), the type defaults to `"choice"`.

  If *type* is not supplied, it defaults to `"string"`.

  If *dest* is not supplied, *optparse* derives a destination from the first long option string (e.g., `--foo-bar` implies `foo_bar`). If there are no long option strings, *optparse* derives a destination from the first short option string (e.g., `-f` implies `f`).

  Example:

```
parser.add_option("-f")
parser.add_option("-p", type="float", nargs=3, dest="point")
```

  As it parses the command line

```
-f foo.txt -p 1 -3.5 4 -fbar.txt
```

  optparse will set

```
options.f = "foo.txt"
options.point = (1.0, -3.5, 4.0)
options.f = "bar.txt"
```

- `"store_const"` [required: *const*; relevant: *dest*]

  The value *const* is stored in *dest*.

  Example:

```
parser.add_option("-q", "--quiet",
                  action="store_const", const=0, dest="verbose")
parser.add_option("-v", "--verbose",
                  action="store_const", const=1, dest="verbose")
parser.add_option("--noisy",
                  action="store_const", const=2, dest="verbose")
```

  If `--noisy` is seen, *optparse* will set

```
options.verbose = 2
```

- `"store_true"` [relevant: *dest*]

  A special case of `"store_const"` that stores a true value to *dest*.

- "store_false" [relevant: *dest*]

  Like "store_true", but stores a false value.

  Example:

```
parser.add_option("--clobber", action="store_true", dest="clobber")
parser.add_option("--no-clobber", action="store_false", dest="clobber")
```

- "append" [relevant: *type*, *dest*, *nargs*, *choices*]

  The option must be followed by an argument, which is appended to the list in *dest*. If no default value for *dest* is supplied, an empty list is automatically created when *optparse* first encounters this option on the command-line. If *nargs* > 1, multiple arguments are consumed, and a tuple of length *nargs* is appended to *dest*.

  The defaults for *type* and *dest* are the same as for the "store" action.

  Example:

```
parser.add_option("-t", "--tracks", action="append", type="int")
```

  If -t3 is seen on the command-line, *optparse* does the equivalent of:

```
options.tracks = []
options.tracks.append(int("3"))
```

  If, a little later on, --tracks=4 is seen, it does:

```
options.tracks.append(int("4"))
```

  The append action calls the append method on the current value of the option. This means that any default value specified must have an append method. It also means that if the default value is non-empty, the default elements will be present in the parsed value for the option, with any values from the command line appended after those default values:

```
>>> parser.add_option("--files", action="append", default=['~/.mypkg/defaults'])
>>> opts, args = parser.parse_args(['--files', 'overrides.mypkg'])
>>> opts.files
['~/.mypkg/defaults', 'overrides.mypkg']
```

- "append_const" [required: *const*; relevant: *dest*]

  Like "store_const", but the value *const* is appended to *dest*; as with "append", *dest* defaults to None, and an empty list is automatically created the first time the option is encountered.

- "count" [relevant: *dest*]

  Increment the integer stored at *dest*. If no default value is supplied, *dest* is set to zero before being incremented the first time.

  Example:

```
parser.add_option("-v", action="count", dest="verbosity")
```

  The first time -v is seen on the command line, *optparse* does the equivalent of:

```
options.verbosity = 0
options.verbosity += 1
```

  Every subsequent occurrence of -v results in

```
options.verbosity += 1
```

- `"callback"` [required: *callback*; relevant: *type*, *nargs*, *callback_args*, *callback_kwargs*]

  Call the function specified by *callback*, which is called as

  ```
  func(option, opt_str, value, parser, *args, **kwargs)
  ```

  See section *Option Callbacks* for more detail.

- `"help"`

  Prints a complete help message for all the options in the current option parser. The help message is constructed from the `usage` string passed to OptionParser's constructor and the *help* string passed to every option.

  If no *help* string is supplied for an option, it will still be listed in the help message. To omit an option entirely, use the special value `optparse.SUPPRESS_HELP`.

  optparse automatically adds a *help* option to all OptionParsers, so you do not normally need to create one.

  Example:

  ```
  from optparse import OptionParser, SUPPRESS_HELP

  # usually, a help option is added automatically, but that can
  # be suppressed using the add_help_option argument
  parser = OptionParser(add_help_option=False)

  parser.add_option("-h", "--help", action="help")
  parser.add_option("-v", action="store_true", dest="verbose",
                    help="Be moderately verbose")
  parser.add_option("--file", dest="filename",
                    help="Input file to read data from")
  parser.add_option("--secret", help=SUPPRESS_HELP)
  ```

  If *optparse* sees either `-h` or `--help` on the command line, it will print something like the following help message to stdout (assuming `sys.argv[0]` is `"foo.py"`):

  ```
  Usage: foo.py [options]

  Options:
    -h, --help        Show this help message and exit
    -v                Be moderately verbose
    --file=FILENAME   Input file to read data from
  ```

  After printing the help message, *optparse* terminates your process with `sys.exit(0)`.

- `"version"`

  Prints the version number supplied to the OptionParser to stdout and exits. The version number is actually formatted and printed by the `print_version()` method of OptionParser. Generally only relevant if the `version` argument is supplied to the OptionParser constructor. As with *help* options, you will rarely create `version` options, since *optparse* automatically adds them when needed.

Standard option types

optparse has five built-in option types: `"string"`, `"int"`, `"choice"`, `"float"` and `"complex"`. If you need to add new option types, see section *Extending optparse*.

Arguments to string options are not checked or converted in any way: the text on the command line is stored in the destination (or passed to the callback) as-is.

Integer arguments (type `"int"`) are parsed as follows:

- if the number starts with `0x`, it is parsed as a hexadecimal number
- if the number starts with `0`, it is parsed as an octal number
- if the number starts with `0b`, it is parsed as a binary number
- otherwise, the number is parsed as a decimal number

The conversion is done by calling *int()* with the appropriate base (2, 8, 10, or 16). If this fails, so will *optparse*, although with a more useful error message.

`"float"` and `"complex"` option arguments are converted directly with *float()* and *complex()*, with similar error-handling.

`"choice"` options are a subtype of `"string"` options. The *choices* option attribute (a sequence of strings) defines the set of allowed option arguments. `optparse.check_choice()` compares user-supplied option arguments against this master list and raises `OptionValueError` if an invalid string is given.

Parsing arguments

The whole point of creating and populating an OptionParser is to call its `parse_args()` method:

```
(options, args) = parser.parse_args(args=None, values=None)
```

where the input parameters are

`args` the list of arguments to process (default: `sys.argv[1:]`)

`values` an `optparse.Values` object to store option arguments in (default: a new instance of `Values`) – if you give an existing object, the option defaults will not be initialized on it

and the return values are

`options` the same object that was passed in as `values`, or the optparse.Values instance created by *optparse*

`args` the leftover positional arguments after all options have been processed

The most common usage is to supply neither keyword argument. If you supply `values`, it will be modified with repeated *setattr()* calls (roughly one for every option argument stored to an option destination) and returned by `parse_args()`.

If `parse_args()` encounters any errors in the argument list, it calls the OptionParser's `error()` method with an appropriate end-user error message. This ultimately terminates your process with an exit status of 2 (the traditional Unix exit status for command-line errors).

Querying and manipulating your option parser

The default behavior of the option parser can be customized slightly, and you can also poke around your option parser and see what's there. OptionParser provides several methods to help you out:

`OptionParser.disable_interspersed_args()`
Set parsing to stop on the first non-option. For example, if `-a` and `-b` are both simple options that take no arguments, *optparse* normally accepts this syntax:

```
prog -a arg1 -b arg2
```

and treats it as equivalent to

```
prog -a -b arg1 arg2
```

To disable this feature, call *disable_interspersed_args()*. This restores traditional Unix syntax, where option parsing stops with the first non-option argument.

Use this if you have a command processor which runs another command which has options of its own and you want to make sure these options don't get confused. For example, each command might have a different set of options.

OptionParser.enable_interspersed_args()
Set parsing to not stop on the first non-option, allowing interspersing switches with command arguments. This is the default behavior.

OptionParser.get_option(*opt_str*)
Returns the Option instance with the option string *opt_str*, or `None` if no options have that option string.

OptionParser.has_option(*opt_str*)
Return true if the OptionParser has an option with option string *opt_str* (e.g., `-q` or `--verbose`).

OptionParser.remove_option(*opt_str*)
If the *OptionParser* has an option corresponding to *opt_str*, that option is removed. If that option provided any other option strings, all of those option strings become invalid. If *opt_str* does not occur in any option belonging to this *OptionParser*, raises *ValueError*.

Conflicts between options

If you're not careful, it's easy to define options with conflicting option strings:

```
parser.add_option("-n", "--dry-run", ...)
...
parser.add_option("-n", "--noisy", ...)
```

(This is particularly true if you've defined your own OptionParser subclass with some standard options.)

Every time you add an option, *optparse* checks for conflicts with existing options. If it finds any, it invokes the current conflict-handling mechanism. You can set the conflict-handling mechanism either in the constructor:

```
parser = OptionParser(..., conflict_handler=handler)
```

or with a separate call:

```
parser.set_conflict_handler(handler)
```

The available conflict handlers are:

"error" (default) assume option conflicts are a programming error and raise OptionConflictError

"resolve" resolve option conflicts intelligently (see below)

As an example, let's define an *OptionParser* that resolves conflicts intelligently and add conflicting options to it:

```
parser = OptionParser(conflict_handler="resolve")
parser.add_option("-n", "--dry-run", ..., help="do no harm")
parser.add_option("-n", "--noisy", ..., help="be noisy")
```

At this point, *optparse* detects that a previously-added option is already using the `-n` option string. Since `conflict_handler` is `"resolve"`, it resolves the situation by removing `-n` from the earlier option's list of option strings. Now `--dry-run` is the only way for the user to activate that option. If the user asks for help, the help message will reflect that:

```
Options:
  --dry-run     do no harm
  ...
  -n, --noisy   be noisy
```

It's possible to whittle away the option strings for a previously-added option until there are none left, and the user has no way of invoking that option from the command-line. In that case, *optparse* removes that option completely, so it doesn't show up in help text or anywhere else. Carrying on with our existing OptionParser:

```
parser.add_option("--dry-run", ..., help="new dry-run option")
```

At this point, the original `-n`/`--dry-run` option is no longer accessible, so *optparse* removes it, leaving this help text:

```
Options:
  ...
  -n, --noisy   be noisy
  --dry-run     new dry-run option
```

Cleanup

OptionParser instances have several cyclic references. This should not be a problem for Python's garbage collector, but you may wish to break the cyclic references explicitly by calling `destroy()` on your OptionParser once you are done with it. This is particularly useful in long-running applications where large object graphs are reachable from your OptionParser.

Other methods

OptionParser supports several other public methods:

`OptionParser.set_usage`(*usage*)
: Set the usage string according to the rules described above for the `usage` constructor keyword argument. Passing `None` sets the default usage string; use `optparse.SUPPRESS_USAGE` to suppress a usage message.

`OptionParser.print_usage`(*file=None*)
: Print the usage message for the current program (`self.usage`) to *file* (default stdout). Any occurrence of the string `%prog` in `self.usage` is replaced with the name of the current program. Does nothing if `self.usage` is empty or not defined.

`OptionParser.get_usage`()
: Same as *print_usage()* but returns the usage string instead of printing it.

`OptionParser.set_defaults`(*dest=value, ...*)
: Set default values for several option destinations at once. Using *set_defaults()* is the preferred way to set default values for options, since multiple options can share the same destination. For example, if several "mode" options all set the same destination, any one of them can set the default, and the last one wins:

```
parser.add_option("--advanced", action="store_const",
                  dest="mode", const="advanced",
                  default="novice")    # overridden below
```

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```
parser.add_option("--novice", action="store_const",
                  dest="mode", const="novice",
                  default="advanced")  # overrides above setting
```

To avoid this confusion, use *set_defaults()*:

```
parser.set_defaults(mode="advanced")
parser.add_option("--advanced", action="store_const",
                  dest="mode", const="advanced")
parser.add_option("--novice", action="store_const",
                  dest="mode", const="novice")
```

37.1.4 Option Callbacks

When *optparse*'s built-in actions and types aren't quite enough for your needs, you have two choices: extend *optparse* or define a callback option. Extending *optparse* is more general, but overkill for a lot of simple cases. Quite often a simple callback is all you need.

There are two steps to defining a callback option:

- define the option itself using the `"callback"` action
- write the callback; this is a function (or method) that takes at least four arguments, as described below

Defining a callback option

As always, the easiest way to define a callback option is by using the *OptionParser.add_option()* method. Apart from *action*, the only option attribute you must specify is `callback`, the function to call:

```
parser.add_option("-c", action="callback", callback=my_callback)
```

`callback` is a function (or other callable object), so you must have already defined `my_callback()` when you create this callback option. In this simple case, *optparse* doesn't even know if `-c` takes any arguments, which usually means that the option takes no arguments—the mere presence of `-c` on the command-line is all it needs to know. In some circumstances, though, you might want your callback to consume an arbitrary number of command-line arguments. This is where writing callbacks gets tricky; it's covered later in this section.

optparse always passes four particular arguments to your callback, and it will only pass additional arguments if you specify them via *callback_args* and *callback_kwargs*. Thus, the minimal callback function signature is:

```
def my_callback(option, opt, value, parser):
```

The four arguments to a callback are described below.

There are several other option attributes that you can supply when you define a callback option:

type has its usual meaning: as with the `"store"` or `"append"` actions, it instructs *optparse* to consume one argument and convert it to *type*. Rather than storing the converted value(s) anywhere, though, *optparse* passes it to your callback function.

nargs also has its usual meaning: if it is supplied and > 1, *optparse* will consume *nargs* arguments, each of which must be convertible to *type*. It then passes a tuple of converted values to your callback.

callback_args a tuple of extra positional arguments to pass to the callback

callback_kwargs a dictionary of extra keyword arguments to pass to the callback

How callbacks are called

All callbacks are called as follows:

```
func(option, opt_str, value, parser, *args, **kwargs)
```

where

option is the Option instance that's calling the callback

opt_str is the option string seen on the command-line that's triggering the callback. (If an abbreviated long option was used, **opt_str** will be the full, canonical option string—e.g. if the user puts **--foo** on the command-line as an abbreviation for **--foobar**, then **opt_str** will be **"--foobar"**.)

value is the argument to this option seen on the command-line. *optparse* will only expect an argument if *type* is set; the type of **value** will be the type implied by the option's type. If *type* for this option is **None** (no argument expected), then **value** will be **None**. If *nargs* > 1, **value** will be a tuple of values of the appropriate type.

parser is the OptionParser instance driving the whole thing, mainly useful because you can access some other interesting data through its instance attributes:

parser.largs the current list of leftover arguments, ie. arguments that have been consumed but are neither options nor option arguments. Feel free to modify **parser.largs**, e.g. by adding more arguments to it. (This list will become **args**, the second return value of **parse_args()**.)

parser.rargs the current list of remaining arguments, ie. with **opt_str** and **value** (if applicable) removed, and only the arguments following them still there. Feel free to modify **parser.rargs**, e.g. by consuming more arguments.

parser.values the object where option values are by default stored (an instance of optparse.OptionValues). This lets callbacks use the same mechanism as the rest of *optparse* for storing option values; you don't need to mess around with globals or closures. You can also access or modify the value(s) of any options already encountered on the command-line.

args is a tuple of arbitrary positional arguments supplied via the *callback_args* option attribute.

kwargs is a dictionary of arbitrary keyword arguments supplied via *callback_kwargs*.

Raising errors in a callback

The callback function should raise **OptionValueError** if there are any problems with the option or its argument(s). *optparse* catches this and terminates the program, printing the error message you supply to stderr. Your message should be clear, concise, accurate, and mention the option at fault. Otherwise, the user will have a hard time figuring out what they did wrong.

Callback example 1: trivial callback

Here's an example of a callback option that takes no arguments, and simply records that the option was seen:

```
def record_foo_seen(option, opt_str, value, parser):
    parser.values.saw_foo = True

parser.add_option("--foo", action="callback", callback=record_foo_seen)
```

Of course, you could do that with the **"store_true"** action.

Callback example 2: check option order

Here's a slightly more interesting example: record the fact that `-a` is seen, but blow up if it comes after `-b` in the command-line.

```
def check_order(option, opt_str, value, parser):
    if parser.values.b:
        raise OptionValueError("can't use -a after -b")
    parser.values.a = 1
...
parser.add_option("-a", action="callback", callback=check_order)
parser.add_option("-b", action="store_true", dest="b")
```

Callback example 3: check option order (generalized)

If you want to re-use this callback for several similar options (set a flag, but blow up if `-b` has already been seen), it needs a bit of work: the error message and the flag that it sets must be generalized.

```
def check_order(option, opt_str, value, parser):
    if parser.values.b:
        raise OptionValueError("can't use %s after -b" % opt_str)
    setattr(parser.values, option.dest, 1)
...
parser.add_option("-a", action="callback", callback=check_order, dest='a')
parser.add_option("-b", action="store_true", dest="b")
parser.add_option("-c", action="callback", callback=check_order, dest='c')
```

Callback example 4: check arbitrary condition

Of course, you could put any condition in there—you're not limited to checking the values of already-defined options. For example, if you have options that should not be called when the moon is full, all you have to do is this:

```
def check_moon(option, opt_str, value, parser):
    if is_moon_full():
        raise OptionValueError("%s option invalid when moon is full"
                               % opt_str)
    setattr(parser.values, option.dest, 1)
...
parser.add_option("--foo",
                  action="callback", callback=check_moon, dest="foo")
```

(The definition of `is_moon_full()` is left as an exercise for the reader.)

Callback example 5: fixed arguments

Things get slightly more interesting when you define callback options that take a fixed number of arguments. Specifying that a callback option takes arguments is similar to defining a `"store"` or `"append"` option: if you define *type*, then the option takes one argument that must be convertible to that type; if you further define *nargs*, then the option takes *nargs* arguments.

Here's an example that just emulates the standard `"store"` action:

```
def store_value(option, opt_str, value, parser):
    setattr(parser.values, option.dest, value)
...
parser.add_option("--foo",
                  action="callback", callback=store_value,
                  type="int", nargs=3, dest="foo")
```

Note that *optparse* takes care of consuming 3 arguments and converting them to integers for you; all you have to do is store them. (Or whatever; obviously you don't need a callback for this example.)

Callback example 6: variable arguments

Things get hairy when you want an option to take a variable number of arguments. For this case, you must write a callback, as *optparse* doesn't provide any built-in capabilities for it. And you have to deal with certain intricacies of conventional Unix command-line parsing that *optparse* normally handles for you. In particular, callbacks should implement the conventional rules for bare `--` and `-` arguments:

- either `--` or `-` can be option arguments
- bare `--` (if not the argument to some option): halt command-line processing and discard the `--`
- bare `-` (if not the argument to some option): halt command-line processing but keep the `-` (append it to `parser.largs`)

If you want an option that takes a variable number of arguments, there are several subtle, tricky issues to worry about. The exact implementation you choose will be based on which trade-offs you're willing to make for your application (which is why *optparse* doesn't support this sort of thing directly).

Nevertheless, here's a stab at a callback for an option with variable arguments:

```
def vararg_callback(option, opt_str, value, parser):
    assert value is None
    value = []

    def floatable(str):
        try:
            float(str)
            return True
        except ValueError:
            return False

    for arg in parser.rargs:
        # stop on --foo like options
        if arg[:2] == "--" and len(arg) > 2:
            break
        # stop on -a, but not on -3 or -3.0
        if arg[:1] == "-" and len(arg) > 1 and not floatable(arg):
            break
        value.append(arg)

    del parser.rargs[:len(value)]
    setattr(parser.values, option.dest, value)

...
parser.add_option("-c", "--callback", dest="vararg_attr",
                  action="callback", callback=vararg_callback)
```

37.1.5 Extending optparse

Since the two major controlling factors in how *optparse* interprets command-line options are the action and type of each option, the most likely direction of extension is to add new actions and new types.

Adding new types

To add new types, you need to define your own subclass of *optparse*'s `Option` class. This class has a couple of attributes that define *optparse*'s types: *TYPES* and *TYPE_CHECKER*.

`Option.TYPES`
: A tuple of type names; in your subclass, simply define a new tuple *TYPES* that builds on the standard one.

`Option.TYPE_CHECKER`
: A dictionary mapping type names to type-checking functions. A type-checking function has the following signature:

```
def check_mytype(option, opt, value)
```

: where `option` is an `Option` instance, `opt` is an option string (e.g., `-f`), and `value` is the string from the command line that must be checked and converted to your desired type. `check_mytype()` should return an object of the hypothetical type `mytype`. The value returned by a type-checking function will wind up in the OptionValues instance returned by `OptionParser.parse_args()`, or be passed to a callback as the `value` parameter.

: Your type-checking function should raise `OptionValueError` if it encounters any problems. `OptionValueError` takes a single string argument, which is passed as-is to *OptionParser*'s `error()` method, which in turn prepends the program name and the string `"error:"` and prints everything to stderr before terminating the process.

Here's a silly example that demonstrates adding a `"complex"` option type to parse Python-style complex numbers on the command line. (This is even sillier than it used to be, because *optparse* 1.3 added built-in support for complex numbers, but never mind.)

First, the necessary imports:

```
from copy import copy
from optparse import Option, OptionValueError
```

You need to define your type-checker first, since it's referred to later (in the *TYPE_CHECKER* class attribute of your Option subclass):

```
def check_complex(option, opt, value):
    try:
        return complex(value)
    except ValueError:
        raise OptionValueError(
            "option %s: invalid complex value: %r" % (opt, value))
```

Finally, the Option subclass:

```
class MyOption (Option):
    TYPES = Option.TYPES + ("complex",)
    TYPE_CHECKER = copy(Option.TYPE_CHECKER)
    TYPE_CHECKER["complex"] = check_complex
```

(If we didn't make a *copy()* of *Option.TYPE_CHECKER*, we would end up modifying the *TYPE_CHECKER* attribute of *optparse*'s Option class. This being Python, nothing stops you from doing that except good manners and common sense.)

That's it! Now you can write a script that uses the new option type just like any other *optparse*-based script, except you have to instruct your OptionParser to use MyOption instead of Option:

```
parser = OptionParser(option_class=MyOption)
parser.add_option("-c", type="complex")
```

Alternately, you can build your own option list and pass it to OptionParser; if you don't use `add_option()` in the above way, you don't need to tell OptionParser which option class to use:

```
option_list = [MyOption("-c", action="store", type="complex", dest="c")]
parser = OptionParser(option_list=option_list)
```

Adding new actions

Adding new actions is a bit trickier, because you have to understand that *optparse* has a couple of classifications for actions:

"store" actions actions that result in *optparse* storing a value to an attribute of the current OptionValues instance; these options require a *dest* attribute to be supplied to the Option constructor.

"typed" actions actions that take a value from the command line and expect it to be of a certain type; or rather, a string that can be converted to a certain type. These options require a *type* attribute to the Option constructor.

These are overlapping sets: some default "store" actions are `"store"`, `"store_const"`, `"append"`, and `"count"`, while the default "typed" actions are `"store"`, `"append"`, and `"callback"`.

When you add an action, you need to categorize it by listing it in at least one of the following class attributes of Option (all are lists of strings):

`Option.ACTIONS`
All actions must be listed in ACTIONS.

`Option.STORE_ACTIONS`
"store" actions are additionally listed here.

`Option.TYPED_ACTIONS`
"typed" actions are additionally listed here.

`Option.ALWAYS_TYPED_ACTIONS`
Actions that always take a type (i.e. whose options always take a value) are additionally listed here. The only effect of this is that *optparse* assigns the default type, `"string"`, to options with no explicit type whose action is listed in *ALWAYS_TYPED_ACTIONS*.

In order to actually implement your new action, you must override Option's `take_action()` method and add a case that recognizes your action.

For example, let's add an `"extend"` action. This is similar to the standard `"append"` action, but instead of taking a single value from the command-line and appending it to an existing list, `"extend"` will take multiple values in a single comma-delimited string, and extend an existing list with them. That is, if `--names` is an `"extend"` option of type `"string"`, the command line

```
--names=foo,bar --names blah --names ding,dong
```

would result in a list

```
["foo", "bar", "blah", "ding", "dong"]
```

Again we define a subclass of Option:

```
class MyOption(Option):

    ACTIONS = Option.ACTIONS + ("extend",)
    STORE_ACTIONS = Option.STORE_ACTIONS + ("extend",)
    TYPED_ACTIONS = Option.TYPED_ACTIONS + ("extend",)
    ALWAYS_TYPED_ACTIONS = Option.ALWAYS_TYPED_ACTIONS + ("extend",)

    def take_action(self, action, dest, opt, value, values, parser):
        if action == "extend":
            lvalue = value.split(",")
            values.ensure_value(dest, []).extend(lvalue)
        else:
            Option.take_action(
                self, action, dest, opt, value, values, parser)
```

Features of note:

- `"extend"` both expects a value on the command-line and stores that value somewhere, so it goes in both *STORE_ACTIONS* and *TYPED_ACTIONS*.
- to ensure that *optparse* assigns the default type of `"string"` to `"extend"` actions, we put the `"extend"` action in *ALWAYS_TYPED_ACTIONS* as well.
- `MyOption.take_action()` implements just this one new action, and passes control back to `Option.take_action()` for the standard *optparse* actions.
- `values` is an instance of the optparse_parser.Values class, which provides the very useful `ensure_value()` method. `ensure_value()` is essentially *getattr()* with a safety valve; it is called as

  ```
  values.ensure_value(attr, value)
  ```

  If the `attr` attribute of `values` doesn't exist or is `None`, then ensure_value() first sets it to `value`, and then returns 'value. This is very handy for actions like `"extend"`, `"append"`, and `"count"`, all of which accumulate data in a variable and expect that variable to be of a certain type (a list for the first two, an integer for the latter). Using `ensure_value()` means that scripts using your action don't have to worry about setting a default value for the option destinations in question; they can just leave the default as `None` and `ensure_value()` will take care of getting it right when it's needed.

37.2 imp — Access the import internals

Source code: Lib/imp.py

Deprecated since version 3.4: The *imp* package is pending deprecation in favor of *importlib*.

This module provides an interface to the mechanisms used to implement the `import` statement. It defines the following constants and functions:

`imp.get_magic()`
: Return the magic string value used to recognize byte-compiled code files (`.pyc` files). (This value may be different for each Python version.)

  Deprecated since version 3.4: Use *importlib.util.MAGIC_NUMBER* instead.

imp.**get_suffixes**()
Return a list of 3-element tuples, each describing a particular type of module. Each triple has the form `(suffix, mode, type)`, where *suffix* is a string to be appended to the module name to form the filename to search for, *mode* is the mode string to pass to the built-in *open()* function to open the file (this can be `'r'` for text files or `'rb'` for binary files), and *type* is the file type, which has one of the values *PY_SOURCE*, *PY_COMPILED*, or *C_EXTENSION*, described below.

Deprecated since version 3.3: Use the constants defined on *importlib.machinery* instead.

imp.**find_module**(*name*[, *path*])
Try to find the module *name*. If *path* is omitted or `None`, the list of directory names given by `sys.path` is searched, but first a few special places are searched: the function tries to find a built-in module with the given name (*C_BUILTIN*), then a frozen module (*PY_FROZEN*), and on some systems some other places are looked in as well (on Windows, it looks in the registry which may point to a specific file).

Otherwise, *path* must be a list of directory names; each directory is searched for files with any of the suffixes returned by *get_suffixes()* above. Invalid names in the list are silently ignored (but all list items must be strings).

If search is successful, the return value is a 3-element tuple `(file, pathname, description)`:

file is an open *file object* positioned at the beginning, *pathname* is the pathname of the file found, and *description* is a 3-element tuple as contained in the list returned by *get_suffixes()* describing the kind of module found.

If the module does not live in a file, the returned *file* is `None`, *pathname* is the empty string, and the *description* tuple contains empty strings for its suffix and mode; the module type is indicated as given in parentheses above. If the search is unsuccessful, *ImportError* is raised. Other exceptions indicate problems with the arguments or environment.

If the module is a package, *file* is `None`, *pathname* is the package path and the last item in the *description* tuple is *PKG_DIRECTORY*.

This function does not handle hierarchical module names (names containing dots). In order to find *P.M*, that is, submodule *M* of package *P*, use *find_module()* and *load_module()* to find and load package *P*, and then use *find_module()* with the *path* argument set to `P.__path__`. When *P* itself has a dotted name, apply this recipe recursively.

Deprecated since version 3.3: Use *importlib.util.find_spec()* instead unless Python 3.3 compatibility is required, in which case use *importlib.find_loader()*. For example usage of the former case, see the *Examples* section of the *importlib* documentation.

imp.**load_module**(*name*, *file*, *pathname*, *description*)
Load a module that was previously found by *find_module()* (or by an otherwise conducted search yielding compatible results). This function does more than importing the module: if the module was already imported, it will reload the module! The *name* argument indicates the full module name (including the package name, if this is a submodule of a package). The *file* argument is an open file, and *pathname* is the corresponding file name; these can be `None` and `''`, respectively, when the module is a package or not being loaded from a file. The *description* argument is a tuple, as would be returned by *get_suffixes()*, describing what kind of module must be loaded.

If the load is successful, the return value is the module object; otherwise, an exception (usually *ImportError*) is raised.

Important: the caller is responsible for closing the *file* argument, if it was not `None`, even when an exception is raised. This is best done using a `try` … `finally` statement.

Deprecated since version 3.3: If previously used in conjunction with *imp.find_module()* then consider using *importlib.import_module()*, otherwise use the loader returned by the replacement you chose for *imp.find_module()*. If you called *imp.load_module()* and related functions directly with file path

arguments then use a combination of *importlib.util.spec_from_file_location()* and *importlib.util.module_from_spec()*. See the *Examples* section of the *importlib* documentation for details of the various approaches.

imp.**new_module**(*name*)
Return a new empty module object called *name*. This object is *not* inserted in `sys.modules`.

Deprecated since version 3.4: Use *importlib.util.module_from_spec()* instead.

imp.**reload**(*module*)
Reload a previously imported *module*. The argument must be a module object, so it must have been successfully imported before. This is useful if you have edited the module source file using an external editor and want to try out the new version without leaving the Python interpreter. The return value is the module object (the same as the *module* argument).

When `reload(module)` is executed:

- Python modules' code is recompiled and the module-level code reexecuted, defining a new set of objects which are bound to names in the module's dictionary. The `init` function of extension modules is not called a second time.
- As with all other objects in Python the old objects are only reclaimed after their reference counts drop to zero.
- The names in the module namespace are updated to point to any new or changed objects.
- Other references to the old objects (such as names external to the module) are not rebound to refer to the new objects and must be updated in each namespace where they occur if that is desired.

There are a number of other caveats:

When a module is reloaded, its dictionary (containing the module's global variables) is retained. Redefinitions of names will override the old definitions, so this is generally not a problem. If the new version of a module does not define a name that was defined by the old version, the old definition remains. This feature can be used to the module's advantage if it maintains a global table or cache of objects — with a `try` statement it can test for the table's presence and skip its initialization if desired:

```
try:
    cache
except NameError:
    cache = {}
```

It is legal though generally not very useful to reload built-in or dynamically loaded modules, except for *sys*, *__main__* and *builtins*. In many cases, however, extension modules are not designed to be initialized more than once, and may fail in arbitrary ways when reloaded.

If a module imports objects from another module using `from` … `import` …, calling *reload()* for the other module does not redefine the objects imported from it — one way around this is to re-execute the `from` statement, another is to use `import` and qualified names (*module*.*name*) instead.

If a module instantiates instances of a class, reloading the module that defines the class does not affect the method definitions of the instances — they continue to use the old class definition. The same is true for derived classes.

Changed in version 3.3: Relies on both `__name__` and `__loader__` being defined on the module being reloaded instead of just `__name__`.

Deprecated since version 3.4: Use *importlib.reload()* instead.

The following functions are conveniences for handling **PEP 3147** byte-compiled file paths.

New in version 3.2.

imp.cache_from_source(*path*, *debug_override=None*)
: Return the **PEP 3147** path to the byte-compiled file associated with the source *path*. For example, if *path* is `/foo/bar/baz.py` the return value would be `/foo/bar/__pycache__/baz.cpython-32.pyc` for Python 3.2. The `cpython-32` string comes from the current magic tag (see *get_tag()*; if `sys.implementation.cache_tag` is not defined then *NotImplementedError* will be raised). By passing in `True` or `False` for *debug_override* you can override the system's value for `__debug__`, leading to optimized bytecode.

  path need not exist.

  Changed in version 3.3: If `sys.implementation.cache_tag` is `None`, then *NotImplementedError* is raised.

  Deprecated since version 3.4: Use *importlib.util.cache_from_source()* instead.

  Changed in version 3.5: The *debug_override* parameter no longer creates a `.pyo` file.

imp.source_from_cache(*path*)
: Given the *path* to a **PEP 3147** file name, return the associated source code file path. For example, if *path* is `/foo/bar/__pycache__/baz.cpython-32.pyc` the returned path would be `/foo/bar/baz.py`. *path* need not exist, however if it does not conform to **PEP 3147** format, a `ValueError` is raised. If `sys.implementation.cache_tag` is not defined, *NotImplementedError* is raised.

  Changed in version 3.3: Raise *NotImplementedError* when `sys.implementation.cache_tag` is not defined.

  Deprecated since version 3.4: Use *importlib.util.source_from_cache()* instead.

imp.get_tag()
: Return the **PEP 3147** magic tag string matching this version of Python's magic number, as returned by *get_magic()*.

  Deprecated since version 3.4: Use `sys.implementation.cache_tag` directly starting in Python 3.3.

The following functions help interact with the import system's internal locking mechanism. Locking semantics of imports are an implementation detail which may vary from release to release. However, Python ensures that circular imports work without any deadlocks.

imp.lock_held()
: Return `True` if the global import lock is currently held, else `False`. On platforms without threads, always return `False`.

  On platforms with threads, a thread executing an import first holds a global import lock, then sets up a per-module lock for the rest of the import. This blocks other threads from importing the same module until the original import completes, preventing other threads from seeing incomplete module objects constructed by the original thread. An exception is made for circular imports, which by construction have to expose an incomplete module object at some point.

  Changed in version 3.3: The locking scheme has changed to per-module locks for the most part. A global import lock is kept for some critical tasks, such as initializing the per-module locks.

  Deprecated since version 3.4.

imp.acquire_lock()
: Acquire the interpreter's global import lock for the current thread. This lock should be used by import hooks to ensure thread-safety when importing modules.

  Once a thread has acquired the import lock, the same thread may acquire it again without blocking; the thread must release it once for each time it has acquired it.

  On platforms without threads, this function does nothing.

  Changed in version 3.3: The locking scheme has changed to per-module locks for the most part. A global import lock is kept for some critical tasks, such as initializing the per-module locks.

Deprecated since version 3.4.

imp.release_lock()
Release the interpreter's global import lock. On platforms without threads, this function does nothing.

Changed in version 3.3: The locking scheme has changed to per-module locks for the most part. A global import lock is kept for some critical tasks, such as initializing the per-module locks.

Deprecated since version 3.4.

The following constants with integer values, defined in this module, are used to indicate the search result of *find_module()*.

imp.PY_SOURCE
The module was found as a source file.

Deprecated since version 3.3.

imp.PY_COMPILED
The module was found as a compiled code object file.

Deprecated since version 3.3.

imp.C_EXTENSION
The module was found as dynamically loadable shared library.

Deprecated since version 3.3.

imp.PKG_DIRECTORY
The module was found as a package directory.

Deprecated since version 3.3.

imp.C_BUILTIN
The module was found as a built-in module.

Deprecated since version 3.3.

imp.PY_FROZEN
The module was found as a frozen module.

Deprecated since version 3.3.

class imp.NullImporter(*path_string*)
The *NullImporter* type is a **PEP 302** import hook that handles non-directory path strings by failing to find any modules. Calling this type with an existing directory or empty string raises *ImportError*. Otherwise, a *NullImporter* instance is returned.

Instances have only one method:

find_module(*fullname*[, *path*])
This method always returns None, indicating that the requested module could not be found.

Changed in version 3.3: None is inserted into sys.path_importer_cache instead of an instance of *NullImporter*.

Deprecated since version 3.4: Insert None into sys.path_importer_cache instead.

37.2.1 Examples

The following function emulates what was the standard import statement up to Python 1.4 (no hierarchical module names). (This *implementation* wouldn't work in that version, since *find_module()* has been extended and *load_module()* has been added in 1.4.)

```
import imp
import sys

def __import__(name, globals=None, locals=None, fromlist=None):
    # Fast path: see if the module has already been imported.
    try:
        return sys.modules[name]
    except KeyError:
        pass

    # If any of the following calls raises an exception,
    # there's a problem we can't handle -- let the caller handle it.

    fp, pathname, description = imp.find_module(name)

    try:
        return imp.load_module(name, fp, pathname, description)
    finally:
        # Since we may exit via an exception, close fp explicitly.
        if fp:
            fp.close()
```

CHAPTER

THIRTYEIGHT

UNDOCUMENTED MODULES

Here's a quick listing of modules that are currently undocumented, but that should be documented. Feel free to contribute documentation for them! (Send via email to docs@python.org.)

The idea and original contents for this chapter were taken from a posting by Fredrik Lundh; the specific contents of this chapter have been substantially revised.

38.1 Platform specific modules

These modules are used to implement the *os.path* module, and are not documented beyond this mention. There's little need to document these.

ntpath — Implementation of *os.path* on Win32 and Win64 platforms.

posixpath — Implementation of *os.path* on POSIX.

APPENDIX

A

GLOSSARY

>>> The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

... The default Python prompt of the interactive shell when entering code for an indented code block, when within a pair of matching left and right delimiters (parentheses, square brackets, curly braces or triple quotes), or after specifying a decorator.

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as *lib2to3*; a standalone entry point is provided as `Tools/scripts/2to3`. See *2to3 - Automated Python 2 to 3 code translation*.

abstract base class Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like *hasattr()* would be clumsy or subtly wrong (for example with magic methods). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by *isinstance()* and *issubclass()*; see the *abc* module documentation. Python comes with many built-in ABCs for data structures (in the *collections.abc* module), numbers (in the *numbers* module), streams (in the *io* module), import finders and loaders (in the *importlib.abc* module). You can create your own ABCs with the *abc* module.

annotation A label associated with a variable, a class attribute or a function parameter or return value, used by convention as a *type hint*.

Annotations of local variables cannot be accessed at runtime, but annotations of global variables, class attributes, and functions are stored in the `__annotations__` special attribute of modules, classes, and functions, respectively.

See *variable annotation*, *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

argument A value passed to a *function* (or *method*) when calling the function. There are two kinds of argument:

- *keyword argument*: an argument preceded by an identifier (e.g. `name=`) in a function call or passed as a value in a dictionary preceded by `**`. For example, `3` and `5` are both keyword arguments in the following calls to *complex()*:

```
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- *positional argument*: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an *iterable* preceded by `*`. For example, `3` and `5` are both positional arguments in the following calls:

```
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the calls section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the *parameter* glossary entry, the FAQ question on the difference between arguments and parameters, and **PEP 362**.

asynchronous context manager An object which controls the environment seen in an `async with` statement by defining `__aenter__()` and `__aexit__()` methods. Introduced by **PEP 492**.

asynchronous generator A function which returns an *asynchronous generator iterator*. It looks like a coroutine function defined with `async def` except that it contains `yield` expressions for producing a series of values usable in an `async for` loop.

Usually refers to a asynchronous generator function, but may refer to an *asynchronous generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

An asynchronous generator function may contain `await` expressions as well as `async for`, and `async with` statements.

asynchronous generator iterator An object created by a *asynchronous generator* function.

This is an *asynchronous iterator* which when called using the `__anext__()` method returns an awaitable object which will execute that the body of the asynchronous generator function until the next `yield` expression.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *asynchronous generator iterator* effectively resumes with another awaitable returned by `__anext__()`, it picks up where it left off. See **PEP 492** and **PEP 525**.

asynchronous iterable An object, that can be used in an `async for` statement. Must return an *asynchronous iterator* from its `__aiter__()` method. Introduced by **PEP 492**.

asynchronous iterator An object that implements `__aiter__()` and `__anext__()` methods. `__anext__` must return an *awaitable* object. `async for` resolves awaitable returned from asynchronous iterator's `__anext__()` method until it raises *`StopAsyncIteration`* exception. Introduced by **PEP 492**.

attribute A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

awaitable An object that can be used in an `await` expression. Can be a *coroutine* or an object with an `__await__()` method. See also **PEP 492**.

BDFL Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

binary file A *file object* able to read and write *bytes-like objects*. Examples of binary files are files opened in binary mode (`'rb'`, `'wb'` or `'rb+'`), `sys.stdin.buffer`, `sys.stdout.buffer`, and instances of *`io.BytesIO`* and *`gzip.GzipFile`*.

See also *text file* for a file object able to read and write *`str`* objects.

bytes-like object An object that supports the bufferobjects and can export a C-*contiguous* buffer. This includes all *`bytes`*, *`bytearray`*, and *`array.array`* objects, as well as many common *`memoryview`* objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as "read-write bytes-like objects". Example mutable buffer objects include *`bytearray`* and a *`memoryview`* of a *`bytearray`*. Other operations require the binary data to be stored in immutable objects ("read-only bytes-like objects"); examples of these include *`bytes`* and a *`memoryview`* of a *`bytes`* object.

bytecode Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for *the dis module*.

class A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

class variable A variable defined in a class and intended to be modified only at class level (i.e., not in an instance of the class).

coercion The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer `3`, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

complex number An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of `-1`), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the *math* module, use *cmath*. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

context manager An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See **PEP 343**.

contiguous A buffer is considered contiguous exactly if it is either *C-contiguous* or *Fortran contiguous*. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be laid out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

coroutine Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the `async def` statement. See also **PEP 492**.

coroutine function A function which returns a *coroutine* object. A coroutine function may be defined with the `async def` statement, and may contain `await`, `async for`, and `async with` keywords. These were introduced by **PEP 492**.

CPython The canonical implementation of the Python programming language, as distributed on python.org. The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

decorator A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are *classmethod()* and *staticmethod()*.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)
```

(continues on next page)

(continued from previous page)

```
@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for function definitions and class definitions for more about decorators.

descriptor Any object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using *a.b* to get, set or delete an attribute looks up the object named *b* in the class dictionary for *a*, but if *b* is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see descriptors.

dictionary An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

dictionary view The objects returned from *dict.keys()*, *dict.values()*, and *dict.items()* are called dictionary views. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use `list(dictview)`. See *Dictionary view objects*.

docstring A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

duck-typing A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using *type()* or *isinstance()*. (Note, however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs *hasattr()* tests or *EAFP* programming.

EAFP Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

expression A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statement*s which cannot be used as expressions, such as `if`. Assignments are also statements, not expressions.

extension module A module written in C or C++, using Python's C API to interact with the core and with user code.

f-string String literals prefixed with `'f'` or `'F'` are commonly called "f-strings" which is short for formatted string literals. See also **PEP 498**.

file object An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw *binary files*, buffered *binary files* and *text files*. Their interfaces are defined in the *io* module. The canonical way to create a file object is by using the

open() function.

file-like object A synonym for *file object*.

finder An object that tries to find the *loader* for a module that is being imported.

Since Python 3.3, there are two types of finder: *meta path finders* for use with *sys.meta_path*, and *path entry finders* for use with *sys.path_hooks*.

See **PEP 302**, **PEP 420** and **PEP 451** for much more detail.

floor division Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See **PEP 238**.

function A series of statements which returns some value to a caller. It can also be passed zero or more *arguments* which may be used in the execution of the body. See also *parameter*, *method*, and the function section.

function annotation An *annotation* of a function parameter or return value.

Function annotations are usually used for *type hints*: for example this function is expected to take two *int* arguments and is also expected to have an *int* return value:

```
def sum_two_numbers(a: int, b: int) -> int:
   return a + b
```

Function annotation syntax is explained in section function.

See *variable annotation* and **PEP 484**, which describe this functionality.

___future___ A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the *__future__* module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

garbage collection The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles. The garbage collector can be controlled using the *gc* module.

generator A function which returns a *generator iterator*. It looks like a normal function except that it contains `yield` expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the *next()* function.

Usually refers to a generator function, but may refer to a *generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

generator iterator An object created by a *generator* function.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *generator iterator* resumes, it picks up where it left off (in contrast to functions which start fresh on every invocation).

generator expression An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))         # sum of squares 0, 1, 4, ... 81
285
```

generic function A function composed of multiple functions implementing the same operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the *single dispatch* glossary entry, the *functools.singledispatch()* decorator, and **PEP 443**.

GIL See *global interpreter lock*.

global interpreter lock The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as *dict*) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a "free-threaded" interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

hash-based pyc A bytecode cache file that uses the hash rather than the last-modified time of the corresponding source file to determine its validity. See pyc-invalidation.

hashable An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python's immutable built-in objects are hashable; mutable containers (such as lists or dictionaries) are not. Objects which are instances of user-defined classes are hashable by default. They all compare unequal (except with themselves), and their hash value is derived from their *id()*.

IDLE An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

immutable An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

import path A list of locations (or *path entries*) that are searched by the *path based finder* for modules to import. During import, this list of locations usually comes from *sys.path*, but for subpackages it may also come from the parent package's `__path__` attribute.

importing The process by which Python code in one module is made available to Python code in another module.

importer An object that both finds and loads a module; both a *finder* and *loader* object.

interactive Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer's main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

interpreted Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically

have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the *garbage collector*. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the `__main__` module or the script being run has finished executing.

iterable An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as *list*, *str*, and *tuple*) and some non-sequence types like *dict*, *file objects*, and objects of any classes you define with an `__iter__()` method or with a `__getitem__()` method that implements *Sequence* semantics.

Iterables can be used in a `for` loop and in many other places where a sequence is needed (*zip()*, *map()*, ...). When an iterable object is passed as an argument to the built-in function *iter()*, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call *iter()* or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

iterator An object representing a stream of data. Repeated calls to the iterator's *__next__()* method (or passing it to the built-in function *next()*) return successive items in the stream. When no more data are available a *StopIteration* exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `__next__()` method just raise *StopIteration* again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a *list*) produces a fresh new iterator each time you pass it to the *iter()* function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in *Iterator Types*.

key function A key function or collation function is a callable that returns a value used for sorting or ordering. For example, *locale.strxfrm()* is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include *min()*, *max()*, *sorted()*, *list.sort()*, *heapq.merge()*, *heapq.nsmallest()*, *heapq.nlargest()*, and *itertools.groupby()*.

There are several ways to create a key function. For example. the *str.lower()* method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the *operator* module provides three key function constructors: *attrgetter()*, *itemgetter()*, and *methodcaller()*. See the Sorting HOW TO for examples of how to create and use key functions.

keyword argument See *argument*.

lambda An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [parameters]: expression`

LBYL Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between "the looking" and "the leaping". For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

list A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements is O(1).

list comprehension A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ['{:#04x}'.format(x) for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

loader An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details and *importlib.abc.Loader* for an *abstract base class*.

mapping A container object that supports arbitrary key lookups and implements the methods specified in the *Mapping* or *MutableMapping* *abstract base classes*. Examples include *dict*, *collections.defaultdict*, *collections.OrderedDict* and *collections.Counter*.

meta path finder A *finder* returned by a search of *sys.meta_path*. Meta path finders are related to, but different from *path entry finders*.

See *importlib.abc.MetaPathFinder* for the methods that meta path finders implement.

metaclass The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in metaclasses.

method A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

method resolution order Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order for details of the algorithm used by the Python interpreter since the 2.3 release.

module An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects. Modules are loaded into Python by the process of *importing*.

See also *package*.

module spec A namespace containing the import-related information used to load a module. An instance of *importlib.machinery.ModuleSpec*.

MRO See *method resolution order*.

mutable Mutable objects can change their value but keep their *id()*. See also *immutable*.

named tuple Any tuple-like class whose indexable elements are also accessible using named attributes (for example, *time.localtime()* returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as *time.struct_time*, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function *collections.namedtuple()*. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

namespace The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions *builtins.open* and *os.open()* are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing *random.seed()* or *itertools.islice()* makes it clear that those functions are implemented by the *random* and *itertools* modules, respectively.

namespace package A **PEP 420** *package* which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a *regular package* because they have no `__init__.py` file.

See also *module*.

nested scope The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The `nonlocal` allows writing to outer scopes.

new-style class Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python's newer, versatile features like `__slots__`, descriptors, properties, `__getattribute__()`, class methods, and static methods.

object Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

package A Python *module* which can contain submodules or recursively, subpackages. Technically, a package is a Python module with an `__path__` attribute.

See also *regular package* and *namespace package*.

parameter A named entity in a *function* (or method) definition that specifies an *argument* (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- *positional-or-keyword*: specifies an argument that can be passed either *positionally* or as a *keyword argument*. This is the default kind of parameter, for example *foo* and *bar* in the following:

```
def func(foo, bar=None): ...
```

- *positional-only*: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. *abs()*).

- *keyword-only*: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare `*` in the parameter list of the function definition before them, for example *kw_only1* and *kw_only2* in the following:

```
def func(arg, *, kw_only1, kw_only2): ...
```

- *var-positional*: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `*`, for example *args* in the following:

```
def func(*args, **kwargs): ...
```

- *var-keyword*: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `**`, for example *kwargs* in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the *argument* glossary entry, the FAQ question on the difference between arguments and parameters, the *inspect.Parameter* class, the function section, and **PEP 362**.

path entry A single location on the *import path* which the *path based finder* consults to find modules for importing.

path entry finder A *finder* returned by a callable on *sys.path_hooks* (i.e. a *path entry hook*) which knows how to locate modules given a *path entry*.

See *importlib.abc.PathEntryFinder* for the methods that path entry finders implement.

path entry hook A callable on the `sys.path_hook` list which returns a *path entry finder* if it knows how to find modules on a specific *path entry*.

path based finder One of the default *meta path finders* which searches an *import path* for modules.

path-like object An object representing a file system path. A path-like object is either a *str* or *bytes* object representing a path, or an object implementing the *os.PathLike* protocol. An object that supports the *os.PathLike* protocol can be converted to a *str* or *bytes* file system path by calling the *os.fspath()* function; *os.fsdecode()* and *os.fsencode()* can be used to guarantee a *str* or *bytes* result instead, respectively. Introduced by **PEP 519**.

PEP Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python or its processes or environment. PEPs should provide a concise technical specification and a rationale for proposed features.

PEPs are intended to be the primary mechanisms for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible for building consensus within the community and documenting dissenting opinions.

See **PEP 1**.

portion A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in **PEP 420**.

positional argument See *argument*.

provisional API A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a "solution of last resort" - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See **PEP 411** for more details.

provisional package See *provisional API*.

Python 3000 Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

Pythonic An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print(piece)
```

qualified name A dotted name showing the "path" from a module's global scope to a class, function or method defined in that module, as defined in **PEP 3155**. For top-level functions and classes, the qualified name is the same as the object's name:

```
>>> class C:
...     class D:
...         def meth(self):
...             pass
...
>>> C.__qualname__
'C'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```

When used to refer to modules, the *fully qualified name* means the entire dotted path to the module, including any parent packages, e.g. `email.mime.text`:

```
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

reference count The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The *sys* module defines a *getrefcount()* function that programmers can call to return the reference count for a particular object.

regular package A traditional *package*, such as a directory containing an `__init__.py` file.

See also *namespace package*.

___slots___ A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

sequence An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `__len__()` method that returns the length of the sequence. Some built-in sequence types are *list*, *str*, *tuple*, and *bytes*. Note that *dict* also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

The *collections.abc.Sequence* abstract base class defines a much richer interface that goes beyond just `__getitem__()` and `__len__()`, adding `count()`, `index()`, `__contains__()`, and `__reversed__()`. Types that implement this expanded interface can be registered explicitly using `register()`.

single dispatch A form of *generic function* dispatch where the implementation is chosen based on the type of a single argument.

slice An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses *slice* objects internally.

special method A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in specialnames.

statement A statement is part of a suite (a "block" of code). A statement is either an *expression* or one of several constructs with a keyword, such as `if`, `while` or `for`.

struct sequence A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like *`_make()`* or *`_asdict()`*. Examples of struct sequences include *`sys.float_info`* and the return value of *`os.stat()`*.

text encoding A codec which encodes Unicode strings to bytes.

text file A *file object* able to read and write *`str`* objects. Often, a text file actually accesses a byte-oriented datastream and handles the *text encoding* automatically. Examples of text files are files opened in text mode (`'r'` or `'w'`), *`sys.stdin`*, *`sys.stdout`*, and instances of *`io.StringIO`*.

See also *binary file* for a file object able to read and write *bytes-like objects*.

triple-quoted string A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

type The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its *`__class__`* attribute or can be retrieved with `type(obj)`.

type alias A synonym for a type, created by assigning the type to an identifier.

Type aliases are useful for simplifying *type hints*. For example:

```
from typing import List, Tuple

def remove_gray_shades(
        colors: List[Tuple[int, int, int]]) -> List[Tuple[int, int, int]]:
    pass
```

could be made more readable like this:

```
from typing import List, Tuple

Color = Tuple[int, int, int]

def remove_gray_shades(colors: List[Color]) -> List[Color]:
    pass
```

See *`typing`* and **PEP 484**, which describe this functionality.

type hint An *annotation* that specifies the expected type for a variable, a class attribute, or a function parameter or return value.

Type hints are optional and are not enforced by Python but they are useful to static type analysis tools, and aid IDEs with code completion and refactoring.

Type hints of global variables, class attributes, and functions, but not local variables, can be accessed using *`typing.get_type_hints()`*.

See *`typing`* and **PEP 484**, which describe this functionality.

universal newlines A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old

Macintosh convention `'\r'`. See **PEP 278** and **PEP 3116**, as well as *bytes.splitlines()* for an additional use.

variable annotation An *annotation* of a variable or a class attribute.

When annotating a variable or a class attribute, assignment is optional:

```
class C:
    field: 'annotation'
```

Variable annotations are usually used for *type hints*: for example this variable is expected to take *int* values:

```
count: int = 0
```

Variable annotation syntax is explained in section annassign.

See *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

virtual environment A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also *venv*.

virtual machine A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

Zen of Python Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing "`import this`" at the interactive prompt.

BIBLIOGRAPHY

[Frie09] Friedl, Jeffrey. Mastering Regular Expressions. 3rd ed., O'Reilly Media, 2009. The third edition of the book no longer covers Python at all, but the first edition covered writing good regular expression patterns in great detail.

[C99] ISO/IEC 9899:1999. "Programming languages – C." A public draft of this standard is available at http://www.open-std.org/jtc1/sc22/wg14/www/docs/n1256.pdf.

APPENDIX

B

ABOUT THESE DOCUMENTS

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the reporting-bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the Docutils project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.

B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See Misc/ACKS in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!

APPENDIX

C

HISTORY AND LICENSE

C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see https://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see https://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

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2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2 and above	2.1.1	2001-now	PSF	yes

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C.3.1 Mersenne Twister

The `_random` module includes code based on a download from http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/MT2002/emt19937ar.html. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.

Before using, initialize the state by using init_genrand(seed)
or init_by_array(init_key, key_length).

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C.3.2 Sockets

The *socket* module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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C.3.10 SipHash24

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Original location:
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Solution inspired by code from:
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   djb (supercop/crypto_auth/siphash24/little2)
   Jean-Philippe Aumasson (https://131002.net/siphash/siphash24.c)
```

C.3.11 strtod and dtoa

The file `Python/dtoa.c`, which supplies C functions dtoa and strtod for conversion of C doubles to and from strings, is derived from the file of the same name by David M. Gay, currently available from http://www.netlib.org/fp/. The original file, as retrieved on March 16, 2009, contains the following copyright and licensing notice:

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C.3.12 OpenSSL

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Installing Python Modules

Release 3.7.0

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and the Python development team

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Email distutils-sig@python.org

As a popular open source development project, Python has an active supporting community of contributors and users that also make their software available for other Python developers to use under open source license terms.

This allows Python users to share and collaborate effectively, benefiting from the solutions others have already created to common (and sometimes even rare!) problems, as well as potentially contributing their own solutions to the common pool.

This guide covers the installation part of the process. For a guide to creating and sharing your own Python projects, refer to the distribution guide.

Note: For corporate and other institutional users, be aware that many organisations have their own policies around using and contributing to open source software. Please take such policies into account when making use of the distribution and installation tools provided with Python.

CHAPTER

ONE

KEY TERMS

- `pip` is the preferred installer program. Starting with Python 3.4, it is included by default with the Python binary installers.
- A *virtual environment* is a semi-isolated Python environment that allows packages to be installed for use by a particular application, rather than being installed system wide.
- `venv` is the standard tool for creating virtual environments, and has been part of Python since Python 3.3. Starting with Python 3.4, it defaults to installing `pip` into all created virtual environments.
- `virtualenv` is a third party alternative (and predecessor) to `venv`. It allows virtual environments to be used on versions of Python prior to 3.4, which either don't provide `venv` at all, or aren't able to automatically install `pip` into created environments.
- The Python Packaging Index is a public repository of open source licensed packages made available for use by other Python users.
- the Python Packaging Authority are the group of developers and documentation authors responsible for the maintenance and evolution of the standard packaging tools and the associated metadata and file format standards. They maintain a variety of tools, documentation, and issue trackers on both GitHub and BitBucket.
- `distutils` is the original build and distribution system first added to the Python standard library in 1998. While direct use of `distutils` is being phased out, it still laid the foundation for the current packaging and distribution infrastructure, and it not only remains part of the standard library, but its name lives on in other ways (such as the name of the mailing list used to coordinate Python packaging standards development).

Deprecated since version 3.6: `pyvenv` was the recommended tool for creating virtual environments for Python 3.3 and 3.4, and is deprecated in Python 3.6.

Changed in version 3.5: The use of `venv` is now recommended for creating virtual environments.

See also:

Python Packaging User Guide: Creating and using virtual environments

CHAPTER

TWO

BASIC USAGE

The standard packaging tools are all designed to be used from the command line.

The following command will install the latest version of a module and its dependencies from the Python Packaging Index:

```
python -m pip install SomePackage
```

Note: For POSIX users (including Mac OS X and Linux users), the examples in this guide assume the use of a *virtual environment*.

For Windows users, the examples in this guide assume that the option to adjust the system PATH environment variable was selected when installing Python.

It's also possible to specify an exact or minimum version directly on the command line. When using comparator operators such as `>`, `<` or some other special character which get interpreted by shell, the package name and the version should be enclosed within double quotes:

```
python -m pip install SomePackage==1.0.4    # specific version
python -m pip install "SomePackage>=1.0.4"  # minimum version
```

Normally, if a suitable module is already installed, attempting to install it again will have no effect. Upgrading existing modules must be requested explicitly:

```
python -m pip install --upgrade SomePackage
```

More information and resources regarding `pip` and its capabilities can be found in the Python Packaging User Guide.

Creation of virtual environments is done through the `venv` module. Installing packages into an active virtual environment uses the commands shown above.

See also:

Python Packaging User Guide: Installing Python Distribution Packages

CHAPTER

THREE

HOW DO I ...?

These are quick answers or links for some common tasks.

3.1 ... install `pip` in versions of Python prior to Python 3.4?

Python only started bundling `pip` with Python 3.4. For earlier versions, `pip` needs to be "bootstrapped" as described in the Python Packaging User Guide.

See also:

Python Packaging User Guide: Requirements for Installing Packages

3.2 ... install packages just for the current user?

Passing the `--user` option to `python -m pip install` will install a package just for the current user, rather than for all users of the system.

3.3 ... install scientific Python packages?

A number of scientific Python packages have complex binary dependencies, and aren't currently easy to install using `pip` directly. At this point in time, it will often be easier for users to install these packages by other means rather than attempting to install them with `pip`.

See also:

Python Packaging User Guide: Installing Scientific Packages

3.4 ... work with multiple versions of Python installed in parallel?

On Linux, Mac OS X, and other POSIX systems, use the versioned Python commands in combination with the `-m` switch to run the appropriate copy of `pip`:

```
python2   -m pip install SomePackage  # default Python 2
python2.7 -m pip install SomePackage  # specifically Python 2.7
python3   -m pip install SomePackage  # default Python 3
python3.4 -m pip install SomePackage  # specifically Python 3.4
```

Appropriately versioned `pip` commands may also be available.

On Windows, use the `py` Python launcher in combination with the `-m` switch:

```
py -2   -m pip install SomePackage  # default Python 2
py -2.7 -m pip install SomePackage  # specifically Python 2.7
py -3   -m pip install SomePackage  # default Python 3
py -3.4 -m pip install SomePackage  # specifically Python 3.4
```

CHAPTER

FOUR

COMMON INSTALLATION ISSUES

4.1 Installing into the system Python on Linux

On Linux systems, a Python installation will typically be included as part of the distribution. Installing into this Python installation requires root access to the system, and may interfere with the operation of the system package manager and other components of the system if a component is unexpectedly upgraded using `pip`.

On such systems, it is often better to use a virtual environment or a per-user installation when installing packages with `pip`.

4.2 Pip not installed

It is possible that `pip` does not get installed by default. One potential fix is:

```
python -m ensurepip --default-pip
```

There are also additional resources for installing pip.

4.3 Installing binary extensions

Python has typically relied heavily on source based distribution, with end users being expected to compile extension modules from source as part of the installation process.

With the introduction of support for the binary `wheel` format, and the ability to publish wheels for at least Windows and Mac OS X through the Python Packaging Index, this problem is expected to diminish over time, as users are more regularly able to install pre-built extensions rather than needing to build them themselves.

Some of the solutions for installing scientific software that are not yet available as pre-built `wheel` files may also help with obtaining other binary extensions without needing to build them locally.

See also:

Python Packaging User Guide: Binary Extensions

APPENDIX

A

GLOSSARY

`>>>` The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

`...` The default Python prompt of the interactive shell when entering code for an indented code block, when within a pair of matching left and right delimiters (parentheses, square brackets, curly braces or triple quotes), or after specifying a decorator.

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See 2to3-reference.

abstract base class Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with magic methods). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections.abc` module), numbers (in the `numbers` module), streams (in the `io` module), import finders and loaders (in the `importlib.abc` module). You can create your own ABCs with the `abc` module.

annotation A label associated with a variable, a class attribute or a function parameter or return value, used by convention as a *type hint*.

Annotations of local variables cannot be accessed at runtime, but annotations of global variables, class attributes, and functions are stored in the `__annotations__` special attribute of modules, classes, and functions, respectively.

See *variable annotation*, *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

argument A value passed to a *function* (or *method*) when calling the function. There are two kinds of argument:

- *keyword argument*: an argument preceded by an identifier (e.g. `name=`) in a function call or passed as a value in a dictionary preceded by `**`. For example, `3` and `5` are both keyword arguments in the following calls to `complex()`:

```
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- *positional argument*: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an *iterable* preceded by `*`. For example, `3` and `5` are both positional arguments in the following calls:

```
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the calls section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the *parameter* glossary entry, the FAQ question on the difference between arguments and parameters, and **PEP 362**.

asynchronous context manager An object which controls the environment seen in an `async with` statement by defining `__aenter__()` and `__aexit__()` methods. Introduced by **PEP 492**.

asynchronous generator A function which returns an *asynchronous generator iterator*. It looks like a coroutine function defined with `async def` except that it contains `yield` expressions for producing a series of values usable in an `async for` loop.

Usually refers to a asynchronous generator function, but may refer to an *asynchronous generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

An asynchronous generator function may contain `await` expressions as well as `async for`, and `async with` statements.

asynchronous generator iterator An object created by a *asynchronous generator* function.

This is an *asynchronous iterator* which when called using the `__anext__()` method returns an awaitable object which will execute that the body of the asynchronous generator function until the next `yield` expression.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *asynchronous generator iterator* effectively resumes with another awaitable returned by `__anext__()`, it picks up where it left off. See **PEP 492** and **PEP 525**.

asynchronous iterable An object, that can be used in an `async for` statement. Must return an *asynchronous iterator* from its `__aiter__()` method. Introduced by **PEP 492**.

asynchronous iterator An object that implements `__aiter__()` and `__anext__()` methods. `__anext__` must return an *awaitable* object. `async for` resolves awaitable returned from asynchronous iterator's `__anext__()` method until it raises `StopAsyncIteration` exception. Introduced by **PEP 492**.

attribute A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

awaitable An object that can be used in an `await` expression. Can be a *coroutine* or an object with an `__await__()` method. See also **PEP 492**.

BDFL Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

binary file A *file object* able to read and write *bytes-like objects*. Examples of binary files are files opened in binary mode (`'rb'`, `'wb'` or `'rb+'`), `sys.stdin.buffer`, `sys.stdout.buffer`, and instances of `io.BytesIO` and `gzip.GzipFile`.

See also *text file* for a file object able to read and write `str` objects.

bytes-like object An object that supports the bufferobjects and can export a C-*contiguous* buffer. This includes all `bytes`, `bytearray`, and `array.array` objects, as well as many common `memoryview` objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as "read-write bytes-like objects". Example mutable buffer objects include `bytearray` and a `memoryview` of a `bytearray`. Other operations require the binary data to be stored in immutable objects ("read-only bytes-like objects"); examples of these include `bytes` and a `memoryview` of a `bytes` object.

bytecode Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for the dis module.

class A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

class variable A variable defined in a class and intended to be modified only at class level (i.e., not in an instance of the class).

coercion The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer `3`, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

complex number An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of `-1`), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

context manager An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See **PEP 343**.

contiguous A buffer is considered contiguous exactly if it is either *C-contiguous* or *Fortran contiguous*. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be laid out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

coroutine Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the `async def` statement. See also **PEP 492**.

coroutine function A function which returns a *coroutine* object. A coroutine function may be defined with the `async def` statement, and may contain `await`, `async for`, and `async with` keywords. These were introduced by **PEP 492**.

CPython The canonical implementation of the Python programming language, as distributed on python.org. The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

decorator A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)
```

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```
@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for function definitions and class definitions for more about decorators.

descriptor Any object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using *a.b* to get, set or delete an attribute looks up the object named *b* in the class dictionary for *a*, but if *b* is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see descriptors.

dictionary An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

dictionary view The objects returned from `dict.keys()`, `dict.values()`, and `dict.items()` are called dictionary views. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use `list(dictview)`. See dict-views.

docstring A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

duck-typing A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note, however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

EAFP Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

expression A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statement*s which cannot be used as expressions, such as `if`. Assignments are also statements, not expressions.

extension module A module written in C or C++, using Python's C API to interact with the core and with user code.

f-string String literals prefixed with `'f'` or `'F'` are commonly called "f-strings" which is short for formatted string literals. See also **PEP 498**.

file object An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw *binary files*, buffered *binary files* and *text files*. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the

`open()` function.

file-like object A synonym for *file object*.

finder An object that tries to find the *loader* for a module that is being imported.

Since Python 3.3, there are two types of finder: *meta path finders* for use with `sys.meta_path`, and *path entry finders* for use with `sys.path_hooks`.

See **PEP 302**, **PEP 420** and **PEP 451** for much more detail.

floor division Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See **PEP 238**.

function A series of statements which returns some value to a caller. It can also be passed zero or more *arguments* which may be used in the execution of the body. See also *parameter*, *method*, and the function section.

function annotation An *annotation* of a function parameter or return value.

Function annotations are usually used for *type hints*: for example this function is expected to take two `int` arguments and is also expected to have an `int` return value:

```
def sum_two_numbers(a: int, b: int) -> int:
   return a + b
```

Function annotation syntax is explained in section function.

See *variable annotation* and **PEP 484**, which describe this functionality.

___future___ A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

garbage collection The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles. The garbage collector can be controlled using the `gc` module.

generator A function which returns a *generator iterator*. It looks like a normal function except that it contains `yield` expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the `next()` function.

Usually refers to a generator function, but may refer to a *generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

generator iterator An object created by a *generator* function.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *generator iterator* resumes, it picks up where it left off (in contrast to functions which start fresh on every invocation).

generator expression An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))         # sum of squares 0, 1, 4, ... 81
285
```

generic function A function composed of multiple functions implementing the same operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the *single dispatch* glossary entry, the `functools.singledispatch()` decorator, and **PEP 443**.

GIL See *global interpreter lock*.

global interpreter lock The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a "free-threaded" interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

hash-based pyc A bytecode cache file that uses the hash rather than the last-modified time of the corresponding source file to determine its validity. See pyc-invalidation.

hashable An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python's immutable built-in objects are hashable; mutable containers (such as lists or dictionaries) are not. Objects which are instances of user-defined classes are hashable by default. They all compare unequal (except with themselves), and their hash value is derived from their `id()`.

IDLE An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

immutable An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

import path A list of locations (or *path entries*) that are searched by the *path based finder* for modules to import. During import, this list of locations usually comes from `sys.path`, but for subpackages it may also come from the parent package's `__path__` attribute.

importing The process by which Python code in one module is made available to Python code in another module.

importer An object that both finds and loads a module; both a *finder* and *loader* object.

interactive Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer's main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

interpreted Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically

have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the *garbage collector*. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the `__main__` module or the script being run has finished executing.

iterable An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict`, *file objects*, and objects of any classes you define with an `__iter__()` method or with a `__getitem__()` method that implements *Sequence* semantics.

Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

iterator An object representing a stream of data. Repeated calls to the iterator's `__next__()` method (or passing it to the built-in function `next()`) return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `__next__()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in typeiter.

key function A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.merge()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example. the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the Sorting HOW TO for examples of how to create and use key functions.

keyword argument See *argument*.

lambda An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [parameters]: expression`

LBYL Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between "the looking" and "the leaping". For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

list A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements is O(1).

list comprehension A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ['{:#04x}'.format(x) for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

loader An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details and `importlib.abc.Loader` for an *abstract base class*.

mapping A container object that supports arbitrary key lookups and implements the methods specified in the `Mapping` or `MutableMapping` abstract base classes. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

meta path finder A *finder* returned by a search of `sys.meta_path`. Meta path finders are related to, but different from *path entry finders*.

See `importlib.abc.MetaPathFinder` for the methods that meta path finders implement.

metaclass The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in metaclasses.

method A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

method resolution order Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order for details of the algorithm used by the Python interpreter since the 2.3 release.

module An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects. Modules are loaded into Python by the process of *importing*.

See also *package*.

module spec A namespace containing the import-related information used to load a module. An instance of `importlib.machinery.ModuleSpec`.

MRO See *method resolution order*.

mutable Mutable objects can change their value but keep their `id()`. See also *immutable*.

named tuple Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

namespace The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `builtins.open` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.islice()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

namespace package A **PEP 420** *package* which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a *regular package* because they have no `__init__.py` file.

See also *module*.

nested scope The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The `nonlocal` allows writing to outer scopes.

new-style class Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python's newer, versatile features like `__slots__`, descriptors, properties, `__getattribute__()`, class methods, and static methods.

object Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

package A Python *module* which can contain submodules or recursively, subpackages. Technically, a package is a Python module with an `__path__` attribute.

See also *regular package* and *namespace package*.

parameter A named entity in a *function* (or method) definition that specifies an *argument* (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- *positional-or-keyword*: specifies an argument that can be passed either *positionally* or as a *keyword argument*. This is the default kind of parameter, for example *foo* and *bar* in the following:

```
def func(foo, bar=None): ...
```

- *positional-only*: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. `abs()`).
- *keyword-only*: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare `*` in the parameter list of the function definition before them, for example *kw_only1* and *kw_only2* in the following:

```
def func(arg, *, kw_only1, kw_only2): ...
```

- *var-positional*: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `*`, for example *args* in the following:

```
def func(*args, **kwargs): ...
```

- *var-keyword*: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `**`, for example *kwargs* in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the *argument* glossary entry, the FAQ question on the difference between arguments and parameters, the `inspect.Parameter` class, the function section, and **PEP 362**.

path entry A single location on the *import path* which the *path based finder* consults to find modules for importing.

path entry finder A *finder* returned by a callable on `sys.path_hooks` (i.e. a *path entry hook*) which knows how to locate modules given a *path entry*.

See `importlib.abc.PathEntryFinder` for the methods that path entry finders implement.

path entry hook A callable on the `sys.path_hook` list which returns a *path entry finder* if it knows how to find modules on a specific *path entry*.

path based finder One of the default *meta path finders* which searches an *import path* for modules.

path-like object An object representing a file system path. A path-like object is either a `str` or `bytes` object representing a path, or an object implementing the `os.PathLike` protocol. An object that supports the `os.PathLike` protocol can be converted to a `str` or `bytes` file system path by calling the `os.fspath()` function; `os.fsdecode()` and `os.fsencode()` can be used to guarantee a `str` or `bytes` result instead, respectively. Introduced by **PEP 519**.

PEP Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python or its processes or environment. PEPs should provide a concise technical specification and a rationale for proposed features.

PEPs are intended to be the primary mechanisms for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible for building consensus within the community and documenting dissenting opinions.

See **PEP 1**.

portion A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in **PEP 420**.

positional argument See *argument*.

provisional API A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a "solution of last resort" - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See **PEP 411** for more details.

provisional package See *provisional API*.

Python 3000 Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

Pythonic An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print(piece)
```

qualified name A dotted name showing the "path" from a module's global scope to a class, function or method defined in that module, as defined in **PEP 3155**. For top-level functions and classes, the qualified name is the same as the object's name:

```
>>> class C:
...     class D:
...         def meth(self):
...             pass
...
>>> C.__qualname__
'C'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```

When used to refer to modules, the *fully qualified name* means the entire dotted path to the module, including any parent packages, e.g. `email.mime.text`:

```
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

reference count The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

regular package A traditional *package*, such as a directory containing an `__init__.py` file.

See also *namespace package*.

___slots___ A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

sequence An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `__len__()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `bytes`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

The `collections.abc.Sequence` abstract base class defines a much richer interface that goes beyond just `__getitem__()` and `__len__()`, adding `count()`, `index()`, `__contains__()`, and `__reversed__()`. Types that implement this expanded interface can be registered explicitly using `register()`.

single dispatch A form of *generic function* dispatch where the implementation is chosen based on the type of a single argument.

slice An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally.

special method A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in specialnames.

statement A statement is part of a suite (a "block" of code). A statement is either an *expression* or one of several constructs with a keyword, such as `if`, `while` or `for`.

struct sequence A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

text encoding A codec which encodes Unicode strings to bytes.

text file A *file object* able to read and write `str` objects. Often, a text file actually accesses a byte-oriented datastream and handles the *text encoding* automatically. Examples of text files are files opened in text mode (`'r'` or `'w'`), `sys.stdin`, `sys.stdout`, and instances of `io.StringIO`.

See also *binary file* for a file object able to read and write *bytes-like objects*.

triple-quoted string A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

type The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

type alias A synonym for a type, created by assigning the type to an identifier.

Type aliases are useful for simplifying *type hints*. For example:

```
from typing import List, Tuple

def remove_gray_shades(
        colors: List[Tuple[int, int, int]]) -> List[Tuple[int, int, int]]:
    pass
```

could be made more readable like this:

```
from typing import List, Tuple

Color = Tuple[int, int, int]

def remove_gray_shades(colors: List[Color]) -> List[Color]:
    pass
```

See `typing` and **PEP 484**, which describe this functionality.

type hint An *annotation* that specifies the expected type for a variable, a class attribute, or a function parameter or return value.

Type hints are optional and are not enforced by Python but they are useful to static type analysis tools, and aid IDEs with code completion and refactoring.

Type hints of global variables, class attributes, and functions, but not local variables, can be accessed using `typing.get_type_hints()`.

See `typing` and **PEP 484**, which describe this functionality.

universal newlines A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old

Macintosh convention `'\r'`. See **PEP 278** and **PEP 3116**, as well as `bytes.splitlines()` for an additional use.

variable annotation An *annotation* of a variable or a class attribute.

When annotating a variable or a class attribute, assignment is optional:

```
class C:
    field: 'annotation'
```

Variable annotations are usually used for *type hints*: for example this variable is expected to take `int` values:

```
count: int = 0
```

Variable annotation syntax is explained in section annassign.

See *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

virtual environment A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also `venv`.

virtual machine A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

Zen of Python Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing "`import this`" at the interactive prompt.

APPENDIX

B

ABOUT THESE DOCUMENTS

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the reporting-bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the Docutils project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.

B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See Misc/ACKS in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!

APPENDIX

C

HISTORY AND LICENSE

C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see https://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see https://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see https://opensource.org/ for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2 and above	2.1.1	2001-now	PSF	yes

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Thanks to the many outside volunteers who have worked under Guido's direction to make these releases possible.

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```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.

Before using, initialize the state by using init_genrand(seed)
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http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html
email: m-mat @ math.sci.hiroshima-u.ac.jp (remove space)
```

C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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Modified by Jack Jansen, CWI, July 1995:
- Use binascii module to do the actual line-by-line conversion
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```

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Original location:
   https://github.com/majek/csiphash/

Solution inspired by code from:
   Samuel Neves (supercop/crypto_auth/siphash24/little)
   djb (supercop/crypto_auth/siphash24/little2)
   Jean-Philippe Aumasson (https://131002.net/siphash/siphash24.c)
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C.3.11 strtod and dtoa

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Jean-loup Gailly        Mark Adler
jloup@gzip.org          madler@alumni.caltech.edu
```

C.3.16 cfuhash

The implementation of the hash table used by the `tracemalloc` is based on the cfuhash project:

```
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C.3.17 libmpdec

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```
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D

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HOWTO Fetch Internet Resources Using The urllib Package

Release 3.7.0

Guido van Rossum
and the Python development team

July 07, 2018

Python Software Foundation
Email: docs@python.org

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Author Michael Foord

Note: There is a French translation of an earlier revision of this HOWTO, available at urllib2 - Le Manuel manquant.

1 Introduction

Related Articles

You may also find useful the following article on fetching web resources with Python:

- Basic Authentication

  A tutorial on *Basic Authentication*, with examples in Python.

urllib.request is a Python module for fetching URLs (Uniform Resource Locators). It offers a very simple interface, in the form of the *urlopen* function. This is capable of fetching URLs using a variety of different protocols. It also offers a slightly more complex interface for handling common situations - like basic authentication, cookies, proxies and so on. These are provided by objects called handlers and openers.

urllib.request supports fetching URLs for many "URL schemes" (identified by the string before the `":"` in URL - for example `"ftp"` is the URL scheme of `"ftp://python.org/"`) using their associated network protocols (e.g. FTP, HTTP). This tutorial focuses on the most common case, HTTP.

For straightforward situations *urlopen* is very easy to use. But as soon as you encounter errors or non-trivial cases when opening HTTP URLs, you will need some understanding of the HyperText Transfer Protocol. The most comprehensive and authoritative reference to HTTP is **RFC 2616**. This is a technical document and not intended to be easy to read. This HOWTO aims to illustrate using *urllib*, with enough detail about HTTP to help you through. It is not intended to replace the `urllib.request` docs, but is supplementary to them.

2 Fetching URLs

The simplest way to use urllib.request is as follows:

```
import urllib.request
with urllib.request.urlopen('http://python.org/') as response:
   html = response.read()
```

If you wish to retrieve a resource via URL and store it in a temporary location, you can do so via the `shutil.copyfileobj()` and `tempfile.NamedTemporaryFile()` functions:

```
import shutil
import tempfile
import urllib.request

with urllib.request.urlopen('http://python.org/') as response:
    with tempfile.NamedTemporaryFile(delete=False) as tmp_file:
        shutil.copyfileobj(response, tmp_file)

with open(tmp_file.name) as html:
    pass
```

Many uses of urllib will be that simple (note that instead of an 'http:' URL we could have used a URL starting with 'ftp:', 'file:', etc.). However, it's the purpose of this tutorial to explain the more complicated cases, concentrating on HTTP.

HTTP is based on requests and responses - the client makes requests and servers send responses. urllib.request mirrors this with a `Request` object which represents the HTTP request you are making. In its simplest form you create a Request object that specifies the URL you want to fetch. Calling `urlopen` with this Request object returns a response object for the URL requested. This response is a file-like object, which means you can for example call `.read()` on the response:

```
import urllib.request

req = urllib.request.Request('http://www.voidspace.org.uk')
with urllib.request.urlopen(req) as response:
   the_page = response.read()
```

Note that urllib.request makes use of the same Request interface to handle all URL schemes. For example, you can make an FTP request like so:

```
req = urllib.request.Request('ftp://example.com/')
```

In the case of HTTP, there are two extra things that Request objects allow you to do: First, you can pass data to be sent to the server. Second, you can pass extra information ("metadata") *about* the data or the about request itself, to the server - this information is sent as HTTP "headers". Let's look at each of these in turn.

2.1 Data

Sometimes you want to send data to a URL (often the URL will refer to a CGI (Common Gateway Interface) script or other web application). With HTTP, this is often done using what's known as a **POST** request. This is often what your browser does when you submit a HTML form that you filled in on the web. Not all POSTs have to come from forms: you can use a POST to transmit arbitrary data to your own application. In the common case of HTML forms, the data needs to be encoded in a standard way, and then passed to the Request object as the `data` argument. The encoding is done using a function from the `urllib.parse` library.

```
import urllib.parse
import urllib.request

url = 'http://www.someserver.com/cgi-bin/register.cgi'
values = {'name' : 'Michael Foord',
          'location' : 'Northampton',
          'language' : 'Python' }

data = urllib.parse.urlencode(values)
data = data.encode('ascii') # data should be bytes
req = urllib.request.Request(url, data)
with urllib.request.urlopen(req) as response:
   the_page = response.read()
```

Note that other encodings are sometimes required (e.g. for file upload from HTML forms - see HTML Specification, Form Submission for more details).

If you do not pass the `data` argument, urllib uses a **GET** request. One way in which GET and POST requests differ is that POST requests often have "side-effects": they change the state of the system in some way (for example by placing an order with the website for a hundredweight of tinned spam to be delivered to your door). Though the HTTP standard makes it clear that POSTs are intended to *always* cause side-effects,

and GET requests *never* to cause side-effects, nothing prevents a GET request from having side-effects, nor a POST requests from having no side-effects. Data can also be passed in an HTTP GET request by encoding it in the URL itself.

This is done as follows:

```
>>> import urllib.request
>>> import urllib.parse
>>> data = {}
>>> data['name'] = 'Somebody Here'
>>> data['location'] = 'Northampton'
>>> data['language'] = 'Python'
>>> url_values = urllib.parse.urlencode(data)
>>> print(url_values)  # The order may differ from below.
name=Somebody+Here&language=Python&location=Northampton
>>> url = 'http://www.example.com/example.cgi'
>>> full_url = url + '?' + url_values
>>> data = urllib.request.urlopen(full_url)
```

Notice that the full URL is created by adding a `?` to the URL, followed by the encoded values.

2.2 Headers

We'll discuss here one particular HTTP header, to illustrate how to add headers to your HTTP request.

Some websites[1] dislike being browsed by programs, or send different versions to different browsers[2]. By default urllib identifies itself as `Python-urllib/x.y` (where `x` and `y` are the major and minor version numbers of the Python release, e.g. `Python-urllib/2.5`), which may confuse the site, or just plain not work. The way a browser identifies itself is through the `User-Agent` header[3]. When you create a Request object you can pass a dictionary of headers in. The following example makes the same request as above, but identifies itself as a version of Internet Explorer[4].

```
import urllib.parse
import urllib.request

url = 'http://www.someserver.com/cgi-bin/register.cgi'
user_agent = 'Mozilla/5.0 (Windows NT 6.1; Win64; x64)'
values = {'name': 'Michael Foord',
          'location': 'Northampton',
          'language': 'Python' }
headers = {'User-Agent': user_agent}

data = urllib.parse.urlencode(values)
data = data.encode('ascii')
req = urllib.request.Request(url, data, headers)
with urllib.request.urlopen(req) as response:
   the_page = response.read()
```

The response also has two useful methods. See the section on *info and geturl* which comes after we have a look at what happens when things go wrong.

[1] Google for example.

[2] Browser sniffing is a very bad practice for website design - building sites using web standards is much more sensible. Unfortunately a lot of sites still send different versions to different browsers.

[3] The user agent for MSIE 6 is *'Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1; .NET CLR 1.1.4322)'*

[4] For details of more HTTP request headers, see Quick Reference to HTTP Headers.

3 Handling Exceptions

urlopen raises `URLError` when it cannot handle a response (though as usual with Python APIs, built-in exceptions such as `ValueError`, `TypeError` etc. may also be raised).

`HTTPError` is the subclass of `URLError` raised in the specific case of HTTP URLs.

The exception classes are exported from the `urllib.error` module.

3.1 URLError

Often, URLError is raised because there is no network connection (no route to the specified server), or the specified server doesn't exist. In this case, the exception raised will have a 'reason' attribute, which is a tuple containing an error code and a text error message.

e.g.

```
>>> req = urllib.request.Request('http://www.pretend_server.org')
>>> try: urllib.request.urlopen(req)
... except urllib.error.URLError as e:
...     print(e.reason)
...
(4, 'getaddrinfo failed')
```

3.2 HTTPError

Every HTTP response from the server contains a numeric "status code". Sometimes the status code indicates that the server is unable to fulfil the request. The default handlers will handle some of these responses for you (for example, if the response is a "redirection" that requests the client fetch the document from a different URL, urllib will handle that for you). For those it can't handle, urlopen will raise an `HTTPError`. Typical errors include '404' (page not found), '403' (request forbidden), and '401' (authentication required).

See section 10 of **RFC 2616** for a reference on all the HTTP error codes.

The `HTTPError` instance raised will have an integer 'code' attribute, which corresponds to the error sent by the server.

Error Codes

Because the default handlers handle redirects (codes in the 300 range), and codes in the 100–299 range indicate success, you will usually only see error codes in the 400–599 range.

`http.server.BaseHTTPRequestHandler.responses` is a useful dictionary of response codes in that shows all the response codes used by **RFC 2616**. The dictionary is reproduced here for convenience

```
# Table mapping response codes to messages; entries have the
# form {code: (shortmessage, longmessage)}.
responses = {
    100: ('Continue', 'Request received, please continue'),
    101: ('Switching Protocols',
          'Switching to new protocol; obey Upgrade header'),

    200: ('OK', 'Request fulfilled, document follows'),
    201: ('Created', 'Document created, URL follows'),
    202: ('Accepted',
```

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```
      'Request accepted, processing continues off-line'),
 203: ('Non-Authoritative Information', 'Request fulfilled from cache'),
 204: ('No Content', 'Request fulfilled, nothing follows'),
 205: ('Reset Content', 'Clear input form for further input.'),
 206: ('Partial Content', 'Partial content follows.'),

 300: ('Multiple Choices',
       'Object has several resources -- see URI list'),
 301: ('Moved Permanently', 'Object moved permanently -- see URI list'),
 302: ('Found', 'Object moved temporarily -- see URI list'),
 303: ('See Other', 'Object moved -- see Method and URL list'),
 304: ('Not Modified',
       'Document has not changed since given time'),
 305: ('Use Proxy',
       'You must use proxy specified in Location to access this '
       'resource.'),
 307: ('Temporary Redirect',
       'Object moved temporarily -- see URI list'),

 400: ('Bad Request',
       'Bad request syntax or unsupported method'),
 401: ('Unauthorized',
       'No permission -- see authorization schemes'),
 402: ('Payment Required',
       'No payment -- see charging schemes'),
 403: ('Forbidden',
       'Request forbidden -- authorization will not help'),
 404: ('Not Found', 'Nothing matches the given URI'),
 405: ('Method Not Allowed',
       'Specified method is invalid for this server.'),
 406: ('Not Acceptable', 'URI not available in preferred format.'),
 407: ('Proxy Authentication Required', 'You must authenticate with '
       'this proxy before proceeding.'),
 408: ('Request Timeout', 'Request timed out; try again later.'),
 409: ('Conflict', 'Request conflict.'),
 410: ('Gone',
       'URI no longer exists and has been permanently removed.'),
 411: ('Length Required', 'Client must specify Content-Length.'),
 412: ('Precondition Failed', 'Precondition in headers is false.'),
 413: ('Request Entity Too Large', 'Entity is too large.'),
 414: ('Request-URI Too Long', 'URI is too long.'),
 415: ('Unsupported Media Type', 'Entity body in unsupported format.'),
 416: ('Requested Range Not Satisfiable',
       'Cannot satisfy request range.'),
 417: ('Expectation Failed',
       'Expect condition could not be satisfied.'),

 500: ('Internal Server Error', 'Server got itself in trouble'),
 501: ('Not Implemented',
       'Server does not support this operation'),
 502: ('Bad Gateway', 'Invalid responses from another server/proxy.'),
 503: ('Service Unavailable',
       'The server cannot process the request due to a high load'),
 504: ('Gateway Timeout',
       'The gateway server did not receive a timely response'),
 505: ('HTTP Version Not Supported', 'Cannot fulfill request.'),
 }
```

When an error is raised the server responds by returning an HTTP error code *and* an error page. You can use the `HTTPError` instance as a response on the page returned. This means that as well as the code attribute, it also has read, geturl, and info, methods as returned by the `urllib.response` module:

```
>>> req = urllib.request.Request('http://www.python.org/fish.html')
>>> try:
...     urllib.request.urlopen(req)
... except urllib.error.HTTPError as e:
...     print(e.code)
...     print(e.read())
...
404
b'<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
  "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">\n\n\n<html
  ...
  <title>Page Not Found</title>\n
  ...
```

3.3 Wrapping it Up

So if you want to be prepared for `HTTPError` *or* `URLError` there are two basic approaches. I prefer the second approach.

Number 1

```
from urllib.request import Request, urlopen
from urllib.error import URLError, HTTPError
req = Request(someurl)
try:
    response = urlopen(req)
except HTTPError as e:
    print('The server couldn\'t fulfill the request.')
    print('Error code: ', e.code)
except URLError as e:
    print('We failed to reach a server.')
    print('Reason: ', e.reason)
else:
    # everything is fine
```

Note: The `except HTTPError` *must* come first, otherwise `except URLError` will *also* catch an `HTTPError`.

Number 2

```
from urllib.request import Request, urlopen
from urllib.error import URLError
req = Request(someurl)
try:
    response = urlopen(req)
except URLError as e:
    if hasattr(e, 'reason'):
        print('We failed to reach a server.')
```

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```
        print('Reason: ', e.reason)
    elif hasattr(e, 'code'):
        print('The server couldn\'t fulfill the request.')
        print('Error code: ', e.code)
else:
    # everything is fine
```

4 info and geturl

The response returned by urlopen (or the `HTTPError` instance) has two useful methods `info()` and `geturl()` and is defined in the module `urllib.response`..

geturl - this returns the real URL of the page fetched. This is useful because `urlopen` (or the opener object used) may have followed a redirect. The URL of the page fetched may not be the same as the URL requested.

info - this returns a dictionary-like object that describes the page fetched, particularly the headers sent by the server. It is currently an `http.client.HTTPMessage` instance.

Typical headers include 'Content-length', 'Content-type', and so on. See the Quick Reference to HTTP Headers for a useful listing of HTTP headers with brief explanations of their meaning and use.

5 Openers and Handlers

When you fetch a URL you use an opener (an instance of the perhaps confusingly-named `urllib.request.OpenerDirector`). Normally we have been using the default opener - via `urlopen` - but you can create custom openers. Openers use handlers. All the "heavy lifting" is done by the handlers. Each handler knows how to open URLs for a particular URL scheme (http, ftp, etc.), or how to handle an aspect of URL opening, for example HTTP redirections or HTTP cookies.

You will want to create openers if you want to fetch URLs with specific handlers installed, for example to get an opener that handles cookies, or to get an opener that does not handle redirections.

To create an opener, instantiate an `OpenerDirector`, and then call `.add_handler(some_handler_instance)` repeatedly.

Alternatively, you can use `build_opener`, which is a convenience function for creating opener objects with a single function call. `build_opener` adds several handlers by default, but provides a quick way to add more and/or override the default handlers.

Other sorts of handlers you might want to can handle proxies, authentication, and other common but slightly specialised situations.

`install_opener` can be used to make an `opener` object the (global) default opener. This means that calls to `urlopen` will use the opener you have installed.

Opener objects have an `open` method, which can be called directly to fetch urls in the same way as the `urlopen` function: there's no need to call `install_opener`, except as a convenience.

6 Basic Authentication

To illustrate creating and installing a handler we will use the `HTTPBasicAuthHandler`. For a more detailed discussion of this subject – including an explanation of how Basic Authentication works - see the Basic Authentication Tutorial.

When authentication is required, the server sends a header (as well as the 401 error code) requesting authentication. This specifies the authentication scheme and a 'realm'. The header looks like: `WWW-Authenticate: SCHEME realm="REALM"`.

e.g.

```
WWW-Authenticate: Basic realm="cPanel Users"
```

The client should then retry the request with the appropriate name and password for the realm included as a header in the request. This is 'basic authentication'. In order to simplify this process we can create an instance of `HTTPBasicAuthHandler` and an opener to use this handler.

The `HTTPBasicAuthHandler` uses an object called a password manager to handle the mapping of URLs and realms to passwords and usernames. If you know what the realm is (from the authentication header sent by the server), then you can use a `HTTPPasswordMgr`. Frequently one doesn't care what the realm is. In that case, it is convenient to use `HTTPPasswordMgrWithDefaultRealm`. This allows you to specify a default username and password for a URL. This will be supplied in the absence of you providing an alternative combination for a specific realm. We indicate this by providing `None` as the realm argument to the `add_password` method.

The top-level URL is the first URL that requires authentication. URLs "deeper" than the URL you pass to .add_password() will also match.

```
# create a password manager
password_mgr = urllib.request.HTTPPasswordMgrWithDefaultRealm()

# Add the username and password.
# If we knew the realm, we could use it instead of None.
top_level_url = "http://example.com/foo/"
password_mgr.add_password(None, top_level_url, username, password)

handler = urllib.request.HTTPBasicAuthHandler(password_mgr)

# create "opener" (OpenerDirector instance)
opener = urllib.request.build_opener(handler)

# use the opener to fetch a URL
opener.open(a_url)

# Install the opener.
# Now all calls to urllib.request.urlopen use our opener.
urllib.request.install_opener(opener)
```

Note: In the above example we only supplied our `HTTPBasicAuthHandler` to `build_opener`. By default openers have the handlers for normal situations – `ProxyHandler` (if a proxy setting such as an `http_proxy` environment variable is set), `UnknownHandler`, `HTTPHandler`, `HTTPDefaultErrorHandler`, `HTTPRedirectHandler`, `FTPHandler`, `FileHandler`, `DataHandler`, `HTTPErrorProcessor`.

`top_level_url` is in fact *either* a full URL (including the 'http:' scheme component and the hostname and optionally the port number) e.g. `"http://example.com/"` *or* an "authority" (i.e. the hostname, optionally including the port number) e.g. `"example.com"` or `"example.com:8080"` (the latter example includes a port number). The authority, if present, must NOT contain the "userinfo" component - for example `"joe:password@example.com"` is not correct.

7 Proxies

urllib will auto-detect your proxy settings and use those. This is through the `ProxyHandler`, which is part of the normal handler chain when a proxy setting is detected. Normally that's a good thing, but there are occasions when it may not be helpful[5]. One way to do this is to setup our own `ProxyHandler`, with no proxies defined. This is done using similar steps to setting up a Basic Authentication handler:

```
>>> proxy_support = urllib.request.ProxyHandler({})
>>> opener = urllib.request.build_opener(proxy_support)
>>> urllib.request.install_opener(opener)
```

Note: Currently `urllib.request` *does not* support fetching of `https` locations through a proxy. However, this can be enabled by extending urllib.request as shown in the recipe[6].

Note: `HTTP_PROXY` will be ignored if a variable `REQUEST_METHOD` is set; see the documentation on `getproxies()`.

---

8 Sockets and Layers

The Python support for fetching resources from the web is layered. urllib uses the `http.client` library, which in turn uses the socket library.

As of Python 2.3 you can specify how long a socket should wait for a response before timing out. This can be useful in applications which have to fetch web pages. By default the socket module has *no timeout* and can hang. Currently, the socket timeout is not exposed at the http.client or urllib.request levels. However, you can set the default timeout globally for all sockets using

```
import socket
import urllib.request

# timeout in seconds
timeout = 10
socket.setdefaulttimeout(timeout)

# this call to urllib.request.urlopen now uses the default timeout
# we have set in the socket module
req = urllib.request.Request('http://www.voidspace.org.uk')
response = urllib.request.urlopen(req)
```

---

9 Footnotes

This document was reviewed and revised by John Lee.

---

[5] In my case I have to use a proxy to access the internet at work. If you attempt to fetch *localhost* URLs through this proxy it blocks them. IE is set to use the proxy, which urllib picks up on. In order to test scripts with a localhost server, I have to prevent urllib from using the proxy.

[6] urllib opener for SSL proxy (CONNECT method): ASPN Cookbook Recipe.

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Unicode HOWTO

Release 3.7.0

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Release 1.12

This HOWTO discusses Python support for Unicode, and explains various problems that people commonly encounter when trying to work with Unicode.

1 Introduction to Unicode

1.1 History of Character Codes

In 1968, the American Standard Code for Information Interchange, better known by its acronym ASCII, was standardized. ASCII defined numeric codes for various characters, with the numeric values running from 0 to 127. For example, the lowercase letter 'a' is assigned 97 as its code value.

ASCII was an American-developed standard, so it only defined unaccented characters. There was an 'e', but no 'é' or 'Í'. This meant that languages which required accented characters couldn't be faithfully represented in ASCII. (Actually the missing accents matter for English, too, which contains words such as 'naïve' and 'café', and some publications have house styles which require spellings such as 'coöperate'.)

For a while people just wrote programs that didn't display accents. In the mid-1980s an Apple II BASIC program written by a French speaker might have lines like these:

```
PRINT "MISE A JOUR TERMINEE"
PRINT "PARAMETRES ENREGISTRES"
```

Those messages should contain accents (terminée, paramètre, enregistrés) and they just look wrong to someone who can read French.

In the 1980s, almost all personal computers were 8-bit, meaning that bytes could hold values ranging from 0 to 255. ASCII codes only went up to 127, so some machines assigned values between 128 and 255 to accented characters. Different machines had different codes, however, which led to problems exchanging files. Eventually various commonly used sets of values for the 128–255 range emerged. Some were true standards, defined by the International Organization for Standardization, and some were *de facto* conventions that were invented by one company or another and managed to catch on.

255 characters aren't very many. For example, you can't fit both the accented characters used in Western Europe and the Cyrillic alphabet used for Russian into the 128–255 range because there are more than 128 such characters.

You could write files using different codes (all your Russian files in a coding system called KOI8, all your French files in a different coding system called Latin1), but what if you wanted to write a French document that quotes some Russian text? In the 1980s people began to want to solve this problem, and the Unicode standardization effort began.

Unicode started out using 16-bit characters instead of 8-bit characters. 16 bits means you have 2^16 = 65,536 distinct values available, making it possible to represent many different characters from many different alphabets; an initial goal was to have Unicode contain the alphabets for every single human language. It turns out that even 16 bits isn't enough to meet that goal, and the modern Unicode specification uses a wider range of codes, 0 through 1,114,111 (`0x10FFFF` in base 16).

There's a related ISO standard, ISO 10646. Unicode and ISO 10646 were originally separate efforts, but the specifications were merged with the 1.1 revision of Unicode.

(This discussion of Unicode's history is highly simplified. The precise historical details aren't necessary for understanding how to use Unicode effectively, but if you're curious, consult the Unicode consortium site listed in the References or the Wikipedia entry for Unicode for more information.)

1.2 Definitions

A **character** is the smallest possible component of a text. 'A', 'B', 'C', etc., are all different characters. So are 'È' and 'Í'. Characters are abstractions, and vary depending on the language or context you're talking about. For example, the symbol for ohms (Ω) is usually drawn much like the capital letter omega (Ω) in the Greek alphabet (they may even be the same in some fonts), but these are two different characters that have different meanings.

The Unicode standard describes how characters are represented by **code points**. A code point is an integer value, usually denoted in base 16. In the standard, a code point is written using the notation `U+12CA` to mean the character with value `0x12ca` (4,810 decimal). The Unicode standard contains a lot of tables listing characters and their corresponding code points:

```
0061    'a'; LATIN SMALL LETTER A
0062    'b'; LATIN SMALL LETTER B
0063    'c'; LATIN SMALL LETTER C
...
007B    '{'; LEFT CURLY BRACKET
```

Strictly, these definitions imply that it's meaningless to say 'this is character `U+12CA`'. `U+12CA` is a code point, which represents some particular character; in this case, it represents the character 'ETHIOPIC SYLLABLE WI'. In informal contexts, this distinction between code points and characters will sometimes be forgotten.

A character is represented on a screen or on paper by a set of graphical elements that's called a **glyph**. The glyph for an uppercase A, for example, is two diagonal strokes and a horizontal stroke, though the exact details will depend on the font being used. Most Python code doesn't need to worry about glyphs; figuring out the correct glyph to display is generally the job of a GUI toolkit or a terminal's font renderer.

1.3 Encodings

To summarize the previous section: a Unicode string is a sequence of code points, which are numbers from 0 through `0x10FFFF` (1,114,111 decimal). This sequence needs to be represented as a set of bytes (meaning, values from 0 through 255) in memory. The rules for translating a Unicode string into a sequence of bytes are called an **encoding**.

The first encoding you might think of is an array of 32-bit integers. In this representation, the string "Python" would look like this:

```
   P           y           t           h           o           n
0x50 00 00 00 79 00 00 00 74 00 00 00 68 00 00 00 6f 00 00 00 6e 00 00 00
   0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
```

This representation is straightforward but using it presents a number of problems.

1. It's not portable; different processors order the bytes differently.
2. It's very wasteful of space. In most texts, the majority of the code points are less than 127, or less than 255, so a lot of space is occupied by `0x00` bytes. The above string takes 24 bytes compared to the 6 bytes needed for an ASCII representation. Increased RAM usage doesn't matter too much (desktop computers have gigabytes of RAM, and strings aren't usually that large), but expanding our usage of disk and network bandwidth by a factor of 4 is intolerable.
3. It's not compatible with existing C functions such as `strlen()`, so a new family of wide string functions would need to be used.
4. Many Internet standards are defined in terms of textual data, and can't handle content with embedded zero bytes.

Generally people don't use this encoding, instead choosing other encodings that are more efficient and convenient. UTF-8 is probably the most commonly supported encoding; it will be discussed below.

Encodings don't have to handle every possible Unicode character, and most encodings don't. The rules for converting a Unicode string into the ASCII encoding, for example, are simple; for each code point:

1. If the code point is < 128, each byte is the same as the value of the code point.
2. If the code point is 128 or greater, the Unicode string can't be represented in this encoding. (Python raises a `UnicodeEncodeError` exception in this case.)

Latin-1, also known as ISO-8859-1, is a similar encoding. Unicode code points 0–255 are identical to the Latin-1 values, so converting to this encoding simply requires converting code points to byte values; if a code point larger than 255 is encountered, the string can't be encoded into Latin-1.

Encodings don't have to be simple one-to-one mappings like Latin-1. Consider IBM's EBCDIC, which was used on IBM mainframes. Letter values weren't in one block: 'a' through 'i' had values from 129 to 137, but 'j' through 'r' were 145 through 153. If you wanted to use EBCDIC as an encoding, you'd probably use some sort of lookup table to perform the conversion, but this is largely an internal detail.

UTF-8 is one of the most commonly used encodings. UTF stands for "Unicode Transformation Format", and the '8' means that 8-bit numbers are used in the encoding. (There are also a UTF-16 and UTF-32 encodings, but they are less frequently used than UTF-8.) UTF-8 uses the following rules:

1. If the code point is < 128, it's represented by the corresponding byte value.
2. If the code point is >= 128, it's turned into a sequence of two, three, or four bytes, where each byte of the sequence is between 128 and 255.

UTF-8 has several convenient properties:

1. It can handle any Unicode code point.
2. A Unicode string is turned into a sequence of bytes containing no embedded zero bytes. This avoids byte-ordering issues, and means UTF-8 strings can be processed by C functions such as `strcpy()` and sent through protocols that can't handle zero bytes.
3. A string of ASCII text is also valid UTF-8 text.
4. UTF-8 is fairly compact; the majority of commonly used characters can be represented with one or two bytes.
5. If bytes are corrupted or lost, it's possible to determine the start of the next UTF-8-encoded code point and resynchronize. It's also unlikely that random 8-bit data will look like valid UTF-8.

1.4 References

The Unicode Consortium site has character charts, a glossary, and PDF versions of the Unicode specification. Be prepared for some difficult reading. A chronology of the origin and development of Unicode is also available on the site.

To help understand the standard, Jukka Korpela has written an introductory guide to reading the Unicode character tables.

Another good introductory article was written by Joel Spolsky. If this introduction didn't make things clear to you, you should try reading this alternate article before continuing.

Wikipedia entries are often helpful; see the entries for "character encoding" and UTF-8, for example.

2 Python's Unicode Support

Now that you've learned the rudiments of Unicode, we can look at Python's Unicode features.

2.1 The String Type

Since Python 3.0, the language features a `str` type that contain Unicode characters, meaning any string created using `"unicode rocks!"`, `'unicode rocks!'`, or the triple-quoted string syntax is stored as Unicode.

The default encoding for Python source code is UTF-8, so you can simply include a Unicode character in a string literal:

```
try:
    with open('/tmp/input.txt', 'r') as f:
        ...
except OSError:
    # 'File not found' error message.
    print("Fichier non trouvé")
```

You can use a different encoding from UTF-8 by putting a specially-formatted comment as the first or second line of the source code:

```
# -*- coding: <encoding name> -*-
```

Side note: Python 3 also supports using Unicode characters in identifiers:

```
répertoire = "/tmp/records.log"
with open(répertoire, "w") as f:
    f.write("test\n")
```

If you can't enter a particular character in your editor or want to keep the source code ASCII-only for some reason, you can also use escape sequences in string literals. (Depending on your system, you may see the actual capital-delta glyph instead of a u escape.)

```
>>> "\N{GREEK CAPITAL LETTER DELTA}"  # Using the character name
'\u0394'
>>> "\u0394"                          # Using a 16-bit hex value
'\u0394'
>>> "\U00000394"                      # Using a 32-bit hex value
'\u0394'
```

In addition, one can create a string using the `decode()` method of `bytes`. This method takes an *encoding* argument, such as `UTF-8`, and optionally an *errors* argument.

The *errors* argument specifies the response when the input string can't be converted according to the encoding's rules. Legal values for this argument are `'strict'` (raise a `UnicodeDecodeError` exception), `'replace'` (use `U+FFFD`, `REPLACEMENT CHARACTER`), `'ignore'` (just leave the character out of the Unicode result), or `'backslashreplace'` (inserts a `\xNN` escape sequence). The following examples show the differences:

```
>>> b'\x80abc'.decode("utf-8", "strict")
Traceback (most recent call last):
    ...
UnicodeDecodeError: 'utf-8' codec can't decode byte 0x80 in position 0:
  invalid start byte
>>> b'\x80abc'.decode("utf-8", "replace")
'\ufffdabc'
>>> b'\x80abc'.decode("utf-8", "backslashreplace")
'\\x80abc'
>>> b'\x80abc'.decode("utf-8", "ignore")
'abc'
```

Encodings are specified as strings containing the encoding's name. Python 3.2 comes with roughly 100 different encodings; see the Python Library Reference at standard-encodings for a list. Some encodings have multiple names; for example, `'latin-1'`, `'iso_8859_1'` and `'8859'` are all synonyms for the same encoding.

One-character Unicode strings can also be created with the `chr()` built-in function, which takes integers and returns a Unicode string of length 1 that contains the corresponding code point. The reverse operation is the built-in `ord()` function that takes a one-character Unicode string and returns the code point value:

```
>>> chr(57344)
'\ue000'
>>> ord('\ue000')
57344
```

2.2 Converting to Bytes

The opposite method of `bytes.decode()` is `str.encode()`, which returns a `bytes` representation of the Unicode string, encoded in the requested *encoding*.

The *errors* parameter is the same as the parameter of the `decode()` method but supports a few more possible handlers. As well as `'strict'`, `'ignore'`, and `'replace'` (which in this case inserts a question mark instead of the unencodable character), there is also `'xmlcharrefreplace'` (inserts an XML character reference), `backslashreplace` (inserts a `\uNNNN` escape sequence) and `namereplace` (inserts a `\N{...}` escape sequence).

The following example shows the different results:

```
>>> u = chr(40960) + 'abcd' + chr(1972)
>>> u.encode('utf-8')
b'\xea\x80\x80abcd\xde\xb4'
>>> u.encode('ascii')
Traceback (most recent call last):
    ...
UnicodeEncodeError: 'ascii' codec can't encode character '\ua000' in
  position 0: ordinal not in range(128)
>>> u.encode('ascii', 'ignore')
b'abcd'
>>> u.encode('ascii', 'replace')
b'?abcd?'
>>> u.encode('ascii', 'xmlcharrefreplace')
b'&#40960;abcd&#1972;'
>>> u.encode('ascii', 'backslashreplace')
b'\\ua000abcd\\u07b4'
>>> u.encode('ascii', 'namereplace')
b'\\N{YI SYLLABLE IT}abcd\\u07b4'
```

The low-level routines for registering and accessing the available encodings are found in the `codecs` module. Implementing new encodings also requires understanding the `codecs` module. However, the encoding and decoding functions returned by this module are usually more low-level than is comfortable, and writing new encodings is a specialized task, so the module won't be covered in this HOWTO.

2.3 Unicode Literals in Python Source Code

In Python source code, specific Unicode code points can be written using the `\u` escape sequence, which is followed by four hex digits giving the code point. The `\U` escape sequence is similar, but expects eight hex digits, not four:

```
>>> s = "a\xac\u1234\u20ac\U00008000"
... #     ^^^^ two-digit hex escape
... #          ^^^^^^ four-digit Unicode escape
... #                      ^^^^^^^^^^ eight-digit Unicode escape
>>> [ord(c) for c in s]
[97, 172, 4660, 8364, 32768]
```

Using escape sequences for code points greater than 127 is fine in small doses, but becomes an annoyance if you're using many accented characters, as you would in a program with messages in French or some other accent-using language. You can also assemble strings using the `chr()` built-in function, but this is even more tedious.

Ideally, you'd want to be able to write literals in your language's natural encoding. You could then edit Python source code with your favorite editor which would display the accented characters naturally, and have the right characters used at runtime.

Python supports writing source code in UTF-8 by default, but you can use almost any encoding if you declare the encoding being used. This is done by including a special comment as either the first or second line of the source file:

```
#!/usr/bin/env python
# -*- coding: latin-1 -*-

u = 'abcdé'
print(ord(u[-1]))
```

The syntax is inspired by Emacs's notation for specifying variables local to a file. Emacs supports many different variables, but Python only supports 'coding'. The `-*-` symbols indicate to Emacs that the comment is special; they have no significance to Python but are a convention. Python looks for `coding: name` or `coding=name` in the comment.

If you don't include such a comment, the default encoding used will be UTF-8 as already mentioned. See also **PEP 263** for more information.

2.4 Unicode Properties

The Unicode specification includes a database of information about code points. For each defined code point, the information includes the character's name, its category, the numeric value if applicable (Unicode has characters representing the Roman numerals and fractions such as one-third and four-fifths). There are also properties related to the code point's use in bidirectional text and other display-related properties.

The following program displays some information about several characters, and prints the numeric value of one particular character:

```
import unicodedata

u = chr(233) + chr(0x0bf2) + chr(3972) + chr(6000) + chr(13231)

for i, c in enumerate(u):
    print(i, '%04x' % ord(c), unicodedata.category(c), end=" ")
    print(unicodedata.name(c))

# Get numeric value of second character
print(unicodedata.numeric(u[1]))
```

When run, this prints:

```
0 00e9 Ll LATIN SMALL LETTER E WITH ACUTE
1 0bf2 No TAMIL NUMBER ONE THOUSAND
2 0f84 Mn TIBETAN MARK HALANTA
3 1770 Lo TAGBANWA LETTER SA
4 33af So SQUARE RAD OVER S SQUARED
1000.0
```

The category codes are abbreviations describing the nature of the character. These are grouped into categories such as "Letter", "Number", "Punctuation", or "Symbol", which in turn are broken up into subcategories. To take the codes from the above output, `'Ll'` means 'Letter, lowercase', `'No'` means "Number, other", `'Mn'` is "Mark, nonspacing", and `'So'` is "Symbol, other". See the General Category Values section of the Unicode Character Database documentation for a list of category codes.

2.5 Unicode Regular Expressions

The regular expressions supported by the `re` module can be provided either as bytes or strings. Some of the special character sequences such as `\d` and `\w` have different meanings depending on whether the pattern is supplied as bytes or a string. For example, `\d` will match the characters `[0-9]` in bytes but in strings will match any character that's in the `'Nd'` category.

The string in this example has the number 57 written in both Thai and Arabic numerals:

```
import re
p = re.compile(r'\d+')

s = "Over \u0e55\u0e57 57 flavours"
m = p.search(s)
print(repr(m.group()))
```

When executed, `\d+` will match the Thai numerals and print them out. If you supply the `re.ASCII` flag to `compile()`, `\d+` will match the substring "57" instead.

Similarly, `\w` matches a wide variety of Unicode characters but only `[a-zA-Z0-9_]` in bytes or if `re.ASCII` is supplied, and `\s` will match either Unicode whitespace characters or `[ \t\n\r\f\v]`.

2.6 References

Some good alternative discussions of Python's Unicode support are:

- Processing Text Files in Python 3, by Nick Coghlan.
- Pragmatic Unicode, a PyCon 2012 presentation by Ned Batchelder.

The `str` type is described in the Python library reference at textseq.

The documentation for the `unicodedata` module.

The documentation for the `codecs` module.

Marc-André Lemburg gave a presentation titled "Python and Unicode" (PDF slides) at EuroPython 2002. The slides are an excellent overview of the design of Python 2's Unicode features (where the Unicode string type is called `unicode` and literals start with `u`).

3 Reading and Writing Unicode Data

Once you've written some code that works with Unicode data, the next problem is input/output. How do you get Unicode strings into your program, and how do you convert Unicode into a form suitable for storage or transmission?

It's possible that you may not need to do anything depending on your input sources and output destinations; you should check whether the libraries used in your application support Unicode natively. XML parsers often return Unicode data, for example. Many relational databases also support Unicode-valued columns and can return Unicode values from an SQL query.

Unicode data is usually converted to a particular encoding before it gets written to disk or sent over a socket. It's possible to do all the work yourself: open a file, read an 8-bit bytes object from it, and convert the bytes with `bytes.decode(encoding)`. However, the manual approach is not recommended.

One problem is the multi-byte nature of encodings; one Unicode character can be represented by several bytes. If you want to read the file in arbitrary-sized chunks (say, 1024 or 4096 bytes), you need to write error-handling code to catch the case where only part of the bytes encoding a single Unicode character are read at the end of a chunk. One solution would be to read the entire file into memory and then perform the decoding, but that prevents you from working with files that are extremely large; if you need to read a 2 GiB file, you need 2 GiB of RAM. (More, really, since for at least a moment you'd need to have both the encoded string and its Unicode version in memory.)

The solution would be to use the low-level decoding interface to catch the case of partial coding sequences. The work of implementing this has already been done for you: the built-in `open()` function can return a file-like object that assumes the file's contents are in a specified encoding and accepts Unicode parameters for methods such as `read()` and `write()`. This works through `open()`'s *encoding* and *errors* parameters which are interpreted just like those in `str.encode()` and `bytes.decode()`.

Reading Unicode from a file is therefore simple:

```
with open('unicode.txt', encoding='utf-8') as f:
    for line in f:
        print(repr(line))
```

It's also possible to open files in update mode, allowing both reading and writing:

```
with open('test', encoding='utf-8', mode='w+') as f:
    f.write('\u4500 blah blah blah\n')
    f.seek(0)
    print(repr(f.readline()[:1]))
```

The Unicode character `U+FEFF` is used as a byte-order mark (BOM), and is often written as the first character of a file in order to assist with autodetection of the file's byte ordering. Some encodings, such as UTF-16, expect a BOM to be present at the start of a file; when such an encoding is used, the BOM will be automatically written as the first character and will be silently dropped when the file is read. There are variants of these encodings, such as 'utf-16-le' and 'utf-16-be' for little-endian and big-endian encodings, that specify one particular byte ordering and don't skip the BOM.

In some areas, it is also convention to use a "BOM" at the start of UTF-8 encoded files; the name is misleading since UTF-8 is not byte-order dependent. The mark simply announces that the file is encoded in UTF-8. Use the 'utf-8-sig' codec to automatically skip the mark if present for reading such files.

3.1 Unicode filenames

Most of the operating systems in common use today support filenames that contain arbitrary Unicode characters. Usually this is implemented by converting the Unicode string into some encoding that varies depending on the system. For example, Mac OS X uses UTF-8 while Windows uses a configurable encoding; on Windows, Python uses the name "mbcs" to refer to whatever the currently configured encoding is. On Unix systems, there will only be a filesystem encoding if you've set the `LANG` or `LC_CTYPE` environment variables; if you haven't, the default encoding is UTF-8.

The `sys.getfilesystemencoding()` function returns the encoding to use on your current system, in case you want to do the encoding manually, but there's not much reason to bother. When opening a file for reading or writing, you can usually just provide the Unicode string as the filename, and it will be automatically converted to the right encoding for you:

```
filename = 'filename\u4500abc'
with open(filename, 'w') as f:
    f.write('blah\n')
```

Functions in the `os` module such as `os.stat()` will also accept Unicode filenames.

The `os.listdir()` function returns filenames and raises an issue: should it return the Unicode version of filenames, or should it return bytes containing the encoded versions? `os.listdir()` will do both, depending on whether you provided the directory path as bytes or a Unicode string. If you pass a Unicode string as the path, filenames will be decoded using the filesystem's encoding and a list of Unicode strings will be returned, while passing a byte path will return the filenames as bytes. For example, assuming the default filesystem encoding is UTF-8, running the following program:

```
fn = 'filename\u4500abc'
f = open(fn, 'w')
f.close()

import os
print(os.listdir(b'.'))
print(os.listdir('.'))
```

will produce the following output:

```
amk:~$ python t.py
[b'filename\xe4\x94\x80abc', ...]
['filename\u4500abc', ...]
```

The first list contains UTF-8-encoded filenames, and the second list contains the Unicode versions.

Note that on most occasions, the Unicode APIs should be used. The bytes APIs should only be used on systems where undecodable file names can be present, i.e. Unix systems.

3.2 Tips for Writing Unicode-aware Programs

This section provides some suggestions on writing software that deals with Unicode.

The most important tip is:

> Software should only work with Unicode strings internally, decoding the input data as soon as possible and encoding the output only at the end.

If you attempt to write processing functions that accept both Unicode and byte strings, you will find your program vulnerable to bugs wherever you combine the two different kinds of strings. There is no automatic encoding or decoding: if you do e.g. `str + bytes`, a `TypeError` will be raised.

When using data coming from a web browser or some other untrusted source, a common technique is to check for illegal characters in a string before using the string in a generated command line or storing it in a database. If you're doing this, be careful to check the decoded string, not the encoded bytes data; some encodings may have interesting properties, such as not being bijective or not being fully ASCII-compatible. This is especially true if the input data also specifies the encoding, since the attacker can then choose a clever way to hide malicious text in the encoded bytestream.

Converting Between File Encodings

The `StreamRecoder` class can transparently convert between encodings, taking a stream that returns data in encoding #1 and behaving like a stream returning data in encoding #2.

For example, if you have an input file *f* that's in Latin-1, you can wrap it with a `StreamRecoder` to return bytes encoded in UTF-8:

```
new_f = codecs.StreamRecoder(f,
    # en/decoder: used by read() to encode its results and
    # by write() to decode its input.
    codecs.getencoder('utf-8'), codecs.getdecoder('utf-8'),

    # reader/writer: used to read and write to the stream.
    codecs.getreader('latin-1'), codecs.getwriter('latin-1') )
```

Files in an Unknown Encoding

What can you do if you need to make a change to a file, but don't know the file's encoding? If you know the encoding is ASCII-compatible and only want to examine or modify the ASCII parts, you can open the file with the `surrogateescape` error handler:

```
with open(fname, 'r', encoding="ascii", errors="surrogateescape") as f:
    data = f.read()

# make changes to the string 'data'

with open(fname + '.new', 'w',
          encoding="ascii", errors="surrogateescape") as f:
    f.write(data)
```

The `surrogateescape` error handler will decode any non-ASCII bytes as code points in the Unicode Private Use Area ranging from U+DC80 to U+DCFF. These private code points will then be turned back into the same bytes when the `surrogateescape` error handler is used when encoding the data and writing it back out.

3.3 References

One section of Mastering Python 3 Input/Output, a PyCon 2010 talk by David Beazley, discusses text processing and binary data handling.

The PDF slides for Marc-André Lemburg's presentation "Writing Unicode-aware Applications in Python" discuss questions of character encodings as well as how to internationalize and localize an application. These slides cover Python 2.x only.

The Guts of Unicode in Python is a PyCon 2013 talk by Benjamin Peterson that discusses the internal Unicode representation in Python 3.3.

4 Acknowledgements

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Sorting HOW TO

Release 3.7.0

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and the Python development team

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Release 0.1

Python lists have a built-in `list.sort()` method that modifies the list in-place. There is also a `sorted()` built-in function that builds a new sorted list from an iterable.

In this document, we explore the various techniques for sorting data using Python.

1 Sorting Basics

A simple ascending sort is very easy: just call the `sorted()` function. It returns a new sorted list:

```
>>> sorted([5, 2, 3, 1, 4])
[1, 2, 3, 4, 5]
```

You can also use the `list.sort()` method. It modifies the list in-place (and returns `None` to avoid confusion). Usually it's less convenient than `sorted()` - but if you don't need the original list, it's slightly more efficient.

```
>>> a = [5, 2, 3, 1, 4]
>>> a.sort()
>>> a
[1, 2, 3, 4, 5]
```

Another difference is that the `list.sort()` method is only defined for lists. In contrast, the `sorted()` function accepts any iterable.

```
>>> sorted({1: 'D', 2: 'B', 3: 'B', 4: 'E', 5: 'A'})
[1, 2, 3, 4, 5]
```

2 Key Functions

Both `list.sort()` and `sorted()` have a *key* parameter to specify a function to be called on each list element prior to making comparisons.

For example, here's a case-insensitive string comparison:

```
>>> sorted("This is a test string from Andrew".split(), key=str.lower)
['a', 'Andrew', 'from', 'is', 'string', 'test', 'This']
```

The value of the *key* parameter should be a function that takes a single argument and returns a key to use for sorting purposes. This technique is fast because the key function is called exactly once for each input record.

A common pattern is to sort complex objects using some of the object's indices as keys. For example:

```
>>> student_tuples = [
...     ('john', 'A', 15),
...     ('jane', 'B', 12),
...     ('dave', 'B', 10),
... ]
>>> sorted(student_tuples, key=lambda student: student[2])   # sort by age
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

The same technique works for objects with named attributes. For example:

```
>>> class Student:
...     def __init__(self, name, grade, age):
...         self.name = name
...         self.grade = grade
...         self.age = age
...     def __repr__(self):
...         return repr((self.name, self.grade, self.age))
```

```
>>> student_objects = [
...     Student('john', 'A', 15),
...     Student('jane', 'B', 12),
...     Student('dave', 'B', 10),
... ]
>>> sorted(student_objects, key=lambda student: student.age)   # sort by age
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

3 Operator Module Functions

The key-function patterns shown above are very common, so Python provides convenience functions to make accessor functions easier and faster. The `operator` module has `itemgetter()`, `attrgetter()`, and a `methodcaller()` function.

Using those functions, the above examples become simpler and faster:

```
>>> from operator import itemgetter, attrgetter
```

```
>>> sorted(student_tuples, key=itemgetter(2))
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

```
>>> sorted(student_objects, key=attrgetter('age'))
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

The operator module functions allow multiple levels of sorting. For example, to sort by *grade* then by *age*:

```
>>> sorted(student_tuples, key=itemgetter(1,2))
[('john', 'A', 15), ('dave', 'B', 10), ('jane', 'B', 12)]
```

```
>>> sorted(student_objects, key=attrgetter('grade', 'age'))
[('john', 'A', 15), ('dave', 'B', 10), ('jane', 'B', 12)]
```

4 Ascending and Descending

Both `list.sort()` and `sorted()` accept a *reverse* parameter with a boolean value. This is used to flag descending sorts. For example, to get the student data in reverse *age* order:

```
>>> sorted(student_tuples, key=itemgetter(2), reverse=True)
[('john', 'A', 15), ('jane', 'B', 12), ('dave', 'B', 10)]
```

```
>>> sorted(student_objects, key=attrgetter('age'), reverse=True)
[('john', 'A', 15), ('jane', 'B', 12), ('dave', 'B', 10)]
```

5 Sort Stability and Complex Sorts

Sorts are guaranteed to be stable. That means that when multiple records have the same key, their original order is preserved.

```
>>> data = [('red', 1), ('blue', 1), ('red', 2), ('blue', 2)]
>>> sorted(data, key=itemgetter(0))
[('blue', 1), ('blue', 2), ('red', 1), ('red', 2)]
```

Notice how the two records for *blue* retain their original order so that `('blue', 1)` is guaranteed to precede `('blue', 2)`.

This wonderful property lets you build complex sorts in a series of sorting steps. For example, to sort the student data by descending *grade* and then ascending *age*, do the *age* sort first and then sort again using *grade*:

```
>>> s = sorted(student_objects, key=attrgetter('age'))     # sort on secondary key
>>> sorted(s, key=attrgetter('grade'), reverse=True)       # now sort on primary key, descending
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

The Timsort algorithm used in Python does multiple sorts efficiently because it can take advantage of any ordering already present in a dataset.

6 The Old Way Using Decorate-Sort-Undecorate

This idiom is called Decorate-Sort-Undecorate after its three steps:

- First, the initial list is decorated with new values that control the sort order.
- Second, the decorated list is sorted.
- Finally, the decorations are removed, creating a list that contains only the initial values in the new order.

For example, to sort the student data by *grade* using the DSU approach:

```
>>> decorated = [(student.grade, i, student) for i, student in enumerate(student_objects)]
>>> decorated.sort()
>>> [student for grade, i, student in decorated]               # undecorate
[('john', 'A', 15), ('jane', 'B', 12), ('dave', 'B', 10)]
```

This idiom works because tuples are compared lexicographically; the first items are compared; if they are the same then the second items are compared, and so on.

It is not strictly necessary in all cases to include the index *i* in the decorated list, but including it gives two benefits:

- The sort is stable – if two items have the same key, their order will be preserved in the sorted list.
- The original items do not have to be comparable because the ordering of the decorated tuples will be determined by at most the first two items. So for example the original list could contain complex numbers which cannot be sorted directly.

Another name for this idiom is Schwartzian transform, after Randal L. Schwartz, who popularized it among Perl programmers.

Now that Python sorting provides key-functions, this technique is not often needed.

7 The Old Way Using the *cmp* Parameter

Many constructs given in this HOWTO assume Python 2.4 or later. Before that, there was no `sorted()` builtin and `list.sort()` took no keyword arguments. Instead, all of the Py2.x versions supported a *cmp* parameter to handle user specified comparison functions.

In Py3.0, the *cmp* parameter was removed entirely (as part of a larger effort to simplify and unify the language, eliminating the conflict between rich comparisons and the `__cmp__()` magic method).

In Py2.x, sort allowed an optional function which can be called for doing the comparisons. That function should take two arguments to be compared and then return a negative value for less-than, return zero if they are equal, or return a positive value for greater-than. For example, we can do:

```
>>> def numeric_compare(x, y):
...     return x - y
>>> sorted([5, 2, 4, 1, 3], cmp=numeric_compare)
[1, 2, 3, 4, 5]
```

Or you can reverse the order of comparison with:

```
>>> def reverse_numeric(x, y):
...     return y - x
>>> sorted([5, 2, 4, 1, 3], cmp=reverse_numeric)
[5, 4, 3, 2, 1]
```

When porting code from Python 2.x to 3.x, the situation can arise when you have the user supplying a comparison function and you need to convert that to a key function. The following wrapper makes that easy to do:

```
def cmp_to_key(mycmp):
    'Convert a cmp= function into a key= function'
    class K:
        def __init__(self, obj, *args):
            self.obj = obj
        def __lt__(self, other):
            return mycmp(self.obj, other.obj) < 0
        def __gt__(self, other):
            return mycmp(self.obj, other.obj) > 0
        def __eq__(self, other):
            return mycmp(self.obj, other.obj) == 0
        def __le__(self, other):
            return mycmp(self.obj, other.obj) <= 0
        def __ge__(self, other):
            return mycmp(self.obj, other.obj) >= 0
        def __ne__(self, other):
            return mycmp(self.obj, other.obj) != 0
    return K
```

To convert to a key function, just wrap the old comparison function:

```
>>> sorted([5, 2, 4, 1, 3], key=cmp_to_key(reverse_numeric))
[5, 4, 3, 2, 1]
```

In Python 3.2, the `functools.cmp_to_key()` function was added to the `functools` module in the standard library.

8 Odd and Ends

- For locale aware sorting, use `locale.strxfrm()` for a key function or `locale.strcoll()` for a comparison function.
- The *reverse* parameter still maintains sort stability (so that records with equal keys retain the original order). Interestingly, that effect can be simulated without the parameter by using the builtin `reversed()` function twice:

```
>>> data = [('red', 1), ('blue', 1), ('red', 2), ('blue', 2)]
>>> standard_way = sorted(data, key=itemgetter(0), reverse=True)
>>> double_reversed = list(reversed(sorted(reversed(data), key=itemgetter(0))))
```

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```
>>> assert standard_way == double_reversed
>>> standard_way
[('red', 1), ('red', 2), ('blue', 1), ('blue', 2)]
```

- The sort routines are guaranteed to use `__lt__()` when making comparisons between two objects. So, it is easy to add a standard sort order to a class by defining an `__lt__()` method:

```
>>> Student.__lt__ = lambda self, other: self.age < other.age
>>> sorted(student_objects)
[('dave', 'B', 10), ('jane', 'B', 12), ('john', 'A', 15)]
```

- Key functions need not depend directly on the objects being sorted. A key function can also access external resources. For instance, if the student grades are stored in a dictionary, they can be used to sort a separate list of student names:

```
>>> students = ['dave', 'john', 'jane']
>>> newgrades = {'john': 'F', 'jane':'A', 'dave': 'C'}
>>> sorted(students, key=newgrades.__getitem__)
['jane', 'dave', 'john']
```

Socket Programming HOWTO

Release 3.7.0

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and the Python development team

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Author Gordon McMillan

Abstract

Sockets are used nearly everywhere, but are one of the most severely misunderstood technologies around. This is a 10,000 foot overview of sockets. It's not really a tutorial - you'll still have work to do in getting things operational. It doesn't cover the fine points (and there are a lot of them), but I hope it will give you enough background to begin using them decently.

1 Sockets

I'm only going to talk about INET (i.e. IPv4) sockets, but they account for at least 99% of the sockets in use. And I'll only talk about STREAM (i.e. TCP) sockets - unless you really know what you're doing (in

which case this HOWTO isn't for you!), you'll get better behavior and performance from a STREAM socket than anything else. I will try to clear up the mystery of what a socket is, as well as some hints on how to work with blocking and non-blocking sockets. But I'll start by talking about blocking sockets. You'll need to know how they work before dealing with non-blocking sockets.

Part of the trouble with understanding these things is that "socket" can mean a number of subtly different things, depending on context. So first, let's make a distinction between a "client" socket - an endpoint of a conversation, and a "server" socket, which is more like a switchboard operator. The client application (your browser, for example) uses "client" sockets exclusively; the web server it's talking to uses both "server" sockets and "client" sockets.

1.1 History

Of the various forms of IPC (Inter Process Communication), sockets are by far the most popular. On any given platform, there are likely to be other forms of IPC that are faster, but for cross-platform communication, sockets are about the only game in town.

They were invented in Berkeley as part of the BSD flavor of Unix. They spread like wildfire with the Internet. With good reason — the combination of sockets with INET makes talking to arbitrary machines around the world unbelievably easy (at least compared to other schemes).

2 Creating a Socket

Roughly speaking, when you clicked on the link that brought you to this page, your browser did something like the following:

```
# create an INET, STREAMing socket
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
# now connect to the web server on port 80 - the normal http port
s.connect(("www.python.org", 80))
```

When the `connect` completes, the socket `s` can be used to send in a request for the text of the page. The same socket will read the reply, and then be destroyed. That's right, destroyed. Client sockets are normally only used for one exchange (or a small set of sequential exchanges).

What happens in the web server is a bit more complex. First, the web server creates a "server socket":

```
# create an INET, STREAMing socket
serversocket = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
# bind the socket to a public host, and a well-known port
serversocket.bind((socket.gethostname(), 80))
# become a server socket
serversocket.listen(5)
```

A couple things to notice: we used `socket.gethostname()` so that the socket would be visible to the outside world. If we had used `s.bind(('localhost', 80))` or `s.bind(('127.0.0.1', 80))` we would still have a "server" socket, but one that was only visible within the same machine. `s.bind(('', 80))` specifies that the socket is reachable by any address the machine happens to have.

A second thing to note: low number ports are usually reserved for "well known" services (HTTP, SNMP etc). If you're playing around, use a nice high number (4 digits).

Finally, the argument to `listen` tells the socket library that we want it to queue up as many as 5 connect requests (the normal max) before refusing outside connections. If the rest of the code is written properly, that should be plenty.

Now that we have a "server" socket, listening on port 80, we can enter the mainloop of the web server:

```
while True:
    # accept connections from outside
    (clientsocket, address) = serversocket.accept()
    # now do something with the clientsocket
    # in this case, we'll pretend this is a threaded server
    ct = client_thread(clientsocket)
    ct.run()
```

There's actually 3 general ways in which this loop could work - dispatching a thread to handle `clientsocket`, create a new process to handle `clientsocket`, or restructure this app to use non-blocking sockets, and multiplex between our "server" socket and any active `clientsocket`s using `select`. More about that later. The important thing to understand now is this: this is *all* a "server" socket does. It doesn't send any data. It doesn't receive any data. It just produces "client" sockets. Each `clientsocket` is created in response to some *other* "client" socket doing a `connect()` to the host and port we're bound to. As soon as we've created that `clientsocket`, we go back to listening for more connections. The two "clients" are free to chat it up - they are using some dynamically allocated port which will be recycled when the conversation ends.

2.1 IPC

If you need fast IPC between two processes on one machine, you should look into pipes or shared memory. If you do decide to use AF_INET sockets, bind the "server" socket to `'localhost'`. On most platforms, this will take a shortcut around a couple of layers of network code and be quite a bit faster.

See also:

The `multiprocessing` integrates cross-platform IPC into a higher-level API.

3 Using a Socket

The first thing to note, is that the web browser's "client" socket and the web server's "client" socket are identical beasts. That is, this is a "peer to peer" conversation. Or to put it another way, *as the designer, you will have to decide what the rules of etiquette are for a conversation*. Normally, the `connect`ing socket starts the conversation, by sending in a request, or perhaps a signon. But that's a design decision - it's not a rule of sockets.

Now there are two sets of verbs to use for communication. You can use `send` and `recv`, or you can transform your client socket into a file-like beast and use `read` and `write`. The latter is the way Java presents its sockets. I'm not going to talk about it here, except to warn you that you need to use `flush` on sockets. These are buffered "files", and a common mistake is to `write` something, and then `read` for a reply. Without a `flush` in there, you may wait forever for the reply, because the request may still be in your output buffer.

Now we come to the major stumbling block of sockets - `send` and `recv` operate on the network buffers. They do not necessarily handle all the bytes you hand them (or expect from them), because their major focus is handling the network buffers. In general, they return when the associated network buffers have been filled (`send`) or emptied (`recv`). They then tell you how many bytes they handled. It is *your* responsibility to call them again until your message has been completely dealt with.

When a `recv` returns 0 bytes, it means the other side has closed (or is in the process of closing) the connection. You will not receive any more data on this connection. Ever. You may be able to send data successfully; I'll talk more about this later.

A protocol like HTTP uses a socket for only one transfer. The client sends a request, then reads a reply. That's it. The socket is discarded. This means that a client can detect the end of the reply by receiving 0 bytes.

But if you plan to reuse your socket for further transfers, you need to realize that *there is no* EOT (End of Transfer) *on a socket.* I repeat: if a socket `send` or `recv` returns after handling 0 bytes, the connection has been broken. If the connection has *not* been broken, you may wait on a `recv` forever, because the socket will *not* tell you that there's nothing more to read (for now). Now if you think about that a bit, you'll come to realize a fundamental truth of sockets: *messages must either be fixed length* (yuck), *or be delimited* (shrug), *or indicate how long they are* (much better), *or end by shutting down the connection.* The choice is entirely yours, (but some ways are righter than others).

Assuming you don't want to end the connection, the simplest solution is a fixed length message:

```
class MySocket:
    """demonstration class only
      - coded for clarity, not efficiency
    """

    def __init__(self, sock=None):
        if sock is None:
            self.sock = socket.socket(
                            socket.AF_INET, socket.SOCK_STREAM)
        else:
            self.sock = sock

    def connect(self, host, port):
        self.sock.connect((host, port))

    def mysend(self, msg):
        totalsent = 0
        while totalsent < MSGLEN:
            sent = self.sock.send(msg[totalsent:])
            if sent == 0:
                raise RuntimeError("socket connection broken")
            totalsent = totalsent + sent

    def myreceive(self):
        chunks = []
        bytes_recd = 0
        while bytes_recd < MSGLEN:
            chunk = self.sock.recv(min(MSGLEN - bytes_recd, 2048))
            if chunk == b'':
                raise RuntimeError("socket connection broken")
            chunks.append(chunk)
            bytes_recd = bytes_recd + len(chunk)
        return b''.join(chunks)
```

The sending code here is usable for almost any messaging scheme - in Python you send strings, and you can use `len()` to determine its length (even if it has embedded `\0` characters). It's mostly the receiving code that gets more complex. (And in C, it's not much worse, except you can't use `strlen` if the message has embedded `\0`s.)

The easiest enhancement is to make the first character of the message an indicator of message type, and have the type determine the length. Now you have two `recv`s - the first to get (at least) that first character so you can look up the length, and the second in a loop to get the rest. If you decide to go the delimited route, you'll be receiving in some arbitrary chunk size, (4096 or 8192 is frequently a good match for network buffer sizes), and scanning what you've received for a delimiter.

One complication to be aware of: if your conversational protocol allows multiple messages to be sent back to back (without some kind of reply), and you pass `recv` an arbitrary chunk size, you may end up reading the start of a following message. You'll need to put that aside and hold onto it, until it's needed.

Prefixing the message with its length (say, as 5 numeric characters) gets more complex, because (believe it or not), you may not get all 5 characters in one `recv`. In playing around, you'll get away with it; but in high network loads, your code will very quickly break unless you use two `recv` loops - the first to determine the length, the second to get the data part of the message. Nasty. This is also when you'll discover that `send` does not always manage to get rid of everything in one pass. And despite having read this, you will eventually get bit by it!

In the interests of space, building your character, (and preserving my competitive position), these enhancements are left as an exercise for the reader. Lets move on to cleaning up.

3.1 Binary Data

It is perfectly possible to send binary data over a socket. The major problem is that not all machines use the same formats for binary data. For example, a Motorola chip will represent a 16 bit integer with the value 1 as the two hex bytes 00 01. Intel and DEC, however, are byte-reversed - that same 1 is 01 00. Socket libraries have calls for converting 16 and 32 bit integers - `ntohl, htonl, ntohs, htons` where "n" means *network* and "h" means *host*, "s" means *short* and "l" means *long*. Where network order is host order, these do nothing, but where the machine is byte-reversed, these swap the bytes around appropriately.

In these days of 32 bit machines, the ascii representation of binary data is frequently smaller than the binary representation. That's because a surprising amount of the time, all those longs have the value 0, or maybe 1. The string "0" would be two bytes, while binary is four. Of course, this doesn't fit well with fixed-length messages. Decisions, decisions.

4 Disconnecting

Strictly speaking, you're supposed to use `shutdown` on a socket before you `close` it. The `shutdown` is an advisory to the socket at the other end. Depending on the argument you pass it, it can mean "I'm not going to send anymore, but I'll still listen", or "I'm not listening, good riddance!". Most socket libraries, however, are so used to programmers neglecting to use this piece of etiquette that normally a `close` is the same as `shutdown(); close()`. So in most situations, an explicit `shutdown` is not needed.

One way to use `shutdown` effectively is in an HTTP-like exchange. The client sends a request and then does a `shutdown(1)`. This tells the server "This client is done sending, but can still receive." The server can detect "EOF" by a receive of 0 bytes. It can assume it has the complete request. The server sends a reply. If the `send` completes successfully then, indeed, the client was still receiving.

Python takes the automatic shutdown a step further, and says that when a socket is garbage collected, it will automatically do a `close` if it's needed. But relying on this is a very bad habit. If your socket just disappears without doing a `close`, the socket at the other end may hang indefinitely, thinking you're just being slow. *Please* `close` your sockets when you're done.

4.1 When Sockets Die

Probably the worst thing about using blocking sockets is what happens when the other side comes down hard (without doing a `close`). Your socket is likely to hang. TCP is a reliable protocol, and it will wait a long, long time before giving up on a connection. If you're using threads, the entire thread is essentially dead. There's not much you can do about it. As long as you aren't doing something dumb, like holding a lock while doing a blocking read, the thread isn't really consuming much in the way of resources. Do *not* try to kill the thread - part of the reason that threads are more efficient than processes is that they avoid the overhead associated with the automatic recycling of resources. In other words, if you do manage to kill the thread, your whole process is likely to be screwed up.

5 Non-blocking Sockets

If you've understood the preceding, you already know most of what you need to know about the mechanics of using sockets. You'll still use the same calls, in much the same ways. It's just that, if you do it right, your app will be almost inside-out.

In Python, you use `socket.setblocking(0)` to make it non-blocking. In C, it's more complex, (for one thing, you'll need to choose between the BSD flavor `O_NONBLOCK` and the almost indistinguishable Posix flavor `O_NDELAY`, which is completely different from `TCP_NODELAY`), but it's the exact same idea. You do this after creating the socket, but before using it. (Actually, if you're nuts, you can switch back and forth.)

The major mechanical difference is that `send`, `recv`, `connect` and `accept` can return without having done anything. You have (of course) a number of choices. You can check return code and error codes and generally drive yourself crazy. If you don't believe me, try it sometime. Your app will grow large, buggy and suck CPU. So let's skip the brain-dead solutions and do it right.

Use `select`.

In C, coding `select` is fairly complex. In Python, it's a piece of cake, but it's close enough to the C version that if you understand `select` in Python, you'll have little trouble with it in C:

```
ready_to_read, ready_to_write, in_error = \
               select.select(
                  potential_readers,
                  potential_writers,
                  potential_errs,
                  timeout)
```

You pass `select` three lists: the first contains all sockets that you might want to try reading; the second all the sockets you might want to try writing to, and the last (normally left empty) those that you want to check for errors. You should note that a socket can go into more than one list. The `select` call is blocking, but you can give it a timeout. This is generally a sensible thing to do - give it a nice long timeout (say a minute) unless you have good reason to do otherwise.

In return, you will get three lists. They contain the sockets that are actually readable, writable and in error. Each of these lists is a subset (possibly empty) of the corresponding list you passed in.

If a socket is in the output readable list, you can be as-close-to-certain-as-we-ever-get-in-this-business that a `recv` on that socket will return *something*. Same idea for the writable list. You'll be able to send *something*. Maybe not all you want to, but *something* is better than nothing. (Actually, any reasonably healthy socket will return as writable - it just means outbound network buffer space is available.)

If you have a "server" socket, put it in the potential_readers list. If it comes out in the readable list, your `accept` will (almost certainly) work. If you have created a new socket to `connect` to someone else, put it in the potential_writers list. If it shows up in the writable list, you have a decent chance that it has connected.

Actually, `select` can be handy even with blocking sockets. It's one way of determining whether you will block - the socket returns as readable when there's something in the buffers. However, this still doesn't help with the problem of determining whether the other end is done, or just busy with something else.

Portability alert: On Unix, `select` works both with the sockets and files. Don't try this on Windows. On Windows, `select` works with sockets only. Also note that in C, many of the more advanced socket options are done differently on Windows. In fact, on Windows I usually use threads (which work very, very well) with my sockets.

Regular Expression HOWTO

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Abstract

This document is an introductory tutorial to using regular expressions in Python with the `re` module. It provides a gentler introduction than the corresponding section in the Library Reference.

1 Introduction

Regular expressions (called REs, or regexes, or regex patterns) are essentially a tiny, highly specialized programming language embedded inside Python and made available through the `re` module. Using this little language, you specify the rules for the set of possible strings that you want to match; this set might contain English sentences, or e-mail addresses, or TeX commands, or anything you like. You can then ask questions such as "Does this string match the pattern?", or "Is there a match for the pattern anywhere in this string?". You can also use REs to modify a string or to split it apart in various ways.

Regular expression patterns are compiled into a series of bytecodes which are then executed by a matching engine written in C. For advanced use, it may be necessary to pay careful attention to how the engine will execute a given RE, and write the RE in a certain way in order to produce bytecode that runs faster. Optimization isn't covered in this document, because it requires that you have a good understanding of the matching engine's internals.

The regular expression language is relatively small and restricted, so not all possible string processing tasks can be done using regular expressions. There are also tasks that *can* be done with regular expressions, but the expressions turn out to be very complicated. In these cases, you may be better off writing Python code to do the processing; while Python code will be slower than an elaborate regular expression, it will also probably be more understandable.

2 Simple Patterns

We'll start by learning about the simplest possible regular expressions. Since regular expressions are used to operate on strings, we'll begin with the most common task: matching characters.

For a detailed explanation of the computer science underlying regular expressions (deterministic and non-deterministic finite automata), you can refer to almost any textbook on writing compilers.

2.1 Matching Characters

Most letters and characters will simply match themselves. For example, the regular expression `test` will match the string `test` exactly. (You can enable a case-insensitive mode that would let this RE match `Test` or `TEST` as well; more about this later.)

There are exceptions to this rule; some characters are special *metacharacters*, and don't match themselves. Instead, they signal that some out-of-the-ordinary thing should be matched, or they affect other portions of the RE by repeating them or changing their meaning. Much of this document is devoted to discussing various metacharacters and what they do.

Here's a complete list of the metacharacters; their meanings will be discussed in the rest of this HOWTO.

```
. ^ $ * + ? { } [ ] \ | ( )
```

The first metacharacters we'll look at are `[` and `]`. They're used for specifying a character class, which is a set of characters that you wish to match. Characters can be listed individually, or a range of characters can be indicated by giving two characters and separating them by a `'-'`. For example, `[abc]` will match any of the characters `a`, `b`, or `c`; this is the same as `[a-c]`, which uses a range to express the same set of characters. If you wanted to match only lowercase letters, your RE would be `[a-z]`.

Metacharacters are not active inside classes. For example, `[akm$]` will match any of the characters `'a'`, `'k'`, `'m'`, or `'$'`; `'$'` is usually a metacharacter, but inside a character class it's stripped of its special nature.

You can match the characters not listed within the class by *complementing* the set. This is indicated by including a `'^'` as the first character of the class; `'^'` outside a character class will simply match the `'^'` character. For example, `[^5]` will match any character except `'5'`.

Perhaps the most important metacharacter is the backslash, `\`. As in Python string literals, the backslash can be followed by various characters to signal various special sequences. It's also used to escape all the metacharacters so you can still match them in patterns; for example, if you need to match a `[` or `\`, you can precede them with a backslash to remove their special meaning: `\[` or `\\`.

Some of the special sequences beginning with `'\'` represent predefined sets of characters that are often useful, such as the set of digits, the set of letters, or the set of anything that isn't whitespace.

Let's take an example: `\w` matches any alphanumeric character. If the regex pattern is expressed in bytes, this is equivalent to the class `[a-zA-Z0-9_]`. If the regex pattern is a string, `\w` will match all the characters marked as letters in the Unicode database provided by the `unicodedata` module. You can use the more restricted definition of `\w` in a string pattern by supplying the `re.ASCII` flag when compiling the regular expression.

The following list of special sequences isn't complete. For a complete list of sequences and expanded class definitions for Unicode string patterns, see the last part of Regular Expression Syntax in the Standard Library reference. In general, the Unicode versions match any character that's in the appropriate category in the Unicode database.

`\d` Matches any decimal digit; this is equivalent to the class `[0-9]`.

`\D` Matches any non-digit character; this is equivalent to the class `[^0-9]`.

`\s` Matches any whitespace character; this is equivalent to the class `[ \t\n\r\f\v]`.

`\S` Matches any non-whitespace character; this is equivalent to the class `[^ \t\n\r\f\v]`.

`\w` Matches any alphanumeric character; this is equivalent to the class `[a-zA-Z0-9_]`.

`\W` Matches any non-alphanumeric character; this is equivalent to the class `[^a-zA-Z0-9_]`.

These sequences can be included inside a character class. For example, `[\s,.]` is a character class that will match any whitespace character, or `','` or `'.'`.

The final metacharacter in this section is `.`. It matches anything except a newline character, and there's an alternate mode (`re.DOTALL`) where it will match even a newline. `.` is often used where you want to match "any character".

2.2 Repeating Things

Being able to match varying sets of characters is the first thing regular expressions can do that isn't already possible with the methods available on strings. However, if that was the only additional capability of regexes, they wouldn't be much of an advance. Another capability is that you can specify that portions of the RE must be repeated a certain number of times.

The first metacharacter for repeating things that we'll look at is `*`. `*` doesn't match the literal character `'*'`; instead, it specifies that the previous character can be matched zero or more times, instead of exactly once.

For example, `ca*t` will match `'ct'` (0 `'a'` characters), `'cat'` (1 `'a'`), `'caaat'` (3 `'a'` characters), and so forth.

Repetitions such as `*` are *greedy*; when repeating a RE, the matching engine will try to repeat it as many times as possible. If later portions of the pattern don't match, the matching engine will then back up and try again with fewer repetitions.

A step-by-step example will make this more obvious. Let's consider the expression `a[bcd]*b`. This matches the letter `'a'`, zero or more letters from the class `[bcd]`, and finally ends with a `'b'`. Now imagine matching this RE against the string `'abcbd'`.

Step	Matched	Explanation
1	`a`	The `a` in the RE matches.
2	`abcbd`	The engine matches `[bcd]*`, going as far as it can, which is to the end of the string.
3	*Failure*	The engine tries to match `b`, but the current position is at the end of the string, so it fails.
4	`abcb`	Back up, so that `[bcd]*` matches one less character.
5	*Failure*	Try `b` again, but the current position is at the last character, which is a `'d'`.
6	`abc`	Back up again, so that `[bcd]*` is only matching `bc`.
6	`abcb`	Try `b` again. This time the character at the current position is `'b'`, so it succeeds.

The end of the RE has now been reached, and it has matched `'abcb'`. This demonstrates how the matching engine goes as far as it can at first, and if no match is found it will then progressively back up and retry the rest of the RE again and again. It will back up until it has tried zero matches for `[bcd]*`, and if that subsequently fails, the engine will conclude that the string doesn't match the RE at all.

Another repeating metacharacter is `+`, which matches one or more times. Pay careful attention to the difference between `*` and `+`; `*` matches *zero* or more times, so whatever's being repeated may not be present at all, while `+` requires at least *one* occurrence. To use a similar example, `ca+t` will match `'cat'` (1 `'a'`), `'caaat'` (3 `'a'`s), but won't match `'ct'`.

There are two more repeating qualifiers. The question mark character, `?`, matches either once or zero times; you can think of it as marking something as being optional. For example, `home-?brew` matches either `'homebrew'` or `'home-brew'`.

The most complicated repeated qualifier is `{m,n}`, where m and n are decimal integers. This qualifier means there must be at least m repetitions, and at most n. For example, `a/{1,3}b` will match `'a/b'`, `'a//b'`, and `'a///b'`. It won't match `'ab'`, which has no slashes, or `'a////b'`, which has four.

You can omit either m or n; in that case, a reasonable value is assumed for the missing value. Omitting m is interpreted as a lower limit of 0, while omitting n results in an upper bound of infinity.

Readers of a reductionist bent may notice that the three other qualifiers can all be expressed using this notation. `{0,}` is the same as `*`, `{1,}` is equivalent to `+`, and `{0,1}` is the same as `?`. It's better to use `*`, `+`, or `?` when you can, simply because they're shorter and easier to read.

3 Using Regular Expressions

Now that we've looked at some simple regular expressions, how do we actually use them in Python? The `re` module provides an interface to the regular expression engine, allowing you to compile REs into objects and then perform matches with them.

3.1 Compiling Regular Expressions

Regular expressions are compiled into pattern objects, which have methods for various operations such as searching for pattern matches or performing string substitutions.

```
>>> import re
>>> p = re.compile('ab*')
>>> p
re.compile('ab*')
```

`re.compile()` also accepts an optional *flags* argument, used to enable various special features and syntax variations. We'll go over the available settings later, but for now a single example will do:

```
>>> p = re.compile('ab*', re.IGNORECASE)
```

The RE is passed to `re.compile()` as a string. REs are handled as strings because regular expressions aren't part of the core Python language, and no special syntax was created for expressing them. (There are applications that don't need REs at all, so there's no need to bloat the language specification by including them.) Instead, the `re` module is simply a C extension module included with Python, just like the `socket` or `zlib` modules.

Putting REs in strings keeps the Python language simpler, but has one disadvantage which is the topic of the next section.

3.2 The Backslash Plague

As stated earlier, regular expressions use the backslash character (`'\'`) to indicate special forms or to allow special characters to be used without invoking their special meaning. This conflicts with Python's usage of the same character for the same purpose in string literals.

Let's say you want to write a RE that matches the string `\section`, which might be found in a LaTeX file. To figure out what to write in the program code, start with the desired string to be matched. Next, you must escape any backslashes and other metacharacters by preceding them with a backslash, resulting in the string `\\section`. The resulting string that must be passed to `re.compile()` must be `\\section`. However, to express this as a Python string literal, both backslashes must be escaped *again*.

Characters	Stage
`\section`	Text string to be matched
`\\section`	Escaped backslash for `re.compile()`
`"\\\\section"`	Escaped backslashes for a string literal

In short, to match a literal backslash, one has to write `'\\\\'` as the RE string, because the regular expression must be \\, and each backslash must be expressed as \\ inside a regular Python string literal. In REs that feature backslashes repeatedly, this leads to lots of repeated backslashes and makes the resulting strings difficult to understand.

The solution is to use Python's raw string notation for regular expressions; backslashes are not handled in any special way in a string literal prefixed with `'r'`, so `r"\n"` is a two-character string containing `'\'` and `'n'`, while `"\n"` is a one-character string containing a newline. Regular expressions will often be written in Python code using this raw string notation.

In addition, special escape sequences that are valid in regular expressions, but not valid as Python string literals, now result in a `DeprecationWarning` and will eventually become a `SyntaxError`, which means the sequences will be invalid if raw string notation or escaping the backslashes isn't used.

Regular String	Raw string
"ab*"	r"ab*"
"\\\\section"	r"\\section"
"\\w+\\s+\\1"	r"\w+\s+\1"

3.3 Performing Matches

Once you have an object representing a compiled regular expression, what do you do with it? Pattern objects have several methods and attributes. Only the most significant ones will be covered here; consult the `re` docs for a complete listing.

Method/Attribute	Purpose
`match()`	Determine if the RE matches at the beginning of the string.
`search()`	Scan through a string, looking for any location where this RE matches.
`findall()`	Find all substrings where the RE matches, and returns them as a list.
`finditer()`	Find all substrings where the RE matches, and returns them as an iterator.

`match()` and `search()` return `None` if no match can be found. If they're successful, a match object instance is returned, containing information about the match: where it starts and ends, the substring it matched, and more.

You can learn about this by interactively experimenting with the `re` module. If you have `tkinter` available, you may also want to look at Tools/demo/redemo.py, a demonstration program included with the Python distribution. It allows you to enter REs and strings, and displays whether the RE matches or fails. `redemo.py` can be quite useful when trying to debug a complicated RE.

This HOWTO uses the standard Python interpreter for its examples. First, run the Python interpreter, import the `re` module, and compile a RE:

```
>>> import re
>>> p = re.compile('[a-z]+')
>>> p
re.compile('[a-z]+')
```

Now, you can try matching various strings against the RE `[a-z]+`. An empty string shouldn't match at all, since `+` means 'one or more repetitions'. `match()` should return `None` in this case, which will cause the interpreter to print no output. You can explicitly print the result of `match()` to make this clear.

```
>>> p.match("")
>>> print(p.match(""))
None
```

Now, let's try it on a string that it should match, such as `tempo`. In this case, `match()` will return a match object, so you should store the result in a variable for later use.

```
>>> m = p.match('tempo')
>>> m
<re.Match object; span=(0, 5), match='tempo'>
```

Now you can query the match object for information about the matching string. Match object instances also have several methods and attributes; the most important ones are:

Method/Attribute	Purpose
`group()`	Return the string matched by the RE
`start()`	Return the starting position of the match
`end()`	Return the ending position of the match
`span()`	Return a tuple containing the (start, end) positions of the match

Trying these methods will soon clarify their meaning:

```
>>> m.group()
'tempo'
>>> m.start(), m.end()
(0, 5)
>>> m.span()
(0, 5)
```

`group()` returns the substring that was matched by the RE. `start()` and `end()` return the starting and ending index of the match. `span()` returns both start and end indexes in a single tuple. Since the `match()` method only checks if the RE matches at the start of a string, `start()` will always be zero. However, the `search()` method of patterns scans through the string, so the match may not start at zero in that case.

```
>>> print(p.match('::: message'))
None
>>> m = p.search('::: message'); print(m)
<re.Match object; span=(4, 11), match='message'>
>>> m.group()
'message'
>>> m.span()
(4, 11)
```

In actual programs, the most common style is to store the match object in a variable, and then check if it was `None`. This usually looks like:

```
p = re.compile( ... )
m = p.match( 'string goes here' )
if m:
    print('Match found: ', m.group())
else:
    print('No match')
```

Two pattern methods return all of the matches for a pattern. `findall()` returns a list of matching strings:

```
>>> p = re.compile(r'\d+')
>>> p.findall('12 drummers drumming, 11 pipers piping, 10 lords a-leaping')
['12', '11', '10']
```

The `r` prefix, making the literal a raw string literal, is needed in this example because escape sequences in a normal "cooked" string literal that are not recognized by Python, as opposed to regular expressions, now result in a `DeprecationWarning` and will eventually become a `SyntaxError`. See *The Backslash Plague*.

`findall()` has to create the entire list before it can be returned as the result. The `finditer()` method returns a sequence of match object instances as an iterator:

```
>>> iterator = p.finditer('12 drummers drumming, 11 ... 10 ...')
>>> iterator
<callable_iterator object at 0x...>
>>> for match in iterator:
```

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```
...     print(match.span())
...
(0, 2)
(22, 24)
(29, 31)
```

3.4 Module-Level Functions

You don't have to create a pattern object and call its methods; the `re` module also provides top-level functions called `match()`, `search()`, `findall()`, `sub()`, and so forth. These functions take the same arguments as the corresponding pattern method with the RE string added as the first argument, and still return either `None` or a match object instance.

```
>>> print(re.match(r'From\s+', 'Fromage amk'))
None
>>> re.match(r'From\s+', 'From amk Thu May 14 19:12:10 1998')
<re.Match object; span=(0, 5), match='From '>
```

Under the hood, these functions simply create a pattern object for you and call the appropriate method on it. They also store the compiled object in a cache, so future calls using the same RE won't need to parse the pattern again and again.

Should you use these module-level functions, or should you get the pattern and call its methods yourself? If you're accessing a regex within a loop, pre-compiling it will save a few function calls. Outside of loops, there's not much difference thanks to the internal cache.

3.5 Compilation Flags

Compilation flags let you modify some aspects of how regular expressions work. Flags are available in the `re` module under two names, a long name such as `IGNORECASE` and a short, one-letter form such as `I`. (If you're familiar with Perl's pattern modifiers, the one-letter forms use the same letters; the short form of `re.VERBOSE` is `re.X`, for example.) Multiple flags can be specified by bitwise OR-ing them; `re.I | re.M` sets both the `I` and `M` flags, for example.

Here's a table of the available flags, followed by a more detailed explanation of each one.

Flag	Meaning
`ASCII`, `A`	Makes several escapes like `\w`, `\b`, `\s` and `\d` match only on ASCII characters with the respective property.
`DOTALL`, `S`	Make `.` match any character, including newlines.
`IGNORECASE`, `I`	Do case-insensitive matches.
`LOCALE`, `L`	Do a locale-aware match.
`MULTILINE`, `M`	Multi-line matching, affecting `^` and `$`.
`VERBOSE`, `X` (for 'extended')	Enable verbose REs, which can be organized more cleanly and understandably.

`I`
`IGNORECASE`
: Perform case-insensitive matching; character class and literal strings will match letters by ignoring case. For example, `[A-Z]` will match lowercase letters, too. Full Unicode matching also works unless the `ASCII` flag is used to disable non-ASCII matches. When the Unicode patterns `[a-z]` or `[A-Z]` are used in combination with the `IGNORECASE` flag, they will match the 52 ASCII letters and 4 additional non-ASCII letters: 'İ' (U+0130, Latin capital letter I with dot above), 'ı' (U+0131, Latin small letter

dotless i), 'ſ' (U+017F, Latin small letter long s) and 'K' (U+212A, Kelvin sign). `Spam` will match `'Spam'`, `'spam'`, `'spAM'`, or `'ſpam'` (the latter is matched only in Unicode mode). This lowercasing doesn't take the current locale into account; it will if you also set the `LOCALE` flag.

L
LOCALE

Make `\w`, `\W`, `\b`, `\B` and case-insensitive matching dependent on the current locale instead of the Unicode database.

Locales are a feature of the C library intended to help in writing programs that take account of language differences. For example, if you're processing encoded French text, you'd want to be able to write `\w+` to match words, but `\w` only matches the character class `[A-Za-z]` in bytes patterns; it won't match bytes corresponding to `é` or `ç`. If your system is configured properly and a French locale is selected, certain C functions will tell the program that the byte corresponding to `é` should also be considered a letter. Setting the `LOCALE` flag when compiling a regular expression will cause the resulting compiled object to use these C functions for `\w`; this is slower, but also enables `\w+` to match French words as you'd expect. The use of this flag is discouraged in Python 3 as the locale mechanism is very unreliable, it only handles one "culture" at a time, and it only works with 8-bit locales. Unicode matching is already enabled by default in Python 3 for Unicode (str) patterns, and it is able to handle different locales/languages.

M
MULTILINE

(`^` and `$` haven't been explained yet; they'll be introduced in section *More Metacharacters*.)

Usually `^` matches only at the beginning of the string, and `$` matches only at the end of the string and immediately before the newline (if any) at the end of the string. When this flag is specified, `^` matches at the beginning of the string and at the beginning of each line within the string, immediately following each newline. Similarly, the `$` metacharacter matches either at the end of the string and at the end of each line (immediately preceding each newline).

S
DOTALL

Makes the `'.'` special character match any character at all, including a newline; without this flag, `'.'` will match anything *except* a newline.

A
ASCII

Make `\w`, `\W`, `\b`, `\B`, `\s` and `\S` perform ASCII-only matching instead of full Unicode matching. This is only meaningful for Unicode patterns, and is ignored for byte patterns.

X
VERBOSE

This flag allows you to write regular expressions that are more readable by granting you more flexibility in how you can format them. When this flag has been specified, whitespace within the RE string is ignored, except when the whitespace is in a character class or preceded by an unescaped backslash; this lets you organize and indent the RE more clearly. This flag also lets you put comments within a RE that will be ignored by the engine; comments are marked by a `'#'` that's neither in a character class or preceded by an unescaped backslash.

For example, here's a RE that uses `re.VERBOSE`; see how much easier it is to read?

```
charref = re.compile(r"""
 &[#]                # Start of a numeric entity reference
 (
     0[0-7]+         # Octal form
   | [0-9]+          # Decimal form
   | x[0-9a-fA-F]+   # Hexadecimal form
```

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```
 )
 ;                    # Trailing semicolon
""", re.VERBOSE)
```

Without the verbose setting, the RE would look like this:

```
charref = re.compile("&#(0[0-7]+"
                     "|[0-9]+"
                     "|x[0-9a-fA-F]+);")
```

In the above example, Python's automatic concatenation of string literals has been used to break up the RE into smaller pieces, but it's still more difficult to understand than the version using `re.VERBOSE`.

4 More Pattern Power

So far we've only covered a part of the features of regular expressions. In this section, we'll cover some new metacharacters, and how to use groups to retrieve portions of the text that was matched.

4.1 More Metacharacters

There are some metacharacters that we haven't covered yet. Most of them will be covered in this section.

Some of the remaining metacharacters to be discussed are *zero-width assertions*. They don't cause the engine to advance through the string; instead, they consume no characters at all, and simply succeed or fail. For example, `\b` is an assertion that the current position is located at a word boundary; the position isn't changed by the `\b` at all. This means that zero-width assertions should never be repeated, because if they match once at a given location, they can obviously be matched an infinite number of times.

`|` Alternation, or the "or" operator. If A and B are regular expressions, `A|B` will match any string that matches either A or B. `|` has very low precedence in order to make it work reasonably when you're alternating multi-character strings. `Crow|Servo` will match either `'Crow'` or `'Servo'`, not `'Cro'`, a `'w'` or an `'S'`, and `'ervo'`.

To match a literal `'|'`, use `\|`, or enclose it inside a character class, as in `[|]`.

`^` Matches at the beginning of lines. Unless the `MULTILINE` flag has been set, this will only match at the beginning of the string. In `MULTILINE` mode, this also matches immediately after each newline within the string.

For example, if you wish to match the word `From` only at the beginning of a line, the RE to use is `^From`.

```
>>> print(re.search('^From', 'From Here to Eternity'))
<re.Match object; span=(0, 4), match='From'>
>>> print(re.search('^From', 'Reciting From Memory'))
None
```

To match a literal `'^'`, use `\^`.

`$` Matches at the end of a line, which is defined as either the end of the string, or any location followed by a newline character.

```
>>> print(re.search('}$', '{block}'))
<re.Match object; span=(6, 7), match='}'>
>>> print(re.search('}$', '{block} '))
```

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```
None
>>> print(re.search('}$', '{block}\n'))
<re.Match object; span=(6, 7), match='}'>
```

To match a literal `'$'`, use `\$` or enclose it inside a character class, as in `[$]`.

`\A` Matches only at the start of the string. When not in `MULTILINE` mode, `\A` and `^` are effectively the same. In `MULTILINE` mode, they're different: `\A` still matches only at the beginning of the string, but `^` may match at any location inside the string that follows a newline character.

`\Z` Matches only at the end of the string.

`\b` Word boundary. This is a zero-width assertion that matches only at the beginning or end of a word. A word is defined as a sequence of alphanumeric characters, so the end of a word is indicated by whitespace or a non-alphanumeric character.

The following example matches `class` only when it's a complete word; it won't match when it's contained inside another word.

```
>>> p = re.compile(r'\bclass\b')
>>> print(p.search('no class at all'))
<re.Match object; span=(3, 8), match='class'>
>>> print(p.search('the declassified algorithm'))
None
>>> print(p.search('one subclass is'))
None
```

There are two subtleties you should remember when using this special sequence. First, this is the worst collision between Python's string literals and regular expression sequences. In Python's string literals, `\b` is the backspace character, ASCII value 8. If you're not using raw strings, then Python will convert the `\b` to a backspace, and your RE won't match as you expect it to. The following example looks the same as our previous RE, but omits the `'r'` in front of the RE string.

```
>>> p = re.compile('\bclass\b')
>>> print(p.search('no class at all'))
None
>>> print(p.search('\b' + 'class' + '\b'))
<re.Match object; span=(0, 7), match='\x08class\x08'>
```

Second, inside a character class, where there's no use for this assertion, `\b` represents the backspace character, for compatibility with Python's string literals.

`\B` Another zero-width assertion, this is the opposite of `\b`, only matching when the current position is not at a word boundary.

4.2 Grouping

Frequently you need to obtain more information than just whether the RE matched or not. Regular expressions are often used to dissect strings by writing a RE divided into several subgroups which match different components of interest. For example, an RFC-822 header line is divided into a header name and a value, separated by a `':'`, like this:

```
From: author@example.com
User-Agent: Thunderbird 1.5.0.9 (X11/20061227)
MIME-Version: 1.0
To: editor@example.com
```

This can be handled by writing a regular expression which matches an entire header line, and has one group which matches the header name, and another group which matches the header's value.

Groups are marked by the `'('`, `')'` metacharacters. `'('` and `')'` have much the same meaning as they do in mathematical expressions; they group together the expressions contained inside them, and you can repeat the contents of a group with a repeating qualifier, such as `*`, `+`, `?`, or `{m,n}`. For example, `(ab)*` will match zero or more repetitions of `ab`.

```
>>> p = re.compile('(ab)*')
>>> print(p.match('abababababab').span())
(0, 10)
```

Groups indicated with `'('`, `')'` also capture the starting and ending index of the text that they match; this can be retrieved by passing an argument to `group()`, `start()`, `end()`, and `span()`. Groups are numbered starting with 0. Group 0 is always present; it's the whole RE, so match object methods all have group 0 as their default argument. Later we'll see how to express groups that don't capture the span of text that they match.

```
>>> p = re.compile('(a)b')
>>> m = p.match('ab')
>>> m.group()
'ab'
>>> m.group(0)
'ab'
```

Subgroups are numbered from left to right, from 1 upward. Groups can be nested; to determine the number, just count the opening parenthesis characters, going from left to right.

```
>>> p = re.compile('(a(b)c)d')
>>> m = p.match('abcd')
>>> m.group(0)
'abcd'
>>> m.group(1)
'abc'
>>> m.group(2)
'b'
```

`group()` can be passed multiple group numbers at a time, in which case it will return a tuple containing the corresponding values for those groups.

```
>>> m.group(2,1,2)
('b', 'abc', 'b')
```

The `groups()` method returns a tuple containing the strings for all the subgroups, from 1 up to however many there are.

```
>>> m.groups()
('abc', 'b')
```

Backreferences in a pattern allow you to specify that the contents of an earlier capturing group must also be found at the current location in the string. For example, `\1` will succeed if the exact contents of group 1 can be found at the current position, and fails otherwise. Remember that Python's string literals also use a backslash followed by numbers to allow including arbitrary characters in a string, so be sure to use a raw string when incorporating backreferences in a RE.

For example, the following RE detects doubled words in a string.

```
>>> p = re.compile(r'\b(\w+)\s+\1\b')
>>> p.search('Paris in the the spring').group()
'the the'
```

Backreferences like this aren't often useful for just searching through a string — there are few text formats which repeat data in this way — but you'll soon find out that they're *very* useful when performing string substitutions.

4.3 Non-capturing and Named Groups

Elaborate REs may use many groups, both to capture substrings of interest, and to group and structure the RE itself. In complex REs, it becomes difficult to keep track of the group numbers. There are two features which help with this problem. Both of them use a common syntax for regular expression extensions, so we'll look at that first.

Perl 5 is well known for its powerful additions to standard regular expressions. For these new features the Perl developers couldn't choose new single-keystroke metacharacters or new special sequences beginning with \ without making Perl's regular expressions confusingly different from standard REs. If they chose `&` as a new metacharacter, for example, old expressions would be assuming that `&` was a regular character and wouldn't have escaped it by writing `\&` or `[&]`.

The solution chosen by the Perl developers was to use `(?...)` as the extension syntax. `?` immediately after a parenthesis was a syntax error because the `?` would have nothing to repeat, so this didn't introduce any compatibility problems. The characters immediately after the `?` indicate what extension is being used, so `(?=foo)` is one thing (a positive lookahead assertion) and `(?:foo)` is something else (a non-capturing group containing the subexpression `foo`).

Python supports several of Perl's extensions and adds an extension syntax to Perl's extension syntax. If the first character after the question mark is a `P`, you know that it's an extension that's specific to Python.

Now that we've looked at the general extension syntax, we can return to the features that simplify working with groups in complex REs.

Sometimes you'll want to use a group to denote a part of a regular expression, but aren't interested in retrieving the group's contents. You can make this fact explicit by using a non-capturing group: `(?:...)`, where you can replace the `...` with any other regular expression.

```
>>> m = re.match("([abc])+", "abc")
>>> m.groups()
('c',)
>>> m = re.match("(?:[abc])+", "abc")
>>> m.groups()
()
```

Except for the fact that you can't retrieve the contents of what the group matched, a non-capturing group behaves exactly the same as a capturing group; you can put anything inside it, repeat it with a repetition metacharacter such as `*`, and nest it within other groups (capturing or non-capturing). `(?:...)` is particularly useful when modifying an existing pattern, since you can add new groups without changing how all the other groups are numbered. It should be mentioned that there's no performance difference in searching between capturing and non-capturing groups; neither form is any faster than the other.

A more significant feature is named groups: instead of referring to them by numbers, groups can be referenced by a name.

The syntax for a named group is one of the Python-specific extensions: `(?P<name>...)`. *name* is, obviously, the name of the group. Named groups behave exactly like capturing groups, and additionally associate a name with a group. The match object methods that deal with capturing groups all accept either integers

that refer to the group by number or strings that contain the desired group's name. Named groups are still given numbers, so you can retrieve information about a group in two ways:

```
>>> p = re.compile(r'(?P<word>\b\w+\b)')
>>> m = p.search( '(((( Lots of punctuation ))))' )
>>> m.group('word')
'Lots'
>>> m.group(1)
'Lots'
```

Named groups are handy because they let you use easily-remembered names, instead of having to remember numbers. Here's an example RE from the `imaplib` module:

```
InternalDate = re.compile(r'INTERNALDATE "'
        r'(?P<day>[ 123][0-9])-(?P<mon>[A-Z][a-z][a-z])-'
        r'(?P<year>[0-9][0-9][0-9][0-9])'
        r' (?P<hour>[0-9][0-9]):(?P<min>[0-9][0-9]):(?P<sec>[0-9][0-9])'
        r' (?P<zonen>[-+])(?P<zoneh>[0-9][0-9])(?P<zonem>[0-9][0-9])'
        r'"')
```

It's obviously much easier to retrieve `m.group('zonem')`, instead of having to remember to retrieve group 9.

The syntax for backreferences in an expression such as `(...)\1` refers to the number of the group. There's naturally a variant that uses the group name instead of the number. This is another Python extension: `(?P=name)` indicates that the contents of the group called *name* should again be matched at the current point. The regular expression for finding doubled words, `\b(\w+)\s+\1\b` can also be written as `\b(?P<word>\w+)\s+(?P=word)\b`:

```
>>> p = re.compile(r'\b(?P<word>\w+)\s+(?P=word)\b')
>>> p.search('Paris in the the spring').group()
'the the'
```

4.4 Lookahead Assertions

Another zero-width assertion is the lookahead assertion. Lookahead assertions are available in both positive and negative form, and look like this:

`(?=...)` Positive lookahead assertion. This succeeds if the contained regular expression, represented here by `...`, successfully matches at the current location, and fails otherwise. But, once the contained expression has been tried, the matching engine doesn't advance at all; the rest of the pattern is tried right where the assertion started.

`(?!...)` Negative lookahead assertion. This is the opposite of the positive assertion; it succeeds if the contained expression *doesn't* match at the current position in the string.

To make this concrete, let's look at a case where a lookahead is useful. Consider a simple pattern to match a filename and split it apart into a base name and an extension, separated by a `.`. For example, in `news.rc`, `news` is the base name, and `rc` is the filename's extension.

The pattern to match this is quite simple:

`.*[.].*$`

Notice that the `.` needs to be treated specially because it's a metacharacter, so it's inside a character class to only match that specific character. Also notice the trailing `$`; this is added to ensure that all the rest of the string must be included in the extension. This regular expression matches `foo.bar` and `autoexec.bat` and `sendmail.cf` and `printers.conf`.

Now, consider complicating the problem a bit; what if you want to match filenames where the extension is not `bat`? Some incorrect attempts:

`.*[.][^b].*$` The first attempt above tries to exclude `bat` by requiring that the first character of the extension is not a `b`. This is wrong, because the pattern also doesn't match `foo.bar`.

```
.*[.]([^b]..|.[^a].|..[^t])$
```

The expression gets messier when you try to patch up the first solution by requiring one of the following cases to match: the first character of the extension isn't `b`; the second character isn't `a`; or the third character isn't `t`. This accepts `foo.bar` and rejects `autoexec.bat`, but it requires a three-letter extension and won't accept a filename with a two-letter extension such as `sendmail.cf`. We'll complicate the pattern again in an effort to fix it.

```
.*[.]([^b].?.?|.[^a]?.?|..?[^t]?)$
```

In the third attempt, the second and third letters are all made optional in order to allow matching extensions shorter than three characters, such as `sendmail.cf`.

The pattern's getting really complicated now, which makes it hard to read and understand. Worse, if the problem changes and you want to exclude both `bat` and `exe` as extensions, the pattern would get even more complicated and confusing.

A negative lookahead cuts through all this confusion:

`.*[.](?!bat$)[^.]*$` The negative lookahead means: if the expression `bat` doesn't match at this point, try the rest of the pattern; if `bat$` does match, the whole pattern will fail. The trailing `$` is required to ensure that something like `sample.batch`, where the extension only starts with `bat`, will be allowed. The `[^.]*` makes sure that the pattern works when there are multiple dots in the filename.

Excluding another filename extension is now easy; simply add it as an alternative inside the assertion. The following pattern excludes filenames that end in either `bat` or `exe`:

```
.*[.](?!bat$|exe$)[^.]*$
```

5 Modifying Strings

Up to this point, we've simply performed searches against a static string. Regular expressions are also commonly used to modify strings in various ways, using the following pattern methods:

Method/Attribute	Purpose
`split()`	Split the string into a list, splitting it wherever the RE matches
`sub()`	Find all substrings where the RE matches, and replace them with a different string
`subn()`	Does the same thing as `sub()`, but returns the new string and the number of replacements

5.1 Splitting Strings

The `split()` method of a pattern splits a string apart wherever the RE matches, returning a list of the pieces. It's similar to the `split()` method of strings but provides much more generality in the delimiters that you can split by; string `split()` only supports splitting by whitespace or by a fixed string. As you'd expect, there's a module-level `re.split()` function, too.

`.split(`*string*[, *maxsplit=0*]`)`

Split *string* by the matches of the regular expression. If capturing parentheses are used in the RE, then their contents will also be returned as part of the resulting list. If *maxsplit* is nonzero, at most *maxsplit* splits are performed.

You can limit the number of splits made, by passing a value for *maxsplit*. When *maxsplit* is nonzero, at most *maxsplit* splits will be made, and the remainder of the string is returned as the final element of the list. In the following example, the delimiter is any sequence of non-alphanumeric characters.

```
>>> p = re.compile(r'\W+')
>>> p.split('This is a test, short and sweet, of split().')
['This', 'is', 'a', 'test', 'short', 'and', 'sweet', 'of', 'split', '']
>>> p.split('This is a test, short and sweet, of split().', 3)
['This', 'is', 'a', 'test, short and sweet, of split().']
```

Sometimes you're not only interested in what the text between delimiters is, but also need to know what the delimiter was. If capturing parentheses are used in the RE, then their values are also returned as part of the list. Compare the following calls:

```
>>> p = re.compile(r'\W+')
>>> p2 = re.compile(r'(\W+)')
>>> p.split('This... is a test.')
['This', 'is', 'a', 'test', '']
>>> p2.split('This... is a test.')
['This', '... ', 'is', ' ', 'a', ' ', 'test', '.', '']
```

The module-level function `re.split()` adds the RE to be used as the first argument, but is otherwise the same.

```
>>> re.split(r'[\W]+', 'Words, words, words.')
['Words', 'words', 'words', '']
>>> re.split(r'([\W]+)', 'Words, words, words.')
['Words', ', ', 'words', ', ', 'words', '.', '']
>>> re.split(r'[\W]+', 'Words, words, words.', 1)
['Words', 'words, words.']
```

5.2 Search and Replace

Another common task is to find all the matches for a pattern, and replace them with a different string. The `sub()` method takes a replacement value, which can be either a string or a function, and the string to be processed.

`.sub(`*replacement*, *string*[, *count=0*]`)`

Returns the string obtained by replacing the leftmost non-overlapping occurrences of the RE in *string* by the replacement *replacement*. If the pattern isn't found, *string* is returned unchanged.

The optional argument *count* is the maximum number of pattern occurrences to be replaced; *count* must be a non-negative integer. The default value of 0 means to replace all occurrences.

Here's a simple example of using the `sub()` method. It replaces colour names with the word `colour`:

```
>>> p = re.compile('(blue|white|red)')
>>> p.sub('colour', 'blue socks and red shoes')
'colour socks and colour shoes'
>>> p.sub('colour', 'blue socks and red shoes', count=1)
'colour socks and red shoes'
```

The `subn()` method does the same work, but returns a 2-tuple containing the new string value and the number of replacements that were performed:

```
>>> p = re.compile('(blue|white|red)')
>>> p.subn('colour', 'blue socks and red shoes')
```

(continues on next page)

(continued from previous page)

```
('colour socks and colour shoes', 2)
>>> p.subn('colour', 'no colours at all')
('no colours at all', 0)
```

Empty matches are replaced only when they're not adjacent to a previous empty match.

```
>>> p = re.compile('x*')
>>> p.sub('-', 'abxd')
'-a-b--d-'
```

If *replacement* is a string, any backslash escapes in it are processed. That is, `\n` is converted to a single newline character, `\r` is converted to a carriage return, and so forth. Unknown escapes such as `\&` are left alone. Backreferences, such as `\6`, are replaced with the substring matched by the corresponding group in the RE. This lets you incorporate portions of the original text in the resulting replacement string.

This example matches the word `section` followed by a string enclosed in `{`, `}`, and changes `section` to `subsection`:

```
>>> p = re.compile('section{ ( [^}]* ) }', re.VERBOSE)
>>> p.sub(r'subsection{\1}','section{First} section{second}')
'subsection{First} subsection{second}'
```

There's also a syntax for referring to named groups as defined by the `(?P<name>...)` syntax. `\g<name>` will use the substring matched by the group named `name`, and `\g<number>` uses the corresponding group number. `\g<2>` is therefore equivalent to `\2`, but isn't ambiguous in a replacement string such as `\g<2>0`. (`\20` would be interpreted as a reference to group 20, not a reference to group 2 followed by the literal character `'0'`.) The following substitutions are all equivalent, but use all three variations of the replacement string.

```
>>> p = re.compile('section{ (?P<name> [^}]* ) }', re.VERBOSE)
>>> p.sub(r'subsection{\1}','section{First}')
'subsection{First}'
>>> p.sub(r'subsection{\g<1>}','section{First}')
'subsection{First}'
>>> p.sub(r'subsection{\g<name>}','section{First}')
'subsection{First}'
```

replacement can also be a function, which gives you even more control. If *replacement* is a function, the function is called for every non-overlapping occurrence of *pattern*. On each call, the function is passed a match object argument for the match and can use this information to compute the desired replacement string and return it.

In the following example, the replacement function translates decimals into hexadecimal:

```
>>> def hexrepl(match):
...     "Return the hex string for a decimal number"
...     value = int(match.group())
...     return hex(value)
...
>>> p = re.compile(r'\d+')
>>> p.sub(hexrepl, 'Call 65490 for printing, 49152 for user code.')
'Call 0xffd2 for printing, 0xc000 for user code.'
```

When using the module-level `re.sub()` function, the pattern is passed as the first argument. The pattern may be provided as an object or as a string; if you need to specify regular expression flags, you must either use a pattern object as the first parameter, or use embedded modifiers in the pattern string, e.g. `sub("(?i)b+", "x", "bbbb BBBB")` returns `'x x'`.

6 Common Problems

Regular expressions are a powerful tool for some applications, but in some ways their behaviour isn't intuitive and at times they don't behave the way you may expect them to. This section will point out some of the most common pitfalls.

6.1 Use String Methods

Sometimes using the `re` module is a mistake. If you're matching a fixed string, or a single character class, and you're not using any `re` features such as the `IGNORECASE` flag, then the full power of regular expressions may not be required. Strings have several methods for performing operations with fixed strings and they're usually much faster, because the implementation is a single small C loop that's been optimized for the purpose, instead of the large, more generalized regular expression engine.

One example might be replacing a single fixed string with another one; for example, you might replace `word` with `deed`. `re.sub()` seems like the function to use for this, but consider the `replace()` method. Note that `replace()` will also replace `word` inside words, turning `swordfish` into `sdeedfish`, but the naive RE `word` would have done that, too. (To avoid performing the substitution on parts of words, the pattern would have to be `\bword\b`, in order to require that `word` have a word boundary on either side. This takes the job beyond `replace()`'s abilities.)

Another common task is deleting every occurrence of a single character from a string or replacing it with another single character. You might do this with something like `re.sub('\n', ' ', S)`, but `translate()` is capable of doing both tasks and will be faster than any regular expression operation can be.

In short, before turning to the `re` module, consider whether your problem can be solved with a faster and simpler string method.

6.2 match() versus search()

The `match()` function only checks if the RE matches at the beginning of the string while `search()` will scan forward through the string for a match. It's important to keep this distinction in mind. Remember, `match()` will only report a successful match which will start at 0; if the match wouldn't start at zero, `match()` will *not* report it.

```
>>> print(re.match('super', 'superstition').span())
(0, 5)
>>> print(re.match('super', 'insuperable'))
None
```

On the other hand, `search()` will scan forward through the string, reporting the first match it finds.

```
>>> print(re.search('super', 'superstition').span())
(0, 5)
>>> print(re.search('super', 'insuperable').span())
(2, 7)
```

Sometimes you'll be tempted to keep using `re.match()`, and just add `.*` to the front of your RE. Resist this temptation and use `re.search()` instead. The regular expression compiler does some analysis of REs in order to speed up the process of looking for a match. One such analysis figures out what the first character of a match must be; for example, a pattern starting with `Crow` must match starting with a `'C'`. The analysis lets the engine quickly scan through the string looking for the starting character, only trying the full match if a `'C'` is found.

Adding `.*` defeats this optimization, requiring scanning to the end of the string and then backtracking to find a match for the rest of the RE. Use `re.search()` instead.

6.3 Greedy versus Non-Greedy

When repeating a regular expression, as in `a*`, the resulting action is to consume as much of the pattern as possible. This fact often bites you when you're trying to match a pair of balanced delimiters, such as the angle brackets surrounding an HTML tag. The naive pattern for matching a single HTML tag doesn't work because of the greedy nature of `.*`.

```
>>> s = '<html><head><title>Title</title>'
>>> len(s)
32
>>> print(re.match('<.*>', s).span())
(0, 32)
>>> print(re.match('<.*>', s).group())
<html><head><title>Title</title>
```

The RE matches the `'<'` in `'<html>'`, and the `.*` consumes the rest of the string. There's still more left in the RE, though, and the `>` can't match at the end of the string, so the regular expression engine has to backtrack character by character until it finds a match for the `>`. The final match extends from the `'<'` in `'<html>'` to the `'>'` in `'</title>'`, which isn't what you want.

In this case, the solution is to use the non-greedy qualifiers `*?`, `+?`, `??`, or `{m,n}?`, which match as *little* text as possible. In the above example, the `'>'` is tried immediately after the first `'<'` matches, and when it fails, the engine advances a character at a time, retrying the `'>'` at every step. This produces just the right result:

```
>>> print(re.match('<.*?>', s).group())
<html>
```

(Note that parsing HTML or XML with regular expressions is painful. Quick-and-dirty patterns will handle common cases, but HTML and XML have special cases that will break the obvious regular expression; by the time you've written a regular expression that handles all of the possible cases, the patterns will be *very* complicated. Use an HTML or XML parser module for such tasks.)

6.4 Using re.VERBOSE

By now you've probably noticed that regular expressions are a very compact notation, but they're not terribly readable. REs of moderate complexity can become lengthy collections of backslashes, parentheses, and metacharacters, making them difficult to read and understand.

For such REs, specifying the `re.VERBOSE` flag when compiling the regular expression can be helpful, because it allows you to format the regular expression more clearly.

The `re.VERBOSE` flag has several effects. Whitespace in the regular expression that *isn't* inside a character class is ignored. This means that an expression such as `dog | cat` is equivalent to the less readable `dog|cat`, but `[a b]` will still match the characters `'a'`, `'b'`, or a space. In addition, you can also put comments inside a RE; comments extend from a `#` character to the next newline. When used with triple-quoted strings, this enables REs to be formatted more neatly:

```
pat = re.compile(r"""
 \s*                 # Skip leading whitespace
 (?P<header>[^:]+)   # Header name
 \s* :               # Whitespace, and a colon
 (?P<value>.*?)      # The header's value -- *? used to
                     # lose the following trailing whitespace
 \s*$                # Trailing whitespace to end-of-line
""", re.VERBOSE)
```

This is far more readable than:

```
pat = re.compile(r"\s*(?P<header>[^:]+)\s*:(?P<value>.*?)\s*$")
```

7 Feedback

Regular expressions are a complicated topic. Did this document help you understand them? Were there parts that were unclear, or Problems you encountered that weren't covered here? If so, please send suggestions for improvements to the author.

The most complete book on regular expressions is almost certainly Jeffrey Friedl's Mastering Regular Expressions, published by O'Reilly. Unfortunately, it exclusively concentrates on Perl and Java's flavours of regular expressions, and doesn't contain any Python material at all, so it won't be useful as a reference for programming in Python. (The first edition covered Python's now-removed `regex` module, which won't help you much.) Consider checking it out from your library.

Porting Python 2 Code to Python 3

Release 3.7.0

Guido van Rossum
and the Python development team

July 07, 2018

Python Software Foundation
Email: docs@python.org

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author Brett Cannon

Abstract

With Python 3 being the future of Python while Python 2 is still in active use, it is good to have your project available for both major releases of Python. This guide is meant to help you figure out how best to support both Python 2 & 3 simultaneously.

If you are looking to port an extension module instead of pure Python code, please see cporting-howto.

If you would like to read one core Python developer's take on why Python 3 came into existence, you can read Nick Coghlan's Python 3 Q & A or Brett Cannon's Why Python 3 exists.

For help with porting, you can email the python-porting mailing list with questions.

1 The Short Explanation

To make your project be single-source Python 2/3 compatible, the basic steps are:

1. Only worry about supporting Python 2.7
2. Make sure you have good test coverage (coverage.py can help; `pip install coverage`)
3. Learn the differences between Python 2 & 3
4. Use Futurize (or Modernize) to update your code (e.g. `pip install future`)
5. Use Pylint to help make sure you don't regress on your Python 3 support (`pip install pylint`)
6. Use caniusepython3 to find out which of your dependencies are blocking your use of Python 3 (`pip install caniusepython3`)
7. Once your dependencies are no longer blocking you, use continuous integration to make sure you stay compatible with Python 2 & 3 (tox can help test against multiple versions of Python; `pip install tox`)
8. Consider using optional static type checking to make sure your type usage works in both Python 2 & 3 (e.g. use mypy to check your typing under both Python 2 & Python 3).

2 Details

A key point about supporting Python 2 & 3 simultaneously is that you can start **today**! Even if your dependencies are not supporting Python 3 yet that does not mean you can't modernize your code **now** to support Python 3. Most changes required to support Python 3 lead to cleaner code using newer practices even in Python 2 code.

Another key point is that modernizing your Python 2 code to also support Python 3 is largely automated for you. While you might have to make some API decisions thanks to Python 3 clarifying text data versus binary data, the lower-level work is now mostly done for you and thus can at least benefit from the automated changes immediately.

Keep those key points in mind while you read on about the details of porting your code to support Python 2 & 3 simultaneously.

2.1 Drop support for Python 2.6 and older

While you can make Python 2.5 work with Python 3, it is **much** easier if you only have to work with Python 2.7. If dropping Python 2.5 is not an option then the six project can help you support Python 2.5 & 3 simultaneously (`pip install six`). Do realize, though, that nearly all the projects listed in this HOWTO will not be available to you.

If you are able to skip Python 2.5 and older, then the required changes to your code should continue to look and feel like idiomatic Python code. At worst you will have to use a function instead of a method in some instances or have to import a function instead of using a built-in one, but otherwise the overall transformation should not feel foreign to you.

But you should aim for only supporting Python 2.7. Python 2.6 is no longer freely supported and thus is not receiving bugfixes. This means **you** will have to work around any issues you come across with Python 2.6. There are also some tools mentioned in this HOWTO which do not support Python 2.6 (e.g., Pylint), and this will become more commonplace as time goes on. It will simply be easier for you if you only support the versions of Python that you have to support.

2.2 Make sure you specify the proper version support in your `setup.py` file

In your `setup.py` file you should have the proper trove classifier specifying what versions of Python you support. As your project does not support Python 3 yet you should at least have `Programming Language :: Python :: 2 :: Only` specified. Ideally you should also specify each major/minor version of Python that you do support, e.g. `Programming Language :: Python :: 2.7`.

2.3 Have good test coverage

Once you have your code supporting the oldest version of Python 2 you want it to, you will want to make sure your test suite has good coverage. A good rule of thumb is that if you want to be confident enough in your test suite that any failures that appear after having tools rewrite your code are actual bugs in the tools and not in your code. If you want a number to aim for, try to get over 80% coverage (and don't feel bad if you find it hard to get better than 90% coverage). If you don't already have a tool to measure test coverage then coverage.py is recommended.

2.4 Learn the differences between Python 2 & 3

Once you have your code well-tested you are ready to begin porting your code to Python 3! But to fully understand how your code is going to change and what you want to look out for while you code, you will want to learn what changes Python 3 makes in terms of Python 2. Typically the two best ways of doing that is reading the "What's New" doc for each release of Python 3 and the Porting to Python 3 book (which is free online). There is also a handy cheat sheet from the Python-Future project.

2.5 Update your code

Once you feel like you know what is different in Python 3 compared to Python 2, it's time to update your code! You have a choice between two tools in porting your code automatically: Futurize and Modernize. Which tool you choose will depend on how much like Python 3 you want your code to be. Futurize does its best to make Python 3 idioms and practices exist in Python 2, e.g. backporting the `bytes` type from Python 3 so that you have semantic parity between the major versions of Python. Modernize, on the other hand, is more conservative and targets a Python 2/3 subset of Python, directly relying on six to help provide compatibility. As Python 3 is the future, it might be best to consider Futurize to begin adjusting to any new practices that Python 3 introduces which you are not accustomed to yet.

Regardless of which tool you choose, they will update your code to run under Python 3 while staying compatible with the version of Python 2 you started with. Depending on how conservative you want to be, you may want to run the tool over your test suite first and visually inspect the diff to make sure the transformation is accurate. After you have transformed your test suite and verified that all the tests still pass as expected, then you can transform your application code knowing that any tests which fail is a translation failure.

Unfortunately the tools can't automate everything to make your code work under Python 3 and so there are a handful of things you will need to update manually to get full Python 3 support (which of these steps are necessary vary between the tools). Read the documentation for the tool you choose to use to see what it fixes by default and what it can do optionally to know what will (not) be fixed for you and what you may have to fix on your own (e.g. using `io.open()` over the built-in `open()` function is off by default in Modernize). Luckily, though, there are only a couple of things to watch out for which can be considered large issues that may be hard to debug if not watched for.

Division

In Python 3, `5 / 2 == 2.5` and not 2; all division between `int` values result in a `float`. This change has actually been planned since Python 2.2 which was released in 2002. Since then users have been encouraged to add `from __future__ import division` to any and all files which use the `/` and `//` operators or to be running the interpreter with the `-Q` flag. If you have not been doing this then you will need to go through your code and do two things:

1. Add `from __future__ import division` to your files
2. Update any division operator as necessary to either use `//` to use floor division or continue using `/` and expect a float

The reason that `/` isn't simply translated to `//` automatically is that if an object defines a `__truediv__` method but not `__floordiv__` then your code would begin to fail (e.g. a user-defined class that uses `/` to signify some operation but not `//` for the same thing or at all).

Text versus binary data

In Python 2 you could use the `str` type for both text and binary data. Unfortunately this confluence of two different concepts could lead to brittle code which sometimes worked for either kind of data, sometimes not. It also could lead to confusing APIs if people didn't explicitly state that something that accepted `str` accepted either text or binary data instead of one specific type. This complicated the situation especially for anyone supporting multiple languages as APIs wouldn't bother explicitly supporting `unicode` when they claimed text data support.

To make the distinction between text and binary data clearer and more pronounced, Python 3 did what most languages created in the age of the internet have done and made text and binary data distinct types that cannot blindly be mixed together (Python predates widespread access to the internet). For any code that deals only with text or only binary data, this separation doesn't pose an issue. But for code that has to deal with both, it does mean you might have to now care about when you are using text compared to binary data, which is why this cannot be entirely automated.

To start, you will need to decide which APIs take text and which take binary (it is **highly** recommended you don't design APIs that can take both due to the difficulty of keeping the code working; as stated earlier it is difficult to do well). In Python 2 this means making sure the APIs that take text can work with `unicode` and those that work with binary data work with the `bytes` type from Python 3 (which is a subset of `str` in Python 2 and acts as an alias for `bytes` type in Python 2). Usually the biggest issue is realizing which methods exist on which types in Python 2 & 3 simultaneously (for text that's `unicode` in Python 2 and `str` in Python 3, for binary that's `str`/`bytes` in Python 2 and `bytes` in Python 3). The following table lists the **unique** methods of each data type across Python 2 & 3 (e.g., the `decode()` method is usable on the equivalent binary data type in either Python 2 or 3, but it can't be used by the textual data type consistently between Python 2 and 3 because `str` in Python 3 doesn't have the method). Do note that as of Python 3.5 the `__mod__` method was added to the bytes type.

Text data	Binary data
	decode
encode	
format	
isdecimal	
isnumeric	

Making the distinction easier to handle can be accomplished by encoding and decoding between binary data and text at the edge of your code. This means that when you receive text in binary data, you should immediately decode it. And if your code needs to send text as binary data then encode it as late as possible.

This allows your code to work with only text internally and thus eliminates having to keep track of what type of data you are working with.

The next issue is making sure you know whether the string literals in your code represent text or binary data. You should add a `b` prefix to any literal that presents binary data. For text you should add a `u` prefix to the text literal. (there is a `__future__` import to force all unspecified literals to be Unicode, but usage has shown it isn't as effective as adding a `b` or `u` prefix to all literals explicitly)

As part of this dichotomy you also need to be careful about opening files. Unless you have been working on Windows, there is a chance you have not always bothered to add the `b` mode when opening a binary file (e.g., `rb` for binary reading). Under Python 3, binary files and text files are clearly distinct and mutually incompatible; see the `io` module for details. Therefore, you **must** make a decision of whether a file will be used for binary access (allowing binary data to be read and/or written) or textual access (allowing text data to be read and/or written). You should also use `io.open()` for opening files instead of the built-in `open()` function as the `io` module is consistent from Python 2 to 3 while the built-in `open()` function is not (in Python 3 it's actually `io.open()`). Do not bother with the outdated practice of using `codecs.open()` as that's only necessary for keeping compatibility with Python 2.5.

The constructors of both `str` and `bytes` have different semantics for the same arguments between Python 2 & 3. Passing an integer to `bytes` in Python 2 will give you the string representation of the integer: `bytes(3) == '3'`. But in Python 3, an integer argument to `bytes` will give you a bytes object as long as the integer specified, filled with null bytes: `bytes(3) == b'\x00\x00\x00'`. A similar worry is necessary when passing a bytes object to `str`. In Python 2 you just get the bytes object back: `str(b'3') == b'3'`. But in Python 3 you get the string representation of the bytes object: `str(b'3') == "b'3'"`.

Finally, the indexing of binary data requires careful handling (slicing does **not** require any special handling). In Python 2, `b'123'[1] == b'2'` while in Python 3 `b'123'[1] == 50`. Because binary data is simply a collection of binary numbers, Python 3 returns the integer value for the byte you index on. But in Python 2 because `bytes == str`, indexing returns a one-item slice of bytes. The six project has a function named `six.indexbytes()` which will return an integer like in Python 3: `six.indexbytes(b'123', 1)`.

To summarize:

1. Decide which of your APIs take text and which take binary data
2. Make sure that your code that works with text also works with `unicode` and code for binary data works with `bytes` in Python 2 (see the table above for what methods you cannot use for each type)
3. Mark all binary literals with a `b` prefix, textual literals with a `u` prefix
4. Decode binary data to text as soon as possible, encode text as binary data as late as possible
5. Open files using `io.open()` and make sure to specify the `b` mode when appropriate
6. Be careful when indexing into binary data

Use feature detection instead of version detection

Inevitably you will have code that has to choose what to do based on what version of Python is running. The best way to do this is with feature detection of whether the version of Python you're running under supports what you need. If for some reason that doesn't work then you should make the version check be against Python 2 and not Python 3. To help explain this, let's look at an example.

Let's pretend that you need access to a feature of importlib that is available in Python's standard library since Python 3.3 and available for Python 2 through importlib2 on PyPI. You might be tempted to write code to access e.g. the `importlib.abc` module by doing the following:

```
import sys

if sys.version_info[0] == 3:
```

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```
    from importlib import abc
else:
    from importlib2 import abc
```

The problem with this code is what happens when Python 4 comes out? It would be better to treat Python 2 as the exceptional case instead of Python 3 and assume that future Python versions will be more compatible with Python 3 than Python 2:

```
import sys

if sys.version_info[0] > 2:
    from importlib import abc
else:
    from importlib2 import abc
```

The best solution, though, is to do no version detection at all and instead rely on feature detection. That avoids any potential issues of getting the version detection wrong and helps keep you future-compatible:

```
try:
    from importlib import abc
except ImportError:
    from importlib2 import abc
```

2.6 Prevent compatibility regressions

Once you have fully translated your code to be compatible with Python 3, you will want to make sure your code doesn't regress and stop working under Python 3. This is especially true if you have a dependency which is blocking you from actually running under Python 3 at the moment.

To help with staying compatible, any new modules you create should have at least the following block of code at the top of it:

```
from __future__ import absolute_import
from __future__ import division
from __future__ import print_function
```

You can also run Python 2 with the `-3` flag to be warned about various compatibility issues your code triggers during execution. If you turn warnings into errors with `-Werror` then you can make sure that you don't accidentally miss a warning.

You can also use the Pylint project and its `--py3k` flag to lint your code to receive warnings when your code begins to deviate from Python 3 compatibility. This also prevents you from having to run Modernize or Futurize over your code regularly to catch compatibility regressions. This does require you only support Python 2.7 and Python 3.4 or newer as that is Pylint's minimum Python version support.

2.7 Check which dependencies block your transition

After you have made your code compatible with Python 3 you should begin to care about whether your dependencies have also been ported. The caniusepython3 project was created to help you determine which projects – directly or indirectly – are blocking you from supporting Python 3. There is both a command-line tool as well as a web interface at https://caniusepython3.com.

The project also provides code which you can integrate into your test suite so that you will have a failing test when you no longer have dependencies blocking you from using Python 3. This allows you to avoid having to manually check your dependencies and to be notified quickly when you can start running on Python 3.

2.8 Update your `setup.py` file to denote Python 3 compatibility

Once your code works under Python 3, you should update the classifiers in your `setup.py` to contain `Programming Language :: Python :: 3` and to not specify sole Python 2 support. This will tell anyone using your code that you support Python 2 **and** 3. Ideally you will also want to add classifiers for each major/minor version of Python you now support.

2.9 Use continuous integration to stay compatible

Once you are able to fully run under Python 3 you will want to make sure your code always works under both Python 2 & 3. Probably the best tool for running your tests under multiple Python interpreters is tox. You can then integrate tox with your continuous integration system so that you never accidentally break Python 2 or 3 support.

You may also want to use the `-bb` flag with the Python 3 interpreter to trigger an exception when you are comparing bytes to strings or bytes to an int (the latter is available starting in Python 3.5). By default type-differing comparisons simply return `False`, but if you made a mistake in your separation of text/binary data handling or indexing on bytes you wouldn't easily find the mistake. This flag will raise an exception when these kinds of comparisons occur, making the mistake much easier to track down.

And that's mostly it! At this point your code base is compatible with both Python 2 and 3 simultaneously. Your testing will also be set up so that you don't accidentally break Python 2 or 3 compatibility regardless of which version you typically run your tests under while developing.

2.10 Consider using optional static type checking

Another way to help port your code is to use a static type checker like mypy or pytype on your code. These tools can be used to analyze your code as if it's being run under Python 2, then you can run the tool a second time as if your code is running under Python 3. By running a static type checker twice like this you can discover if you're e.g. misusing binary data type in one version of Python compared to another. If you add optional type hints to your code you can also explicitly state whether your APIs use textual or binary data, helping to make sure everything functions as expected in both versions of Python.

Logging Cookbook

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This page contains a number of recipes related to logging, which have been found useful in the past.

1 Using logging in multiple modules

Multiple calls to `logging.getLogger('someLogger')` return a reference to the same logger object. This is true not only within the same module, but also across modules as long as it is in the same Python interpreter process. It is true for references to the same object; additionally, application code can define and configure a parent logger in one module and create (but not configure) a child logger in a separate module, and all logger calls to the child will pass up to the parent. Here is a main module:

```
import logging
import auxiliary_module

# create logger with 'spam_application'
logger = logging.getLogger('spam_application')
logger.setLevel(logging.DEBUG)
# create file handler which logs even debug messages
fh = logging.FileHandler('spam.log')
fh.setLevel(logging.DEBUG)
# create console handler with a higher log level
ch = logging.StreamHandler()
ch.setLevel(logging.ERROR)
# create formatter and add it to the handlers
formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s - %(message)s')
fh.setFormatter(formatter)
ch.setFormatter(formatter)
# add the handlers to the logger
```

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```
logger.addHandler(fh)
logger.addHandler(ch)

logger.info('creating an instance of auxiliary_module.Auxiliary')
a = auxiliary_module.Auxiliary()
logger.info('created an instance of auxiliary_module.Auxiliary')
logger.info('calling auxiliary_module.Auxiliary.do_something')
a.do_something()
logger.info('finished auxiliary_module.Auxiliary.do_something')
logger.info('calling auxiliary_module.some_function()')
auxiliary_module.some_function()
logger.info('done with auxiliary_module.some_function()')
```

Here is the auxiliary module:

```
import logging

# create logger
module_logger = logging.getLogger('spam_application.auxiliary')

class Auxiliary:
    def __init__(self):
        self.logger = logging.getLogger('spam_application.auxiliary.Auxiliary')
        self.logger.info('creating an instance of Auxiliary')

    def do_something(self):
        self.logger.info('doing something')
        a = 1 + 1
        self.logger.info('done doing something')

def some_function():
    module_logger.info('received a call to "some_function"')
```

The output looks like this:

```
2005-03-23 23:47:11,663 - spam_application - INFO -
   creating an instance of auxiliary_module.Auxiliary
2005-03-23 23:47:11,665 - spam_application.auxiliary.Auxiliary - INFO -
   creating an instance of Auxiliary
2005-03-23 23:47:11,665 - spam_application - INFO -
   created an instance of auxiliary_module.Auxiliary
2005-03-23 23:47:11,668 - spam_application - INFO -
   calling auxiliary_module.Auxiliary.do_something
2005-03-23 23:47:11,668 - spam_application.auxiliary.Auxiliary - INFO -
   doing something
2005-03-23 23:47:11,669 - spam_application.auxiliary.Auxiliary - INFO -
   done doing something
2005-03-23 23:47:11,670 - spam_application - INFO -
   finished auxiliary_module.Auxiliary.do_something
2005-03-23 23:47:11,671 - spam_application - INFO -
   calling auxiliary_module.some_function()
2005-03-23 23:47:11,672 - spam_application.auxiliary - INFO -
   received a call to 'some_function'
2005-03-23 23:47:11,673 - spam_application - INFO -
   done with auxiliary_module.some_function()
```

2 Logging from multiple threads

Logging from multiple threads requires no special effort. The following example shows logging from the main (initial) thread and another thread:

```
import logging
import threading
import time

def worker(arg):
    while not arg['stop']:
        logging.debug('Hi from myfunc')
        time.sleep(0.5)

def main():
    logging.basicConfig(level=logging.DEBUG, format='%(relativeCreated)6d %(threadName)s
↪%(message)s')
    info = {'stop': False}
    thread = threading.Thread(target=worker, args=(info,))
    thread.start()
    while True:
        try:
            logging.debug('Hello from main')
            time.sleep(0.75)
        except KeyboardInterrupt:
            info['stop'] = True
            break
    thread.join()

if __name__ == '__main__':
    main()
```

When run, the script should print something like the following:

```
   0 Thread-1 Hi from myfunc
   3 MainThread Hello from main
 505 Thread-1 Hi from myfunc
 755 MainThread Hello from main
1007 Thread-1 Hi from myfunc
1507 MainThread Hello from main
1508 Thread-1 Hi from myfunc
2010 Thread-1 Hi from myfunc
2258 MainThread Hello from main
2512 Thread-1 Hi from myfunc
3009 MainThread Hello from main
3013 Thread-1 Hi from myfunc
3515 Thread-1 Hi from myfunc
3761 MainThread Hello from main
4017 Thread-1 Hi from myfunc
4513 MainThread Hello from main
4518 Thread-1 Hi from myfunc
```

This shows the logging output interspersed as one might expect. This approach works for more threads than shown here, of course.

3 Multiple handlers and formatters

Loggers are plain Python objects. The `addHandler()` method has no minimum or maximum quota for the number of handlers you may add. Sometimes it will be beneficial for an application to log all messages of all severities to a text file while simultaneously logging errors or above to the console. To set this up, simply configure the appropriate handlers. The logging calls in the application code will remain unchanged. Here is a slight modification to the previous simple module-based configuration example:

```
import logging

logger = logging.getLogger('simple_example')
logger.setLevel(logging.DEBUG)
# create file handler which logs even debug messages
fh = logging.FileHandler('spam.log')
fh.setLevel(logging.DEBUG)
# create console handler with a higher log level
ch = logging.StreamHandler()
ch.setLevel(logging.ERROR)
# create formatter and add it to the handlers
formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s - %(message)s')
ch.setFormatter(formatter)
fh.setFormatter(formatter)
# add the handlers to logger
logger.addHandler(ch)
logger.addHandler(fh)

# 'application' code
logger.debug('debug message')
logger.info('info message')
logger.warn('warn message')
logger.error('error message')
logger.critical('critical message')
```

Notice that the 'application' code does not care about multiple handlers. All that changed was the addition and configuration of a new handler named *fh*.

The ability to create new handlers with higher- or lower-severity filters can be very helpful when writing and testing an application. Instead of using many `print` statements for debugging, use `logger.debug`: Unlike the print statements, which you will have to delete or comment out later, the logger.debug statements can remain intact in the source code and remain dormant until you need them again. At that time, the only change that needs to happen is to modify the severity level of the logger and/or handler to debug.

4 Logging to multiple destinations

Let's say you want to log to console and file with different message formats and in differing circumstances. Say you want to log messages with levels of DEBUG and higher to file, and those messages at level INFO and higher to the console. Let's also assume that the file should contain timestamps, but the console messages should not. Here's how you can achieve this:

```
import logging

# set up logging to file - see previous section for more details
logging.basicConfig(level=logging.DEBUG,
                    format='%(asctime)s %(name)-12s %(levelname)-8s %(message)s',
```

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```
                    datefmt='%m-%d %H:%M',
                    filename='/temp/myapp.log',
                    filemode='w')
# define a Handler which writes INFO messages or higher to the sys.stderr
console = logging.StreamHandler()
console.setLevel(logging.INFO)
# set a format which is simpler for console use
formatter = logging.Formatter('%(name)-12s: %(levelname)-8s %(message)s')
# tell the handler to use this format
console.setFormatter(formatter)
# add the handler to the root logger
logging.getLogger('').addHandler(console)

# Now, we can log to the root logger, or any other logger. First the root...
logging.info('Jackdaws love my big sphinx of quartz.')

# Now, define a couple of other loggers which might represent areas in your
# application:

logger1 = logging.getLogger('myapp.area1')
logger2 = logging.getLogger('myapp.area2')

logger1.debug('Quick zephyrs blow, vexing daft Jim.')
logger1.info('How quickly daft jumping zebras vex.')
logger2.warning('Jail zesty vixen who grabbed pay from quack.')
logger2.error('The five boxing wizards jump quickly.')
```

When you run this, on the console you will see

```
root        : INFO     Jackdaws love my big sphinx of quartz.
myapp.area1 : INFO     How quickly daft jumping zebras vex.
myapp.area2 : WARNING  Jail zesty vixen who grabbed pay from quack.
myapp.area2 : ERROR    The five boxing wizards jump quickly.
```

and in the file you will see something like

```
10-22 22:19 root         INFO     Jackdaws love my big sphinx of quartz.
10-22 22:19 myapp.area1  DEBUG    Quick zephyrs blow, vexing daft Jim.
10-22 22:19 myapp.area1  INFO     How quickly daft jumping zebras vex.
10-22 22:19 myapp.area2  WARNING  Jail zesty vixen who grabbed pay from quack.
10-22 22:19 myapp.area2  ERROR    The five boxing wizards jump quickly.
```

As you can see, the DEBUG message only shows up in the file. The other messages are sent to both destinations.

This example uses console and file handlers, but you can use any number and combination of handlers you choose.

5 Configuration server example

Here is an example of a module using the logging configuration server:

```
import logging
import logging.config
import time
```

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```
import os

# read initial config file
logging.config.fileConfig('logging.conf')

# create and start listener on port 9999
t = logging.config.listen(9999)
t.start()

logger = logging.getLogger('simpleExample')

try:
    # loop through logging calls to see the difference
    # new configurations make, until Ctrl+C is pressed
    while True:
        logger.debug('debug message')
        logger.info('info message')
        logger.warn('warn message')
        logger.error('error message')
        logger.critical('critical message')
        time.sleep(5)
except KeyboardInterrupt:
    # cleanup
    logging.config.stopListening()
    t.join()
```

And here is a script that takes a filename and sends that file to the server, properly preceded with the binary-encoded length, as the new logging configuration:

```
#!/usr/bin/env python
import socket, sys, struct

with open(sys.argv[1], 'rb') as f:
    data_to_send = f.read()

HOST = 'localhost'
PORT = 9999
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
print('connecting...')
s.connect((HOST, PORT))
print('sending config...')
s.send(struct.pack('>L', len(data_to_send)))
s.send(data_to_send)
s.close()
print('complete')
```

6 Dealing with handlers that block

Sometimes you have to get your logging handlers to do their work without blocking the thread you're logging from. This is common in Web applications, though of course it also occurs in other scenarios.

A common culprit which demonstrates sluggish behaviour is the `SMTPHandler`: sending emails can take a long time, for a number of reasons outside the developer's control (for example, a poorly performing mail or network infrastructure). But almost any network-based handler can block: Even a `SocketHandler` operation

may do a DNS query under the hood which is too slow (and this query can be deep in the socket library code, below the Python layer, and outside your control).

One solution is to use a two-part approach. For the first part, attach only a `QueueHandler` to those loggers which are accessed from performance-critical threads. They simply write to their queue, which can be sized to a large enough capacity or initialized with no upper bound to their size. The write to the queue will typically be accepted quickly, though you will probably need to catch the `queue.Full` exception as a precaution in your code. If you are a library developer who has performance-critical threads in their code, be sure to document this (together with a suggestion to attach only `QueueHandlers` to your loggers) for the benefit of other developers who will use your code.

The second part of the solution is `QueueListener`, which has been designed as the counterpart to `QueueHandler`. A `QueueListener` is very simple: it's passed a queue and some handlers, and it fires up an internal thread which listens to its queue for LogRecords sent from `QueueHandlers` (or any other source of `LogRecords`, for that matter). The `LogRecords` are removed from the queue and passed to the handlers for processing.

The advantage of having a separate `QueueListener` class is that you can use the same instance to service multiple `QueueHandlers`. This is more resource-friendly than, say, having threaded versions of the existing handler classes, which would eat up one thread per handler for no particular benefit.

An example of using these two classes follows (imports omitted):

```
que = queue.Queue(-1)  # no limit on size
queue_handler = QueueHandler(que)
handler = logging.StreamHandler()
listener = QueueListener(que, handler)
root = logging.getLogger()
root.addHandler(queue_handler)
formatter = logging.Formatter('%(threadName)s: %(message)s')
handler.setFormatter(formatter)
listener.start()
# The log output will display the thread which generated
# the event (the main thread) rather than the internal
# thread which monitors the internal queue. This is what
# you want to happen.
root.warning('Look out!')
listener.stop()
```

which, when run, will produce:

```
MainThread: Look out!
```

Changed in version 3.5: Prior to Python 3.5, the `QueueListener` always passed every message received from the queue to every handler it was initialized with. (This was because it was assumed that level filtering was all done on the other side, where the queue is filled.) From 3.5 onwards, this behaviour can be changed by passing a keyword argument `respect_handler_level=True` to the listener's constructor. When this is done, the listener compares the level of each message with the handler's level, and only passes a message to a handler if it's appropriate to do so.

7 Sending and receiving logging events across a network

Let's say you want to send logging events across a network, and handle them at the receiving end. A simple way of doing this is attaching a `SocketHandler` instance to the root logger at the sending end:

```
import logging, logging.handlers

rootLogger = logging.getLogger('')
rootLogger.setLevel(logging.DEBUG)
socketHandler = logging.handlers.SocketHandler('localhost',
                    logging.handlers.DEFAULT_TCP_LOGGING_PORT)
# don't bother with a formatter, since a socket handler sends the event as
# an unformatted pickle
rootLogger.addHandler(socketHandler)

# Now, we can log to the root logger, or any other logger. First the root...
logging.info('Jackdaws love my big sphinx of quartz.')

# Now, define a couple of other loggers which might represent areas in your
# application:

logger1 = logging.getLogger('myapp.area1')
logger2 = logging.getLogger('myapp.area2')

logger1.debug('Quick zephyrs blow, vexing daft Jim.')
logger1.info('How quickly daft jumping zebras vex.')
logger2.warning('Jail zesty vixen who grabbed pay from quack.')
logger2.error('The five boxing wizards jump quickly.')
```

At the receiving end, you can set up a receiver using the `socketserver` module. Here is a basic working example:

```
import pickle
import logging
import logging.handlers
import socketserver
import struct


class LogRecordStreamHandler(socketserver.StreamRequestHandler):
    """Handler for a streaming logging request.

    This basically logs the record using whatever logging policy is
    configured locally.
    """

    def handle(self):
        """
        Handle multiple requests - each expected to be a 4-byte length,
        followed by the LogRecord in pickle format. Logs the record
        according to whatever policy is configured locally.
        """
        while True:
            chunk = self.connection.recv(4)
            if len(chunk) < 4:
                break
            slen = struct.unpack('>L', chunk)[0]
            chunk = self.connection.recv(slen)
            while len(chunk) < slen:
                chunk = chunk + self.connection.recv(slen - len(chunk))
            obj = self.unPickle(chunk)
            record = logging.makeLogRecord(obj)
```

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```
            self.handleLogRecord(record)

    def unPickle(self, data):
        return pickle.loads(data)

    def handleLogRecord(self, record):
        # if a name is specified, we use the named logger rather than the one
        # implied by the record.
        if self.server.logname is not None:
            name = self.server.logname
        else:
            name = record.name
        logger = logging.getLogger(name)
        # N.B. EVERY record gets logged. This is because Logger.handle
        # is normally called AFTER logger-level filtering. If you want
        # to do filtering, do it at the client end to save wasting
        # cycles and network bandwidth!
        logger.handle(record)

class LogRecordSocketReceiver(socketserver.ThreadingTCPServer):
    """
    Simple TCP socket-based logging receiver suitable for testing.
    """

    allow_reuse_address = True

    def __init__(self, host='localhost',
                 port=logging.handlers.DEFAULT_TCP_LOGGING_PORT,
                 handler=LogRecordStreamHandler):
        socketserver.ThreadingTCPServer.__init__(self, (host, port), handler)
        self.abort = 0
        self.timeout = 1
        self.logname = None

    def serve_until_stopped(self):
        import select
        abort = 0
        while not abort:
            rd, wr, ex = select.select([self.socket.fileno()],
                                       [], [],
                                       self.timeout)
            if rd:
                self.handle_request()
            abort = self.abort

def main():
    logging.basicConfig(
        format='%(relativeCreated)5d %(name)-15s %(levelname)-8s %(message)s')
    tcpserver = LogRecordSocketReceiver()
    print('About to start TCP server...')
    tcpserver.serve_until_stopped()

if __name__ == '__main__':
    main()
```

First run the server, and then the client. On the client side, nothing is printed on the console; on the server side, you should see something like:

```
About to start TCP server...
   59 root            INFO     Jackdaws love my big sphinx of quartz.
   59 myapp.area1     DEBUG    Quick zephyrs blow, vexing daft Jim.
   69 myapp.area1     INFO     How quickly daft jumping zebras vex.
   69 myapp.area2     WARNING  Jail zesty vixen who grabbed pay from quack.
   69 myapp.area2     ERROR    The five boxing wizards jump quickly.
```

Note that there are some security issues with pickle in some scenarios. If these affect you, you can use an alternative serialization scheme by overriding the `makePickle()` method and implementing your alternative there, as well as adapting the above script to use your alternative serialization.

8 Adding contextual information to your logging output

Sometimes you want logging output to contain contextual information in addition to the parameters passed to the logging call. For example, in a networked application, it may be desirable to log client-specific information in the log (e.g. remote client's username, or IP address). Although you could use the *extra* parameter to achieve this, it's not always convenient to pass the information in this way. While it might be tempting to create `Logger` instances on a per-connection basis, this is not a good idea because these instances are not garbage collected. While this is not a problem in practice, when the number of `Logger` instances is dependent on the level of granularity you want to use in logging an application, it could be hard to manage if the number of `Logger` instances becomes effectively unbounded.

8.1 Using LoggerAdapters to impart contextual information

An easy way in which you can pass contextual information to be output along with logging event information is to use the `LoggerAdapter` class. This class is designed to look like a `Logger`, so that you can call `debug()`, `info()`, `warning()`, `error()`, `exception()`, `critical()` and `log()`. These methods have the same signatures as their counterparts in `Logger`, so you can use the two types of instances interchangeably.

When you create an instance of `LoggerAdapter`, you pass it a `Logger` instance and a dict-like object which contains your contextual information. When you call one of the logging methods on an instance of `LoggerAdapter`, it delegates the call to the underlying instance of `Logger` passed to its constructor, and arranges to pass the contextual information in the delegated call. Here's a snippet from the code of `LoggerAdapter`:

```
def debug(self, msg, *args, **kwargs):
    """
    Delegate a debug call to the underlying logger, after adding
    contextual information from this adapter instance.
    """
    msg, kwargs = self.process(msg, kwargs)
    self.logger.debug(msg, *args, **kwargs)
```

The `process()` method of `LoggerAdapter` is where the contextual information is added to the logging output. It's passed the message and keyword arguments of the logging call, and it passes back (potentially) modified versions of these to use in the call to the underlying logger. The default implementation of this method leaves the message alone, but inserts an 'extra' key in the keyword argument whose value is the dict-like object passed to the constructor. Of course, if you had passed an 'extra' keyword argument in the call to the adapter, it will be silently overwritten.

The advantage of using 'extra' is that the values in the dict-like object are merged into the `LogRecord` instance's ___dict___, allowing you to use customized strings with your `Formatter` instances which know about the keys of the dict-like object. If you need a different method, e.g. if you want to prepend or append

the contextual information to the message string, you just need to subclass `LoggerAdapter` and override `process()` to do what you need. Here is a simple example:

```
class CustomAdapter(logging.LoggerAdapter):
    """
    This example adapter expects the passed in dict-like object to have a
    'connid' key, whose value in brackets is prepended to the log message.
    """
    def process(self, msg, kwargs):
        return '[%s] %s' % (self.extra['connid'], msg), kwargs
```

which you can use like this:

```
logger = logging.getLogger(__name__)
adapter = CustomAdapter(logger, {'connid': some_conn_id})
```

Then any events that you log to the adapter will have the value of `some_conn_id` prepended to the log messages.

Using objects other than dicts to pass contextual information

You don't need to pass an actual dict to a `LoggerAdapter` - you could pass an instance of a class which implements `__getitem__` and `__iter__` so that it looks like a dict to logging. This would be useful if you want to generate values dynamically (whereas the values in a dict would be constant).

8.2 Using Filters to impart contextual information

You can also add contextual information to log output using a user-defined `Filter`. `Filter` instances are allowed to modify the `LogRecords` passed to them, including adding additional attributes which can then be output using a suitable format string, or if needed a custom `Formatter`.

For example in a web application, the request being processed (or at least, the interesting parts of it) can be stored in a threadlocal (`threading.local`) variable, and then accessed from a `Filter` to add, say, information from the request - say, the remote IP address and remote user's username - to the `LogRecord`, using the attribute names 'ip' and 'user' as in the `LoggerAdapter` example above. In that case, the same format string can be used to get similar output to that shown above. Here's an example script:

```
import logging
from random import choice

class ContextFilter(logging.Filter):
    """
    This is a filter which injects contextual information into the log.

    Rather than use actual contextual information, we just use random
    data in this demo.
    """

    USERS = ['jim', 'fred', 'sheila']
    IPS = ['123.231.231.123', '127.0.0.1', '192.168.0.1']

    def filter(self, record):

        record.ip = choice(ContextFilter.IPS)
        record.user = choice(ContextFilter.USERS)
```

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```
        return True

if __name__ == '__main__':
    levels = (logging.DEBUG, logging.INFO, logging.WARNING, logging.ERROR, logging.CRITICAL)
    logging.basicConfig(level=logging.DEBUG,
                        format='%(asctime)-15s %(name)-5s %(levelname)-8s IP: %(ip)-15s User:
↪%(user)-8s %(message)s')
    a1 = logging.getLogger('a.b.c')
    a2 = logging.getLogger('d.e.f')

    f = ContextFilter()
    a1.addFilter(f)
    a2.addFilter(f)
    a1.debug('A debug message')
    a1.info('An info message with %s', 'some parameters')
    for x in range(10):
        lvl = choice(levels)
        lvlname = logging.getLevelName(lvl)
        a2.log(lvl, 'A message at %s level with %d %s', lvlname, 2, 'parameters')
```

which, when run, produces something like:

```
2010-09-06 22:38:15,292 a.b.c DEBUG    IP: 123.231.231.123 User: fred     A debug message
2010-09-06 22:38:15,300 a.b.c INFO     IP: 192.168.0.1     User: sheila   An info message with␣
↪some parameters
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 127.0.0.1       User: sheila   A message at CRITICAL␣
↪level with 2 parameters
2010-09-06 22:38:15,300 d.e.f ERROR    IP: 127.0.0.1       User: jim      A message at ERROR level␣
↪with 2 parameters
2010-09-06 22:38:15,300 d.e.f DEBUG    IP: 127.0.0.1       User: sheila   A message at DEBUG level␣
↪with 2 parameters
2010-09-06 22:38:15,300 d.e.f ERROR    IP: 123.231.231.123 User: fred     A message at ERROR level␣
↪with 2 parameters
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 192.168.0.1     User: jim      A message at CRITICAL␣
↪level with 2 parameters
2010-09-06 22:38:15,300 d.e.f CRITICAL IP: 127.0.0.1       User: sheila   A message at CRITICAL␣
↪level with 2 parameters
2010-09-06 22:38:15,300 d.e.f DEBUG    IP: 192.168.0.1     User: jim      A message at DEBUG level␣
↪with 2 parameters
2010-09-06 22:38:15,301 d.e.f ERROR    IP: 127.0.0.1       User: sheila   A message at ERROR level␣
↪with 2 parameters
2010-09-06 22:38:15,301 d.e.f DEBUG    IP: 123.231.231.123 User: fred     A message at DEBUG level␣
↪with 2 parameters
2010-09-06 22:38:15,301 d.e.f INFO     IP: 123.231.231.123 User: fred     A message at INFO level␣
↪with 2 parameters
```

9 Logging to a single file from multiple processes

Although logging is thread-safe, and logging to a single file from multiple threads in a single process *is* supported, logging to a single file from *multiple processes* is *not* supported, because there is no standard way to serialize access to a single file across multiple processes in Python. If you need to log to a single file from multiple processes, one way of doing this is to have all the processes log to a `SocketHandler`, and have a separate process which implements a socket server which reads from the socket and logs to file. (If you prefer, you can dedicate one thread in one of the existing processes to perform this function.) *This*

section documents this approach in more detail and includes a working socket receiver which can be used as a starting point for you to adapt in your own applications.

If you are using a recent version of Python which includes the `multiprocessing` module, you could write your own handler which uses the `Lock` class from this module to serialize access to the file from your processes. The existing `FileHandler` and subclasses do not make use of `multiprocessing` at present, though they may do so in the future. Note that at present, the `multiprocessing` module does not provide working lock functionality on all platforms (see https://bugs.python.org/issue3770).

Alternatively, you can use a `Queue` and a `QueueHandler` to send all logging events to one of the processes in your multi-process application. The following example script demonstrates how you can do this; in the example a separate listener process listens for events sent by other processes and logs them according to its own logging configuration. Although the example only demonstrates one way of doing it (for example, you may want to use a listener thread rather than a separate listener process – the implementation would be analogous) it does allow for completely different logging configurations for the listener and the other processes in your application, and can be used as the basis for code meeting your own specific requirements:

```
# You'll need these imports in your own code
import logging
import logging.handlers
import multiprocessing

# Next two import lines for this demo only
from random import choice, random
import time

#
# Because you'll want to define the logging configurations for listener and workers, the
# listener and worker process functions take a configurer parameter which is a callable
# for configuring logging for that process. These functions are also passed the queue,
# which they use for communication.
#
# In practice, you can configure the listener however you want, but note that in this
# simple example, the listener does not apply level or filter logic to received records.
# In practice, you would probably want to do this logic in the worker processes, to avoid
# sending events which would be filtered out between processes.
#
# The size of the rotated files is made small so you can see the results easily.
def listener_configurer():
    root = logging.getLogger()
    h = logging.handlers.RotatingFileHandler('mptest.log', 'a', 300, 10)
    f = logging.Formatter('%(asctime)s %(processName)-10s %(name)s %(levelname)-8s %(message)s')
    h.setFormatter(f)
    root.addHandler(h)

# This is the listener process top-level loop: wait for logging events
# (LogRecords)on the queue and handle them, quit when you get a None for a
# LogRecord.
def listener_process(queue, configurer):
    configurer()
    while True:
        try:
            record = queue.get()
            if record is None:  # We send this as a sentinel to tell the listener to quit.
                break
            logger = logging.getLogger(record.name)
            logger.handle(record)  # No level or filter logic applied - just do it!
        except Exception:
```

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```
            import sys, traceback
            print('Whoops! Problem:', file=sys.stderr)
            traceback.print_exc(file=sys.stderr)

# Arrays used for random selections in this demo

LEVELS = [logging.DEBUG, logging.INFO, logging.WARNING,
          logging.ERROR, logging.CRITICAL]

LOGGERS = ['a.b.c', 'd.e.f']

MESSAGES = [
    'Random message #1',
    'Random message #2',
    'Random message #3',
]

# The worker configuration is done at the start of the worker process run.
# Note that on Windows you can't rely on fork semantics, so each process
# will run the logging configuration code when it starts.
def worker_configurer(queue):
    h = logging.handlers.QueueHandler(queue)  # Just the one handler needed
    root = logging.getLogger()
    root.addHandler(h)
    # send all messages, for demo; no other level or filter logic applied.
    root.setLevel(logging.DEBUG)

# This is the worker process top-level loop, which just logs ten events with
# random intervening delays before terminating.
# The print messages are just so you know it's doing something!
def worker_process(queue, configurer):
    configurer(queue)
    name = multiprocessing.current_process().name
    print('Worker started: %s' % name)
    for i in range(10):
        time.sleep(random())
        logger = logging.getLogger(choice(LOGGERS))
        level = choice(LEVELS)
        message = choice(MESSAGES)
        logger.log(level, message)
    print('Worker finished: %s' % name)

# Here's where the demo gets orchestrated. Create the queue, create and start
# the listener, create ten workers and start them, wait for them to finish,
# then send a None to the queue to tell the listener to finish.
def main():
    queue = multiprocessing.Queue(-1)
    listener = multiprocessing.Process(target=listener_process,
                                       args=(queue, listener_configurer))
    listener.start()
    workers = []
    for i in range(10):
        worker = multiprocessing.Process(target=worker_process,
                                         args=(queue, worker_configurer))
        workers.append(worker)
        worker.start()
```

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```
    for w in workers:
        w.join()
    queue.put_nowait(None)
    listener.join()

if __name__ == '__main__':
    main()
```

A variant of the above script keeps the logging in the main process, in a separate thread:

```
import logging
import logging.config
import logging.handlers
from multiprocessing import Process, Queue
import random
import threading
import time

def logger_thread(q):
    while True:
        record = q.get()
        if record is None:
            break
        logger = logging.getLogger(record.name)
        logger.handle(record)


def worker_process(q):
    qh = logging.handlers.QueueHandler(q)
    root = logging.getLogger()
    root.setLevel(logging.DEBUG)
    root.addHandler(qh)
    levels = [logging.DEBUG, logging.INFO, logging.WARNING, logging.ERROR,
              logging.CRITICAL]
    loggers = ['foo', 'foo.bar', 'foo.bar.baz',
               'spam', 'spam.ham', 'spam.ham.eggs']
    for i in range(100):
        lvl = random.choice(levels)
        logger = logging.getLogger(random.choice(loggers))
        logger.log(lvl, 'Message no. %d', i)

if __name__ == '__main__':
    q = Queue()
    d = {
        'version': 1,
        'formatters': {
            'detailed': {
                'class': 'logging.Formatter',
                'format': '%(asctime)s %(name)-15s %(levelname)-8s %(processName)-10s %(message)s'
            }
        },
        'handlers': {
            'console': {
                'class': 'logging.StreamHandler',
                'level': 'INFO',
            },
```

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```
            'file': {
                'class': 'logging.FileHandler',
                'filename': 'mplog.log',
                'mode': 'w',
                'formatter': 'detailed',
            },
            'foofile': {
                'class': 'logging.FileHandler',
                'filename': 'mplog-foo.log',
                'mode': 'w',
                'formatter': 'detailed',
            },
            'errors': {
                'class': 'logging.FileHandler',
                'filename': 'mplog-errors.log',
                'mode': 'w',
                'level': 'ERROR',
                'formatter': 'detailed',
            },
        },
        'loggers': {
            'foo': {
                'handlers': ['foofile']
            }
        },
        'root': {
            'level': 'DEBUG',
            'handlers': ['console', 'file', 'errors']
        },
    }
    workers = []
    for i in range(5):
        wp = Process(target=worker_process, name='worker %d' % (i + 1), args=(q,))
        workers.append(wp)
        wp.start()
    logging.config.dictConfig(d)
    lp = threading.Thread(target=logger_thread, args=(q,))
    lp.start()
    # At this point, the main process could do some useful work of its own
    # Once it's done that, it can wait for the workers to terminate...
    for wp in workers:
        wp.join()
    # And now tell the logging thread to finish up, too
    q.put(None)
    lp.join()
```

This variant shows how you can e.g. apply configuration for particular loggers - e.g. the `foo` logger has a special handler which stores all events in the `foo` subsystem in a file `mplog-foo.log`. This will be used by the logging machinery in the main process (even though the logging events are generated in the worker processes) to direct the messages to the appropriate destinations.

10 Using file rotation

Sometimes you want to let a log file grow to a certain size, then open a new file and log to that. You may want to keep a certain number of these files, and when that many files have been created, rotate the files so

that the number of files and the size of the files both remain bounded. For this usage pattern, the logging package provides a `RotatingFileHandler`:

```
import glob
import logging
import logging.handlers

LOG_FILENAME = 'logging_rotatingfile_example.out'

# Set up a specific logger with our desired output level
my_logger = logging.getLogger('MyLogger')
my_logger.setLevel(logging.DEBUG)

# Add the log message handler to the logger
handler = logging.handlers.RotatingFileHandler(
              LOG_FILENAME, maxBytes=20, backupCount=5)

my_logger.addHandler(handler)

# Log some messages
for i in range(20):
    my_logger.debug('i = %d' % i)

# See what files are created
logfiles = glob.glob('%s*' % LOG_FILENAME)

for filename in logfiles:
    print(filename)
```

The result should be 6 separate files, each with part of the log history for the application:

```
logging_rotatingfile_example.out
logging_rotatingfile_example.out.1
logging_rotatingfile_example.out.2
logging_rotatingfile_example.out.3
logging_rotatingfile_example.out.4
logging_rotatingfile_example.out.5
```

The most current file is always `logging_rotatingfile_example.out`, and each time it reaches the size limit it is renamed with the suffix `.1`. Each of the existing backup files is renamed to increment the suffix (`.1` becomes `.2`, etc.) and the `.6` file is erased.

Obviously this example sets the log length much too small as an extreme example. You would want to set *maxBytes* to an appropriate value.

11 Use of alternative formatting styles

When logging was added to the Python standard library, the only way of formatting messages with variable content was to use the %-formatting method. Since then, Python has gained two new formatting approaches: `string.Template` (added in Python 2.4) and `str.format()` (added in Python 2.6).

Logging (as of 3.2) provides improved support for these two additional formatting styles. The `Formatter` class been enhanced to take an additional, optional keyword parameter named `style`. This defaults to `'%'`, but other possible values are `'{'` and `'$'`, which correspond to the other two formatting styles. Backwards compatibility is maintained by default (as you would expect), but by explicitly specifying a style parameter, you get the ability to specify format strings which work with `str.format()` or `string.Template`. Here's an example console session to show the possibilities:

```
>>> import logging
>>> root = logging.getLogger()
>>> root.setLevel(logging.DEBUG)
>>> handler = logging.StreamHandler()
>>> bf = logging.Formatter('{asctime} {name} {levelname:8s} {message}',
...                        style='{')
>>> handler.setFormatter(bf)
>>> root.addHandler(handler)
>>> logger = logging.getLogger('foo.bar')
>>> logger.debug('This is a DEBUG message')
2010-10-28 15:11:55,341 foo.bar DEBUG    This is a DEBUG message
>>> logger.critical('This is a CRITICAL message')
2010-10-28 15:12:11,526 foo.bar CRITICAL This is a CRITICAL message
>>> df = logging.Formatter('$asctime $name ${levelname} $message',
...                        style='$')
>>> handler.setFormatter(df)
>>> logger.debug('This is a DEBUG message')
2010-10-28 15:13:06,924 foo.bar DEBUG This is a DEBUG message
>>> logger.critical('This is a CRITICAL message')
2010-10-28 15:13:11,494 foo.bar CRITICAL This is a CRITICAL message
>>>
```

Note that the formatting of logging messages for final output to logs is completely independent of how an individual logging message is constructed. That can still use %-formatting, as shown here:

```
>>> logger.error('This is an%s %s %s', 'other,', 'ERROR,', 'message')
2010-10-28 15:19:29,833 foo.bar ERROR This is another, ERROR, message
>>>
```

Logging calls (`logger.debug()`, `logger.info()` etc.) only take positional parameters for the actual logging message itself, with keyword parameters used only for determining options for how to handle the actual logging call (e.g. the `exc_info` keyword parameter to indicate that traceback information should be logged, or the `extra` keyword parameter to indicate additional contextual information to be added to the log). So you cannot directly make logging calls using `str.format()` or `string.Template` syntax, because internally the logging package uses %-formatting to merge the format string and the variable arguments. There would be no changing this while preserving backward compatibility, since all logging calls which are out there in existing code will be using %-format strings.

There is, however, a way that you can use {}- and $- formatting to construct your individual log messages. Recall that for a message you can use an arbitrary object as a message format string, and that the logging package will call `str()` on that object to get the actual format string. Consider the following two classes:

```
class BraceMessage:
    def __init__(self, fmt, *args, **kwargs):
        self.fmt = fmt
        self.args = args
        self.kwargs = kwargs

    def __str__(self):
        return self.fmt.format(*self.args, **self.kwargs)

class DollarMessage:
    def __init__(self, fmt, **kwargs):
        self.fmt = fmt
        self.kwargs = kwargs

    def __str__(self):
```

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```
        from string import Template
        return Template(self.fmt).substitute(**self.kwargs)
```

Either of these can be used in place of a format string, to allow {}- or $-formatting to be used to build the actual "message" part which appears in the formatted log output in place of "%(message)s" or "{message}" or "$message". It's a little unwieldy to use the class names whenever you want to log something, but it's quite palatable if you use an alias such as ___ (double underscore — not to be confused with _, the single underscore used as a synonym/alias for `gettext.gettext()` or its brethren).

The above classes are not included in Python, though they're easy enough to copy and paste into your own code. They can be used as follows (assuming that they're declared in a module called `wherever`):

```
>>> from wherever import BraceMessage as __
>>> print(__('Message with {0} {name}', 2, name='placeholders'))
Message with 2 placeholders
>>> class Point: pass
...
>>> p = Point()
>>> p.x = 0.5
>>> p.y = 0.5
>>> print(__('Message with coordinates: ({point.x:.2f}, {point.y:.2f})',
...       point=p))
Message with coordinates: (0.50, 0.50)
>>> from wherever import DollarMessage as __
>>> print(__('Message with $num $what', num=2, what='placeholders'))
Message with 2 placeholders
>>>
```

While the above examples use `print()` to show how the formatting works, you would of course use `logger.debug()` or similar to actually log using this approach.

One thing to note is that you pay no significant performance penalty with this approach: the actual formatting happens not when you make the logging call, but when (and if) the logged message is actually about to be output to a log by a handler. So the only slightly unusual thing which might trip you up is that the parentheses go around the format string and the arguments, not just the format string. That's because the ___ notation is just syntax sugar for a constructor call to one of the XXXMessage classes.

If you prefer, you can use a `LoggerAdapter` to achieve a similar effect to the above, as in the following example:

```
import logging

class Message(object):
    def __init__(self, fmt, args):
        self.fmt = fmt
        self.args = args

    def __str__(self):
        return self.fmt.format(*self.args)

class StyleAdapter(logging.LoggerAdapter):
    def __init__(self, logger, extra=None):
        super(StyleAdapter, self).__init__(logger, extra or {})

    def log(self, level, msg, *args, **kwargs):
        if self.isEnabledFor(level):
            msg, kwargs = self.process(msg, kwargs)
```

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```
            self.logger._log(level, Message(msg, args), (), **kwargs)

logger = StyleAdapter(logging.getLogger(__name__))

def main():
    logger.debug('Hello, {}', 'world!')

if __name__ == '__main__':
    logging.basicConfig(level=logging.DEBUG)
    main()
```

The above script should log the message `Hello, world!` when run with Python 3.2 or later.

12 Customizing `LogRecord`

Every logging event is represented by a `LogRecord` instance. When an event is logged and not filtered out by a logger's level, a `LogRecord` is created, populated with information about the event and then passed to the handlers for that logger (and its ancestors, up to and including the logger where further propagation up the hierarchy is disabled). Before Python 3.2, there were only two places where this creation was done:

- `Logger.makeRecord()`, which is called in the normal process of logging an event. This invoked `LogRecord` directly to create an instance.
- `makeLogRecord()`, which is called with a dictionary containing attributes to be added to the LogRecord. This is typically invoked when a suitable dictionary has been received over the network (e.g. in pickle form via a `SocketHandler`, or in JSON form via an `HTTPHandler`).

This has usually meant that if you need to do anything special with a `LogRecord`, you've had to do one of the following.

- Create your own `Logger` subclass, which overrides `Logger.makeRecord()`, and set it using `setLoggerClass()` before any loggers that you care about are instantiated.
- Add a `Filter` to a logger or handler, which does the necessary special manipulation you need when its `filter()` method is called.

The first approach would be a little unwieldy in the scenario where (say) several different libraries wanted to do different things. Each would attempt to set its own `Logger` subclass, and the one which did this last would win.

The second approach works reasonably well for many cases, but does not allow you to e.g. use a specialized subclass of `LogRecord`. Library developers can set a suitable filter on their loggers, but they would have to remember to do this every time they introduced a new logger (which they would do simply by adding new packages or modules and doing

```
logger = logging.getLogger(__name__)
```

at module level). It's probably one too many things to think about. Developers could also add the filter to a `NullHandler` attached to their top-level logger, but this would not be invoked if an application developer attached a handler to a lower-level library logger — so output from that handler would not reflect the intentions of the library developer.

In Python 3.2 and later, `LogRecord` creation is done through a factory, which you can specify. The factory is just a callable you can set with `setLogRecordFactory()`, and interrogate with `getLogRecordFactory()`. The factory is invoked with the same signature as the `LogRecord` constructor, as `LogRecord` is the default setting for the factory.

This approach allows a custom factory to control all aspects of LogRecord creation. For example, you could return a subclass, or just add some additional attributes to the record once created, using a pattern similar to this:

```
old_factory = logging.getLogRecordFactory()

def record_factory(*args, **kwargs):
    record = old_factory(*args, **kwargs)
    record.custom_attribute = 0xdecafbad
    return record

logging.setLogRecordFactory(record_factory)
```

This pattern allows different libraries to chain factories together, and as long as they don't overwrite each other's attributes or unintentionally overwrite the attributes provided as standard, there should be no surprises. However, it should be borne in mind that each link in the chain adds run-time overhead to all logging operations, and the technique should only be used when the use of a `Filter` does not provide the desired result.

13 Subclassing QueueHandler - a ZeroMQ example

You can use a `QueueHandler` subclass to send messages to other kinds of queues, for example a ZeroMQ 'publish' socket. In the example below,the socket is created separately and passed to the handler (as its 'queue'):

```
import zmq   # using pyzmq, the Python binding for ZeroMQ
import json  # for serializing records portably

ctx = zmq.Context()
sock = zmq.Socket(ctx, zmq.PUB)  # or zmq.PUSH, or other suitable value
sock.bind('tcp://*:5556')        # or wherever

class ZeroMQSocketHandler(QueueHandler):
    def enqueue(self, record):
        self.queue.send_json(record.__dict__)


handler = ZeroMQSocketHandler(sock)
```

Of course there are other ways of organizing this, for example passing in the data needed by the handler to create the socket:

```
class ZeroMQSocketHandler(QueueHandler):
    def __init__(self, uri, socktype=zmq.PUB, ctx=None):
        self.ctx = ctx or zmq.Context()
        socket = zmq.Socket(self.ctx, socktype)
        socket.bind(uri)
        super().__init__(socket)

    def enqueue(self, record):
        self.queue.send_json(record.__dict__)

    def close(self):
        self.queue.close()
```

14 Subclassing QueueListener - a ZeroMQ example

You can also subclass `QueueListener` to get messages from other kinds of queues, for example a ZeroMQ 'subscribe' socket. Here's an example:

```
class ZeroMQSocketListener(QueueListener):
    def __init__(self, uri, *handlers, **kwargs):
        self.ctx = kwargs.get('ctx') or zmq.Context()
        socket = zmq.Socket(self.ctx, zmq.SUB)
        socket.setsockopt_string(zmq.SUBSCRIBE, '')  # subscribe to everything
        socket.connect(uri)
        super().__init__(socket, *handlers, **kwargs)

    def dequeue(self):
        msg = self.queue.recv_json()
        return logging.makeLogRecord(msg)
```

See also:

Module `logging` API reference for the logging module.

Module `logging.config` Configuration API for the logging module.

Module `logging.handlers` Useful handlers included with the logging module.

A basic logging tutorial

A more advanced logging tutorial

15 An example dictionary-based configuration

Below is an example of a logging configuration dictionary - it's taken from the documentation on the Django project. This dictionary is passed to `dictConfig()` to put the configuration into effect:

```
LOGGING = {
    'version': 1,
    'disable_existing_loggers': True,
    'formatters': {
        'verbose': {
            'format': '%(levelname)s %(asctime)s %(module)s %(process)d %(thread)d %(message)s'
        },
        'simple': {
            'format': '%(levelname)s %(message)s'
        },
    },
    'filters': {
        'special': {
            '()': 'project.logging.SpecialFilter',
            'foo': 'bar',
        }
    },
    'handlers': {
        'null': {
            'level':'DEBUG',
            'class':'django.utils.log.NullHandler',
        },
        'console':{
```

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```
            'level':'DEBUG',
            'class':'logging.StreamHandler',
            'formatter': 'simple'
        },
        'mail_admins': {
            'level': 'ERROR',
            'class': 'django.utils.log.AdminEmailHandler',
            'filters': ['special']
        }
    },
    'loggers': {
        'django': {
            'handlers':['null'],
            'propagate': True,
            'level':'INFO',
        },
        'django.request': {
            'handlers': ['mail_admins'],
            'level': 'ERROR',
            'propagate': False,
        },
        'myproject.custom': {
            'handlers': ['console', 'mail_admins'],
            'level': 'INFO',
            'filters': ['special']
        }
    }
}
```

For more information about this configuration, you can see the relevant section of the Django documentation.

16 Using a rotator and namer to customize log rotation processing

An example of how you can define a namer and rotator is given in the following snippet, which shows zlib-based compression of the log file:

```
def namer(name):
    return name + ".gz"

def rotator(source, dest):
    with open(source, "rb") as sf:
        data = sf.read()
        compressed = zlib.compress(data, 9)
        with open(dest, "wb") as df:
            df.write(compressed)
    os.remove(source)

rh = logging.handlers.RotatingFileHandler(...)
rh.rotator = rotator
rh.namer = namer
```

These are not “true” .gz files, as they are bare compressed data, with no “container” such as you’d find in an actual gzip file. This snippet is just for illustration purposes.

17 A more elaborate multiprocessing example

The following working example shows how logging can be used with multiprocessing using configuration files. The configurations are fairly simple, but serve to illustrate how more complex ones could be implemented in a real multiprocessing scenario.

In the example, the main process spawns a listener process and some worker processes. Each of the main process, the listener and the workers have three separate configurations (the workers all share the same configuration). We can see logging in the main process, how the workers log to a QueueHandler and how the listener implements a QueueListener and a more complex logging configuration, and arranges to dispatch events received via the queue to the handlers specified in the configuration. Note that these configurations are purely illustrative, but you should be able to adapt this example to your own scenario.

Here's the script - the docstrings and the comments hopefully explain how it works:

```
import logging
import logging.config
import logging.handlers
from multiprocessing import Process, Queue, Event, current_process
import os
import random
import time

class MyHandler:
    """
    A simple handler for logging events. It runs in the listener process and
    dispatches events to loggers based on the name in the received record,
    which then get dispatched, by the logging system, to the handlers
    configured for those loggers.
    """
    def handle(self, record):
        logger = logging.getLogger(record.name)
        # The process name is transformed just to show that it's the listener
        # doing the logging to files and console
        record.processName = '%s (for %s)' % (current_process().name, record.processName)
        logger.handle(record)

def listener_process(q, stop_event, config):
    """
    This could be done in the main process, but is just done in a separate
    process for illustrative purposes.

    This initialises logging according to the specified configuration,
    starts the listener and waits for the main process to signal completion
    via the event. The listener is then stopped, and the process exits.
    """
    logging.config.dictConfig(config)
    listener = logging.handlers.QueueListener(q, MyHandler())
    listener.start()
    if os.name == 'posix':
        # On POSIX, the setup logger will have been configured in the
        # parent process, but should have been disabled following the
        # dictConfig call.
        # On Windows, since fork isn't used, the setup logger won't
        # exist in the child, so it would be created and the message
        # would appear - hence the "if posix" clause.
        logger = logging.getLogger('setup')
```

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```
        logger.critical('Should not appear, because of disabled logger ...')
    stop_event.wait()
    listener.stop()

def worker_process(config):
    """
    A number of these are spawned for the purpose of illustration. In
    practice, they could be a heterogeneous bunch of processes rather than
    ones which are identical to each other.

    This initialises logging according to the specified configuration,
    and logs a hundred messages with random levels to randomly selected
    loggers.

    A small sleep is added to allow other processes a chance to run. This
    is not strictly needed, but it mixes the output from the different
    processes a bit more than if it's left out.
    """
    logging.config.dictConfig(config)
    levels = [logging.DEBUG, logging.INFO, logging.WARNING, logging.ERROR,
              logging.CRITICAL]
    loggers = ['foo', 'foo.bar', 'foo.bar.baz',
               'spam', 'spam.ham', 'spam.ham.eggs']
    if os.name == 'posix':
        # On POSIX, the setup logger will have been configured in the
        # parent process, but should have been disabled following the
        # dictConfig call.
        # On Windows, since fork isn't used, the setup logger won't
        # exist in the child, so it would be created and the message
        # would appear - hence the "if posix" clause.
        logger = logging.getLogger('setup')
        logger.critical('Should not appear, because of disabled logger ...')
    for i in range(100):
        lvl = random.choice(levels)
        logger = logging.getLogger(random.choice(loggers))
        logger.log(lvl, 'Message no. %d', i)
        time.sleep(0.01)

def main():
    q = Queue()
    # The main process gets a simple configuration which prints to the console.
    config_initial = {
        'version': 1,
        'formatters': {
            'detailed': {
                'class': 'logging.Formatter',
                'format': '%(asctime)s %(name)-15s %(levelname)-8s %(processName)-10s %(message)s'
            }
        },
        'handlers': {
            'console': {
                'class': 'logging.StreamHandler',
                'level': 'INFO',
            },
        },
        'root': {
```

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```
            'level': 'DEBUG',
            'handlers': ['console']
        },
    }
    # The worker process configuration is just a QueueHandler attached to the
    # root logger, which allows all messages to be sent to the queue.
    # We disable existing loggers to disable the "setup" logger used in the
    # parent process. This is needed on POSIX because the logger will
    # be there in the child following a fork().
    config_worker = {
        'version': 1,
        'disable_existing_loggers': True,
        'handlers': {
            'queue': {
                'class': 'logging.handlers.QueueHandler',
                'queue': q,
            },
        },
        'root': {
            'level': 'DEBUG',
            'handlers': ['queue']
        },
    }
    # The listener process configuration shows that the full flexibility of
    # logging configuration is available to dispatch events to handlers however
    # you want.
    # We disable existing loggers to disable the "setup" logger used in the
    # parent process. This is needed on POSIX because the logger will
    # be there in the child following a fork().
    config_listener = {
        'version': 1,
        'disable_existing_loggers': True,
        'formatters': {
            'detailed': {
                'class': 'logging.Formatter',
                'format': '%(asctime)s %(name)-15s %(levelname)-8s %(processName)-10s %(message)s'
            },
            'simple': {
                'class': 'logging.Formatter',
                'format': '%(name)-15s %(levelname)-8s %(processName)-10s %(message)s'
            }
        },
        'handlers': {
            'console': {
                'class': 'logging.StreamHandler',
                'level': 'INFO',
                'formatter': 'simple',
            },
            'file': {
                'class': 'logging.FileHandler',
                'filename': 'mplog.log',
                'mode': 'w',
                'formatter': 'detailed',
            },
            'foofile': {
                'class': 'logging.FileHandler',
```

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```
                'filename': 'mplog-foo.log',
                'mode': 'w',
                'formatter': 'detailed',
            },
            'errors': {
                'class': 'logging.FileHandler',
                'filename': 'mplog-errors.log',
                'mode': 'w',
                'level': 'ERROR',
                'formatter': 'detailed',
            },
        },
        'loggers': {
            'foo': {
                'handlers': ['foofile']
            }
        },
        'root': {
            'level': 'DEBUG',
            'handlers': ['console', 'file', 'errors']
        },
    }
    # Log some initial events, just to show that logging in the parent works
    # normally.
    logging.config.dictConfig(config_initial)
    logger = logging.getLogger('setup')
    logger.info('About to create workers ...')
    workers = []
    for i in range(5):
        wp = Process(target=worker_process, name='worker %d' % (i + 1),
                     args=(config_worker,))
        workers.append(wp)
        wp.start()
        logger.info('Started worker: %s', wp.name)
    logger.info('About to create listener ...')
    stop_event = Event()
    lp = Process(target=listener_process, name='listener',
                 args=(q, stop_event, config_listener))
    lp.start()
    logger.info('Started listener')
    # We now hang around for the workers to finish their work.
    for wp in workers:
        wp.join()
    # Workers all done, listening can now stop.
    # Logging in the parent still works normally.
    logger.info('Telling listener to stop ...')
    stop_event.set()
    lp.join()
    logger.info('All done.')

if __name__ == '__main__':
    main()
```

18 Inserting a BOM into messages sent to a SysLogHandler

RFC 5424 requires that a Unicode message be sent to a syslog daemon as a set of bytes which have the following structure: an optional pure-ASCII component, followed by a UTF-8 Byte Order Mark (BOM), followed by Unicode encoded using UTF-8. (See the **relevant section of the specification**.)

In Python 3.1, code was added to `SysLogHandler` to insert a BOM into the message, but unfortunately, it was implemented incorrectly, with the BOM appearing at the beginning of the message and hence not allowing any pure-ASCII component to appear before it.

As this behaviour is broken, the incorrect BOM insertion code is being removed from Python 3.2.4 and later. However, it is not being replaced, and if you want to produce **RFC 5424**-compliant messages which include a BOM, an optional pure-ASCII sequence before it and arbitrary Unicode after it, encoded using UTF-8, then you need to do the following:

1. Attach a `Formatter` instance to your `SysLogHandler` instance, with a format string such as:

   ```
   'ASCII section\ufeffUnicode section'
   ```

   The Unicode code point U+FEFF, when encoded using UTF-8, will be encoded as a UTF-8 BOM – the byte-string `b'\xef\xbb\xbf'`.

2. Replace the ASCII section with whatever placeholders you like, but make sure that the data that appears in there after substitution is always ASCII (that way, it will remain unchanged after UTF-8 encoding).

3. Replace the Unicode section with whatever placeholders you like; if the data which appears there after substitution contains characters outside the ASCII range, that's fine – it will be encoded using UTF-8.

The formatted message *will* be encoded using UTF-8 encoding by `SysLogHandler`. If you follow the above rules, you should be able to produce **RFC 5424**-compliant messages. If you don't, logging may not complain, but your messages will not be RFC 5424-compliant, and your syslog daemon may complain.

19 Implementing structured logging

Although most logging messages are intended for reading by humans, and thus not readily machine-parseable, there might be circumstances where you want to output messages in a structured format which *is* capable of being parsed by a program (without needing complex regular expressions to parse the log message). This is straightforward to achieve using the logging package. There are a number of ways in which this could be achieved, but the following is a simple approach which uses JSON to serialise the event in a machine-parseable manner:

```
import json
import logging

class StructuredMessage(object):
    def __init__(self, message, **kwargs):
        self.message = message
        self.kwargs = kwargs

    def __str__(self):
        return '%s >>> %s' % (self.message, json.dumps(self.kwargs))

_ = StructuredMessage   # optional, to improve readability

logging.basicConfig(level=logging.INFO, format='%(message)s')
logging.info(_('message 1', foo='bar', bar='baz', num=123, fnum=123.456))
```

If the above script is run, it prints:

```
message 1 >>> {"fnum": 123.456, "num": 123, "bar": "baz", "foo": "bar"}
```

Note that the order of items might be different according to the version of Python used.

If you need more specialised processing, you can use a custom JSON encoder, as in the following complete example:

```
from __future__ import unicode_literals

import json
import logging

# This next bit is to ensure the script runs unchanged on 2.x and 3.x
try:
    unicode
except NameError:
    unicode = str

class Encoder(json.JSONEncoder):
    def default(self, o):
        if isinstance(o, set):
            return tuple(o)
        elif isinstance(o, unicode):
            return o.encode('unicode_escape').decode('ascii')
        return super(Encoder, self).default(o)

class StructuredMessage(object):
    def __init__(self, message, **kwargs):
        self.message = message
        self.kwargs = kwargs

    def __str__(self):
        s = Encoder().encode(self.kwargs)
        return '%s >>> %s' % (self.message, s)

_ = StructuredMessage   # optional, to improve readability

def main():
    logging.basicConfig(level=logging.INFO, format='%(message)s')
    logging.info(_('message 1', set_value={1, 2, 3}, snowman='\u2603'))

if __name__ == '__main__':
    main()
```

When the above script is run, it prints:

```
message 1 >>> {"snowman": "\u2603", "set_value": [1, 2, 3]}
```

Note that the order of items might be different according to the version of Python used.

20 Customizing handlers with `dictConfig()`

There are times when you want to customize logging handlers in particular ways, and if you use `dictConfig()` you may be able to do this without subclassing. As an example, consider that you may want to set the

ownership of a log file. On POSIX, this is easily done using `shutil.chown()`, but the file handlers in the stdlib don't offer built-in support. You can customize handler creation using a plain function such as:

```
def owned_file_handler(filename, mode='a', encoding=None, owner=None):
    if owner:
        if not os.path.exists(filename):
            open(filename, 'a').close()
        shutil.chown(filename, *owner)
    return logging.FileHandler(filename, mode, encoding)
```

You can then specify, in a logging configuration passed to `dictConfig()`, that a logging handler be created by calling this function:

```
LOGGING = {
    'version': 1,
    'disable_existing_loggers': False,
    'formatters': {
        'default': {
            'format': '%(asctime)s %(levelname)s %(name)s %(message)s'
        },
    },
    'handlers': {
        'file':{
            # The values below are popped from this dictionary and
            # used to create the handler, set the handler's level and
            # its formatter.
            '()': owned_file_handler,
            'level':'DEBUG',
            'formatter': 'default',
            # The values below are passed to the handler creator callable
            # as keyword arguments.
            'owner': ['pulse', 'pulse'],
            'filename': 'chowntest.log',
            'mode': 'w',
            'encoding': 'utf-8',
        },
    },
    'root': {
        'handlers': ['file'],
        'level': 'DEBUG',
    },
}
```

In this example I am setting the ownership using the `pulse` user and group, just for the purposes of illustration. Putting it together into a working script, `chowntest.py`:

```
import logging, logging.config, os, shutil

def owned_file_handler(filename, mode='a', encoding=None, owner=None):
    if owner:
        if not os.path.exists(filename):
            open(filename, 'a').close()
        shutil.chown(filename, *owner)
    return logging.FileHandler(filename, mode, encoding)

LOGGING = {
    'version': 1,
    'disable_existing_loggers': False,
```

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```
    'formatters': {
        'default': {
            'format': '%(asctime)s %(levelname)s %(name)s %(message)s'
        },
    },
    'handlers': {
        'file':{
            # The values below are popped from this dictionary and
            # used to create the handler, set the handler's level and
            # its formatter.
            '()': owned_file_handler,
            'level':'DEBUG',
            'formatter': 'default',
            # The values below are passed to the handler creator callable
            # as keyword arguments.
            'owner': ['pulse', 'pulse'],
            'filename': 'chowntest.log',
            'mode': 'w',
            'encoding': 'utf-8',
        },
    },
    'root': {
        'handlers': ['file'],
        'level': 'DEBUG',
    },
}

logging.config.dictConfig(LOGGING)
logger = logging.getLogger('mylogger')
logger.debug('A debug message')
```

To run this, you will probably need to run as `root`:

```
$ sudo python3.3 chowntest.py
$ cat chowntest.log
2013-11-05 09:34:51,128 DEBUG mylogger A debug message
$ ls -l chowntest.log
-rw-r--r-- 1 pulse pulse 55 2013-11-05 09:34 chowntest.log
```

Note that this example uses Python 3.3 because that's where `shutil.chown()` makes an appearance. This approach should work with any Python version that supports `dictConfig()` - namely, Python 2.7, 3.2 or later. With pre-3.3 versions, you would need to implement the actual ownership change using e.g. `os.chown()`.

In practice, the handler-creating function may be in a utility module somewhere in your project. Instead of the line in the configuration:

```
'()': owned_file_handler,
```

you could use e.g.:

```
'()': 'ext://project.util.owned_file_handler',
```

where `project.util` can be replaced with the actual name of the package where the function resides. In the above working script, using `'ext://__main__.owned_file_handler'` should work. Here, the actual callable is resolved by `dictConfig()` from the `ext://` specification.

This example hopefully also points the way to how you could implement other types of file change - e.g. setting specific POSIX permission bits - in the same way, using `os.chmod()`.

Of course, the approach could also be extended to types of handler other than a `FileHandler` - for example, one of the rotating file handlers, or a different type of handler altogether.

21 Using particular formatting styles throughout your application

In Python 3.2, the `Formatter` gained a `style` keyword parameter which, while defaulting to `%` for backward compatibility, allowed the specification of `{` or `$` to support the formatting approaches supported by `str.format()` and `string.Template`. Note that this governs the formatting of logging messages for final output to logs, and is completely orthogonal to how an individual logging message is constructed.

Logging calls (`debug()`, `info()` etc.) only take positional parameters for the actual logging message itself, with keyword parameters used only for determining options for how to handle the logging call (e.g. the `exc_info` keyword parameter to indicate that traceback information should be logged, or the `extra` keyword parameter to indicate additional contextual information to be added to the log). So you cannot directly make logging calls using `str.format()` or `string.Template` syntax, because internally the logging package uses %-formatting to merge the format string and the variable arguments. There would no changing this while preserving backward compatibility, since all logging calls which are out there in existing code will be using %-format strings.

There have been suggestions to associate format styles with specific loggers, but that approach also runs into backward compatibility problems because any existing code could be using a given logger name and using %-formatting.

For logging to work interoperably between any third-party libraries and your code, decisions about formatting need to be made at the level of the individual logging call. This opens up a couple of ways in which alternative formatting styles can be accommodated.

21.1 Using LogRecord factories

In Python 3.2, along with the `Formatter` changes mentioned above, the logging package gained the ability to allow users to set their own `LogRecord` subclasses, using the `setLogRecordFactory()` function. You can use this to set your own subclass of `LogRecord`, which does the Right Thing by overriding the `getMessage()` method. The base class implementation of this method is where the `msg % args` formatting happens, and where you can substitute your alternate formatting; however, you should be careful to support all formatting styles and allow %-formatting as the default, to ensure interoperability with other code. Care should also be taken to call `str(self.msg)`, just as the base implementation does.

Refer to the reference documentation on `setLogRecordFactory()` and `LogRecord` for more information.

21.2 Using custom message objects

There is another, perhaps simpler way that you can use {}- and $- formatting to construct your individual log messages. You may recall (from arbitrary-object-messages) that when logging you can use an arbitrary object as a message format string, and that the logging package will call `str()` on that object to get the actual format string. Consider the following two classes:

```
class BraceMessage(object):
    def __init__(self, fmt, *args, **kwargs):
        self.fmt = fmt
        self.args = args
        self.kwargs = kwargs
```

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```
    def __str__(self):
        return self.fmt.format(*self.args, **self.kwargs)

class DollarMessage(object):
    def __init__(self, fmt, **kwargs):
        self.fmt = fmt
        self.kwargs = kwargs

    def __str__(self):
        from string import Template
        return Template(self.fmt).substitute(**self.kwargs)
```

Either of these can be used in place of a format string, to allow {}- or $-formatting to be used to build the actual "message" part which appears in the formatted log output in place of "%(message)s" or "{message}" or "$message". If you find it a little unwieldy to use the class names whenever you want to log something, you can make it more palatable if you use an alias such as `M` or `_` for the message (or perhaps `__`, if you are using `_` for localization).

Examples of this approach are given below. Firstly, formatting with `str.format()`:

```
>>> __ = BraceMessage
>>> print(__('Message with {0} {1}', 2, 'placeholders'))
Message with 2 placeholders
>>> class Point: pass
...
>>> p = Point()
>>> p.x = 0.5
>>> p.y = 0.5
>>> print(__('Message with coordinates: ({point.x:.2f}, {point.y:.2f})', point=p))
Message with coordinates: (0.50, 0.50)
```

Secondly, formatting with `string.Template`:

```
>>> __ = DollarMessage
>>> print(__('Message with $num $what', num=2, what='placeholders'))
Message with 2 placeholders
>>>
```

One thing to note is that you pay no significant performance penalty with this approach: the actual formatting happens not when you make the logging call, but when (and if) the logged message is actually about to be output to a log by a handler. So the only slightly unusual thing which might trip you up is that the parentheses go around the format string and the arguments, not just the format string. That's because the ___ notation is just syntax sugar for a constructor call to one of the `XXXMessage` classes shown above.

22 Configuring filters with `dictConfig()`

You *can* configure filters using `dictConfig()`, though it might not be obvious at first glance how to do it (hence this recipe). Since `Filter` is the only filter class included in the standard library, and it is unlikely to cater to many requirements (it's only there as a base class), you will typically need to define your own `Filter` subclass with an overridden `filter()` method. To do this, specify the `()` key in the configuration dictionary for the filter, specifying a callable which will be used to create the filter (a class is the most obvious, but you can provide any callable which returns a `Filter` instance). Here is a complete example:

```
import logging
import logging.config
import sys

class MyFilter(logging.Filter):
    def __init__(self, param=None):
        self.param = param

    def filter(self, record):
        if self.param is None:
            allow = True
        else:
            allow = self.param not in record.msg
        if allow:
            record.msg = 'changed: ' + record.msg
        return allow

LOGGING = {
    'version': 1,
    'filters': {
        'myfilter': {
            '()': MyFilter,
            'param': 'noshow',
        }
    },
    'handlers': {
        'console': {
            'class': 'logging.StreamHandler',
            'filters': ['myfilter']
        }
    },
    'root': {
        'level': 'DEBUG',
        'handlers': ['console']
    },
}

if __name__ == '__main__':
    logging.config.dictConfig(LOGGING)
    logging.debug('hello')
    logging.debug('hello - noshow')
```

This example shows how you can pass configuration data to the callable which constructs the instance, in the form of keyword parameters. When run, the above script will print:

```
changed: hello
```

which shows that the filter is working as configured.

A couple of extra points to note:

- If you can't refer to the callable directly in the configuration (e.g. if it lives in a different module, and you can't import it directly where the configuration dictionary is), you can use the form `ext://...` as described in logging-config-dict-externalobj. For example, you could have used the text `'ext://__main__.MyFilter'` instead of `MyFilter` in the above example.
- As well as for filters, this technique can also be used to configure custom handlers and formatters. See logging-config-dict-userdef for more information on how logging supports using user-defined objects in its configuration, and see the other cookbook recipe *Customizing handlers with dictConfig()* above.

23 Customized exception formatting

There might be times when you want to do customized exception formatting - for argument's sake, let's say you want exactly one line per logged event, even when exception information is present. You can do this with a custom formatter class, as shown in the following example:

```
import logging

class OneLineExceptionFormatter(logging.Formatter):
    def formatException(self, exc_info):
        """
        Format an exception so that it prints on a single line.
        """
        result = super(OneLineExceptionFormatter, self).formatException(exc_info)
        return repr(result)  # or format into one line however you want to

    def format(self, record):
        s = super(OneLineExceptionFormatter, self).format(record)
        if record.exc_text:
            s = s.replace('\n', '') + '|'
        return s

def configure_logging():
    fh = logging.FileHandler('output.txt', 'w')
    f = OneLineExceptionFormatter('%(asctime)s|%(levelname)s|%(message)s|',
                                  '%d/%m/%Y %H:%M:%S')
    fh.setFormatter(f)
    root = logging.getLogger()
    root.setLevel(logging.DEBUG)
    root.addHandler(fh)

def main():
    configure_logging()
    logging.info('Sample message')
    try:
        x = 1 / 0
    except ZeroDivisionError as e:
        logging.exception('ZeroDivisionError: %s', e)

if __name__ == '__main__':
    main()
```

When run, this produces a file with exactly two lines:

```
28/01/2015 07:21:23|INFO|Sample message|
28/01/2015 07:21:23|ERROR|ZeroDivisionError: integer division or modulo by zero|'Traceback (most␣
↪recent call last):\n  File "logtest7.py", line 30, in main\n    x = 1 / 0\nZeroDivisionError:␣
↪integer division or modulo by zero'|
```

While the above treatment is simplistic, it points the way to how exception information can be formatted to your liking. The `traceback` module may be helpful for more specialized needs.

24 Speaking logging messages

There might be situations when it is desirable to have logging messages rendered in an audible rather than a visible format. This is easy to do if you have text-to-speech (TTS) functionality available in your system,

even if it doesn't have a Python binding. Most TTS systems have a command line program you can run, and this can be invoked from a handler using `subprocess`. It's assumed here that TTS command line programs won't expect to interact with users or take a long time to complete, and that the frequency of logged messages will be not so high as to swamp the user with messages, and that it's acceptable to have the messages spoken one at a time rather than concurrently, The example implementation below waits for one message to be spoken before the next is processed, and this might cause other handlers to be kept waiting. Here is a short example showing the approach, which assumes that the `espeak` TTS package is available:

```
import logging
import subprocess
import sys

class TTSHandler(logging.Handler):
    def emit(self, record):
        msg = self.format(record)
        # Speak slowly in a female English voice
        cmd = ['espeak', '-s150', '-ven+f3', msg]
        p = subprocess.Popen(cmd, stdout=subprocess.PIPE,
                             stderr=subprocess.STDOUT)
        # wait for the program to finish
        p.communicate()

def configure_logging():
    h = TTSHandler()
    root = logging.getLogger()
    root.addHandler(h)
    # the default formatter just returns the message
    root.setLevel(logging.DEBUG)

def main():
    logging.info('Hello')
    logging.debug('Goodbye')

if __name__ == '__main__':
    configure_logging()
    sys.exit(main())
```

When run, this script should say "Hello" and then "Goodbye" in a female voice.

The above approach can, of course, be adapted to other TTS systems and even other systems altogether which can process messages via external programs run from a command line.

25 Buffering logging messages and outputting them conditionally

There might be situations where you want to log messages in a temporary area and only output them if a certain condition occurs. For example, you may want to start logging debug events in a function, and if the function completes without errors, you don't want to clutter the log with the collected debug information, but if there is an error, you want all the debug information to be output as well as the error.

Here is an example which shows how you could do this using a decorator for your functions where you want logging to behave this way. It makes use of the `logging.handlers.MemoryHandler`, which allows buffering of logged events until some condition occurs, at which point the buffered events are `flushed` - passed to another handler (the `target` handler) for processing. By default, the `MemoryHandler` flushed when its buffer gets filled up or an event whose level is greater than or equal to a specified threshold is seen. You can use this recipe with a more specialised subclass of `MemoryHandler` if you want custom flushing behavior.

The example script has a simple function, `foo`, which just cycles through all the logging levels, writing to

`sys.stderr` to say what level it's about to log at, and then actually logging a message at that level. You can pass a parameter to `foo` which, if true, will log at ERROR and CRITICAL levels - otherwise, it only logs at DEBUG, INFO and WARNING levels.

The script just arranges to decorate `foo` with a decorator which will do the conditional logging that's required. The decorator takes a logger as a parameter and attaches a memory handler for the duration of the call to the decorated function. The decorator can be additionally parameterised using a target handler, a level at which flushing should occur, and a capacity for the buffer. These default to a `StreamHandler` which writes to `sys.stderr`, `logging.ERROR` and `100` respectively.

Here's the script:

```
import logging
from logging.handlers import MemoryHandler
import sys

logger = logging.getLogger(__name__)
logger.addHandler(logging.NullHandler())

def log_if_errors(logger, target_handler=None, flush_level=None, capacity=None):
    if target_handler is None:
        target_handler = logging.StreamHandler()
    if flush_level is None:
        flush_level = logging.ERROR
    if capacity is None:
        capacity = 100
    handler = MemoryHandler(capacity, flushLevel=flush_level, target=target_handler)

    def decorator(fn):
        def wrapper(*args, **kwargs):
            logger.addHandler(handler)
            try:
                return fn(*args, **kwargs)
            except Exception:
                logger.exception('call failed')
                raise
            finally:
                super(MemoryHandler, handler).flush()
                logger.removeHandler(handler)
        return wrapper

    return decorator

def write_line(s):
    sys.stderr.write('%s\n' % s)

def foo(fail=False):
    write_line('about to log at DEBUG ...')
    logger.debug('Actually logged at DEBUG')
    write_line('about to log at INFO ...')
    logger.info('Actually logged at INFO')
    write_line('about to log at WARNING ...')
    logger.warning('Actually logged at WARNING')
    if fail:
        write_line('about to log at ERROR ...')
        logger.error('Actually logged at ERROR')
        write_line('about to log at CRITICAL ...')
        logger.critical('Actually logged at CRITICAL')
```

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```
    return fail

decorated_foo = log_if_errors(logger)(foo)

if __name__ == '__main__':
    logger.setLevel(logging.DEBUG)
    write_line('Calling undecorated foo with False')
    assert not foo(False)
    write_line('Calling undecorated foo with True')
    assert foo(True)
    write_line('Calling decorated foo with False')
    assert not decorated_foo(False)
    write_line('Calling decorated foo with True')
    assert decorated_foo(True)
```

When this script is run, the following output should be observed:

```
Calling undecorated foo with False
about to log at DEBUG ...
about to log at INFO ...
about to log at WARNING ...
Calling undecorated foo with True
about to log at DEBUG ...
about to log at INFO ...
about to log at WARNING ...
about to log at ERROR ...
about to log at CRITICAL ...
Calling decorated foo with False
about to log at DEBUG ...
about to log at INFO ...
about to log at WARNING ...
Calling decorated foo with True
about to log at DEBUG ...
about to log at INFO ...
about to log at WARNING ...
about to log at ERROR ...
Actually logged at DEBUG
Actually logged at INFO
Actually logged at WARNING
Actually logged at ERROR
about to log at CRITICAL ...
Actually logged at CRITICAL
```

As you can see, actual logging output only occurs when an event is logged whose severity is ERROR or greater, but in that case, any previous events at lower severities are also logged.

You can of course use the conventional means of decoration:

```
@log_if_errors(logger)
def foo(fail=False):
    ...
```

26 Formatting times using UTC (GMT) via configuration

Sometimes you want to format times using UTC, which can be done using a class such as *UTCFormatter*, shown below:

```
import logging
import time

class UTCFormatter(logging.Formatter):
    converter = time.gmtime
```

and you can then use the `UTCFormatter` in your code instead of `Formatter`. If you want to do that via configuration, you can use the `dictConfig()` API with an approach illustrated by the following complete example:

```
import logging
import logging.config
import time

class UTCFormatter(logging.Formatter):
    converter = time.gmtime

LOGGING = {
    'version': 1,
    'disable_existing_loggers': False,
    'formatters': {
        'utc': {
            '()': UTCFormatter,
            'format': '%(asctime)s %(message)s',
        },
        'local': {
            'format': '%(asctime)s %(message)s',
        }
    },
    'handlers': {
        'console1': {
            'class': 'logging.StreamHandler',
            'formatter': 'utc',
        },
        'console2': {
            'class': 'logging.StreamHandler',
            'formatter': 'local',
        },
    },
    'root': {
        'handlers': ['console1', 'console2'],
   }
}

if __name__ == '__main__':
    logging.config.dictConfig(LOGGING)
    logging.warning('The local time is %s', time.asctime())
```

When this script is run, it should print something like:

```
2015-10-17 12:53:29,501 The local time is Sat Oct 17 13:53:29 2015
2015-10-17 13:53:29,501 The local time is Sat Oct 17 13:53:29 2015
```

showing how the time is formatted both as local time and UTC, one for each handler.

27 Using a context manager for selective logging

There are times when it would be useful to temporarily change the logging configuration and revert it back after doing something. For this, a context manager is the most obvious way of saving and restoring the logging context. Here is a simple example of such a context manager, which allows you to optionally change the logging level and add a logging handler purely in the scope of the context manager:

```
import logging
import sys

class LoggingContext(object):
    def __init__(self, logger, level=None, handler=None, close=True):
        self.logger = logger
        self.level = level
        self.handler = handler
        self.close = close

    def __enter__(self):
        if self.level is not None:
            self.old_level = self.logger.level
            self.logger.setLevel(self.level)
        if self.handler:
            self.logger.addHandler(self.handler)

    def __exit__(self, et, ev, tb):
        if self.level is not None:
            self.logger.setLevel(self.old_level)
        if self.handler:
            self.logger.removeHandler(self.handler)
        if self.handler and self.close:
            self.handler.close()
        # implicit return of None => don't swallow exceptions
```

If you specify a level value, the logger's level is set to that value in the scope of the with block covered by the context manager. If you specify a handler, it is added to the logger on entry to the block and removed on exit from the block. You can also ask the manager to close the handler for you on block exit - you could do this if you don't need the handler any more.

To illustrate how it works, we can add the following block of code to the above:

```
if __name__ == '__main__':
    logger = logging.getLogger('foo')
    logger.addHandler(logging.StreamHandler())
    logger.setLevel(logging.INFO)
    logger.info('1. This should appear just once on stderr.')
    logger.debug('2. This should not appear.')
    with LoggingContext(logger, level=logging.DEBUG):
        logger.debug('3. This should appear once on stderr.')
    logger.debug('4. This should not appear.')
    h = logging.StreamHandler(sys.stdout)
    with LoggingContext(logger, level=logging.DEBUG, handler=h, close=True):
        logger.debug('5. This should appear twice - once on stderr and once on stdout.')
    logger.info('6. This should appear just once on stderr.')
    logger.debug('7. This should not appear.')
```

We initially set the logger's level to `INFO`, so message #1 appears and message #2 doesn't. We then change the level to `DEBUG` temporarily in the following `with` block, and so message #3 appears. After the block exits, the logger's level is restored to `INFO` and so message #4 doesn't appear. In the next `with` block, we set the level to `DEBUG` again but also add a handler writing to `sys.stdout`. Thus, message #5 appears twice on the console (once via `stderr` and once via `stdout`). After the `with` statement's completion, the status is as it was before so message #6 appears (like message #1) whereas message #7 doesn't (just like message #2).

If we run the resulting script, the result is as follows:

```
$ python logctx.py
1. This should appear just once on stderr.
3. This should appear once on stderr.
5. This should appear twice - once on stderr and once on stdout.
5. This should appear twice - once on stderr and once on stdout.
6. This should appear just once on stderr.
```

If we run it again, but pipe `stderr` to `/dev/null`, we see the following, which is the only message written to `stdout`:

```
$ python logctx.py 2>/dev/null
5. This should appear twice - once on stderr and once on stdout.
```

Once again, but piping `stdout` to `/dev/null`, we get:

```
$ python logctx.py >/dev/null
1. This should appear just once on stderr.
3. This should appear once on stderr.
5. This should appear twice - once on stderr and once on stdout.
6. This should appear just once on stderr.
```

In this case, the message #5 printed to `stdout` doesn't appear, as expected.

Of course, the approach described here can be generalised, for example to attach logging filters temporarily. Note that the above code works in Python 2 as well as Python 3.

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Logging HOWTO

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1 Basic Logging Tutorial

Logging is a means of tracking events that happen when some software runs. The software's developer adds logging calls to their code to indicate that certain events have occurred. An event is described by a descriptive message which can optionally contain variable data (i.e. data that is potentially different for each occurrence of the event). Events also have an importance which the developer ascribes to the event; the importance can also be called the *level* or *severity*.

1.1 When to use logging

Logging provides a set of convenience functions for simple logging usage. These are `debug()`, `info()`, `warning()`, `error()` and `critical()`. To determine when to use logging, see the table below, which states, for each of a set of common tasks, the best tool to use for it.

Task you want to perform	The best tool for the task
Display console output for ordinary usage of a command line script or program	`print()`
Report events that occur during normal operation of a program (e.g. for status monitoring or fault investigation)	`logging.info()` (or `logging.debug()` for very detailed output for diagnostic purposes)
Issue a warning regarding a particular runtime event	`warnings.warn()` in library code if the issue is avoidable and the client application should be modified to eliminate the warning `logging.warning()` if there is nothing the client application can do about the situation, but the event should still be noted
Report an error regarding a particular runtime event	Raise an exception
Report suppression of an error without raising an exception (e.g. error handler in a long-running server process)	`logging.error()`, `logging.exception()` or `logging.critical()` as appropriate for the specific error and application domain

The logging functions are named after the level or severity of the events they are used to track. The standard levels and their applicability are described below (in increasing order of severity):

Level	When it's used
`DEBUG`	Detailed information, typically of interest only when diagnosing problems.
`INFO`	Confirmation that things are working as expected.
`WARNING`	An indication that something unexpected happened, or indicative of some problem in the near future (e.g. 'disk space low'). The software is still working as expected.
`ERROR`	Due to a more serious problem, the software has not been able to perform some function.
`CRITICAL`	A serious error, indicating that the program itself may be unable to continue running.

The default level is `WARNING`, which means that only events of this level and above will be tracked, unless the logging package is configured to do otherwise.

Events that are tracked can be handled in different ways. The simplest way of handling tracked events is to print them to the console. Another common way is to write them to a disk file.

1.2 A simple example

A very simple example is:

```
import logging
logging.warning('Watch out!')  # will print a message to the console
logging.info('I told you so')  # will not print anything
```

If you type these lines into a script and run it, you'll see:

```
WARNING:root:Watch out!
```

printed out on the console. The `INFO` message doesn't appear because the default level is `WARNING`. The printed message includes the indication of the level and the description of the event provided in the logging call, i.e. 'Watch out!'. Don't worry about the 'root' part for now: it will be explained later. The actual output can be formatted quite flexibly if you need that; formatting options will also be explained later.

1.3 Logging to a file

A very common situation is that of recording logging events in a file, so let's look at that next. Be sure to try the following in a newly-started Python interpreter, and don't just continue from the session described above:

```
import logging
logging.basicConfig(filename='example.log',level=logging.DEBUG)
logging.debug('This message should go to the log file')
logging.info('So should this')
logging.warning('And this, too')
```

And now if we open the file and look at what we have, we should find the log messages:

```
DEBUG:root:This message should go to the log file
INFO:root:So should this
WARNING:root:And this, too
```

This example also shows how you can set the logging level which acts as the threshold for tracking. In this case, because we set the threshold to `DEBUG`, all of the messages were printed.

If you want to set the logging level from a command-line option such as:

```
--log=INFO
```

and you have the value of the parameter passed for `--log` in some variable *loglevel*, you can use:

```
getattr(logging, loglevel.upper())
```

to get the value which you'll pass to `basicConfig()` via the *level* argument. You may want to error check any user input value, perhaps as in the following example:

```
# assuming loglevel is bound to the string value obtained from the
# command line argument. Convert to upper case to allow the user to
# specify --log=DEBUG or --log=debug
numeric_level = getattr(logging, loglevel.upper(), None)
if not isinstance(numeric_level, int):
    raise ValueError('Invalid log level: %s' % loglevel)
logging.basicConfig(level=numeric_level, ...)
```

The call to `basicConfig()` should come *before* any calls to `debug()`, `info()` etc. As it's intended as a one-off simple configuration facility, only the first call will actually do anything: subsequent calls are effectively no-ops.

If you run the above script several times, the messages from successive runs are appended to the file *example.log*. If you want each run to start afresh, not remembering the messages from earlier runs, you can specify the *filemode* argument, by changing the call in the above example to:

```
logging.basicConfig(filename='example.log', filemode='w', level=logging.DEBUG)
```

The output will be the same as before, but the log file is no longer appended to, so the messages from earlier runs are lost.

1.4 Logging from multiple modules

If your program consists of multiple modules, here's an example of how you could organize logging in it:

```
# myapp.py
import logging
import mylib

def main():
    logging.basicConfig(filename='myapp.log', level=logging.INFO)
    logging.info('Started')
    mylib.do_something()
    logging.info('Finished')

if __name__ == '__main__':
    main()
```

```
# mylib.py
import logging

def do_something():
    logging.info('Doing something')
```

If you run *myapp.py*, you should see this in *myapp.log*:

```
INFO:root:Started
INFO:root:Doing something
INFO:root:Finished
```

which is hopefully what you were expecting to see. You can generalize this to multiple modules, using the pattern in *mylib.py*. Note that for this simple usage pattern, you won't know, by looking in the log file, *where* in your application your messages came from, apart from looking at the event description. If you want to track the location of your messages, you'll need to refer to the documentation beyond the tutorial level – see *Advanced Logging Tutorial*.

1.5 Logging variable data

To log variable data, use a format string for the event description message and append the variable data as arguments. For example:

```
import logging
logging.warning('%s before you %s', 'Look', 'leap!')
```

will display:

```
WARNING:root:Look before you leap!
```

As you can see, merging of variable data into the event description message uses the old, %-style of string formatting. This is for backwards compatibility: the logging package pre-dates newer formatting options such as `str.format()` and `string.Template`. These newer formatting options *are* supported, but exploring them is outside the scope of this tutorial: see formatting-styles for more information.

1.6 Changing the format of displayed messages

To change the format which is used to display messages, you need to specify the format you want to use:

```
import logging
logging.basicConfig(format='%(levelname)s:%(message)s', level=logging.DEBUG)
logging.debug('This message should appear on the console')
logging.info('So should this')
logging.warning('And this, too')
```

which would print:

```
DEBUG:This message should appear on the console
INFO:So should this
WARNING:And this, too
```

Notice that the 'root' which appeared in earlier examples has disappeared. For a full set of things that can appear in format strings, you can refer to the documentation for logrecord-attributes, but for simple usage, you just need the *levelname* (severity), *message* (event description, including variable data) and perhaps to display when the event occurred. This is described in the next section.

1.7 Displaying the date/time in messages

To display the date and time of an event, you would place '%(asctime)s' in your format string:

```
import logging
logging.basicConfig(format='%(asctime)s %(message)s')
logging.warning('is when this event was logged.')
```

which should print something like this:

```
2010-12-12 11:41:42,612 is when this event was logged.
```

The default format for date/time display (shown above) is like ISO8601 or **RFC 3339**. If you need more control over the formatting of the date/time, provide a *datefmt* argument to `basicConfig`, as in this example:

```
import logging
logging.basicConfig(format='%(asctime)s %(message)s', datefmt='%m/%d/%Y %I:%M:%S %p')
logging.warning('is when this event was logged.')
```

which would display something like this:

```
12/12/2010 11:46:36 AM is when this event was logged.
```

The format of the *datefmt* argument is the same as supported by `time.strftime()`.

1.8 Next Steps

That concludes the basic tutorial. It should be enough to get you up and running with logging. There's a lot more that the logging package offers, but to get the best out of it, you'll need to invest a little more of your time in reading the following sections. If you're ready for that, grab some of your favourite beverage and carry on.

If your logging needs are simple, then use the above examples to incorporate logging into your own scripts, and if you run into problems or don't understand something, please post a question on the comp.lang.python Usenet group (available at https://groups.google.com/forum/#!forum/comp.lang.python) and you should receive help before too long.

Still here? You can carry on reading the next few sections, which provide a slightly more advanced/in-depth tutorial than the basic one above. After that, you can take a look at the logging-cookbook.

2 Advanced Logging Tutorial

The logging library takes a modular approach and offers several categories of components: loggers, handlers, filters, and formatters.

- Loggers expose the interface that application code directly uses.
- Handlers send the log records (created by loggers) to the appropriate destination.
- Filters provide a finer grained facility for determining which log records to output.
- Formatters specify the layout of log records in the final output.

Log event information is passed between loggers, handlers, filters and formatters in a `LogRecord` instance.

Logging is performed by calling methods on instances of the `Logger` class (hereafter called *loggers*). Each instance has a name, and they are conceptually arranged in a namespace hierarchy using dots (periods) as separators. For example, a logger named 'scan' is the parent of loggers 'scan.text', 'scan.html' and 'scan.pdf'. Logger names can be anything you want, and indicate the area of an application in which a logged message originates.

A good convention to use when naming loggers is to use a module-level logger, in each module which uses logging, named as follows:

```
logger = logging.getLogger(__name__)
```

This means that logger names track the package/module hierarchy, and it's intuitively obvious where events are logged just from the logger name.

The root of the hierarchy of loggers is called the root logger. That's the logger used by the functions `debug()`, `info()`, `warning()`, `error()` and `critical()`, which just call the same-named method of the root logger. The functions and the methods have the same signatures. The root logger's name is printed as 'root' in the logged output.

It is, of course, possible to log messages to different destinations. Support is included in the package for writing log messages to files, HTTP GET/POST locations, email via SMTP, generic sockets, queues, or OS-specific logging mechanisms such as syslog or the Windows NT event log. Destinations are served by *handler* classes. You can create your own log destination class if you have special requirements not met by any of the built-in handler classes.

By default, no destination is set for any logging messages. You can specify a destination (such as console or file) by using `basicConfig()` as in the tutorial examples. If you call the functions `debug()`, `info()`, `warning()`, `error()` and `critical()`, they will check to see if no destination is set; and if one is not set, they will set a destination of the console (`sys.stderr`) and a default format for the displayed message before delegating to the root logger to do the actual message output.

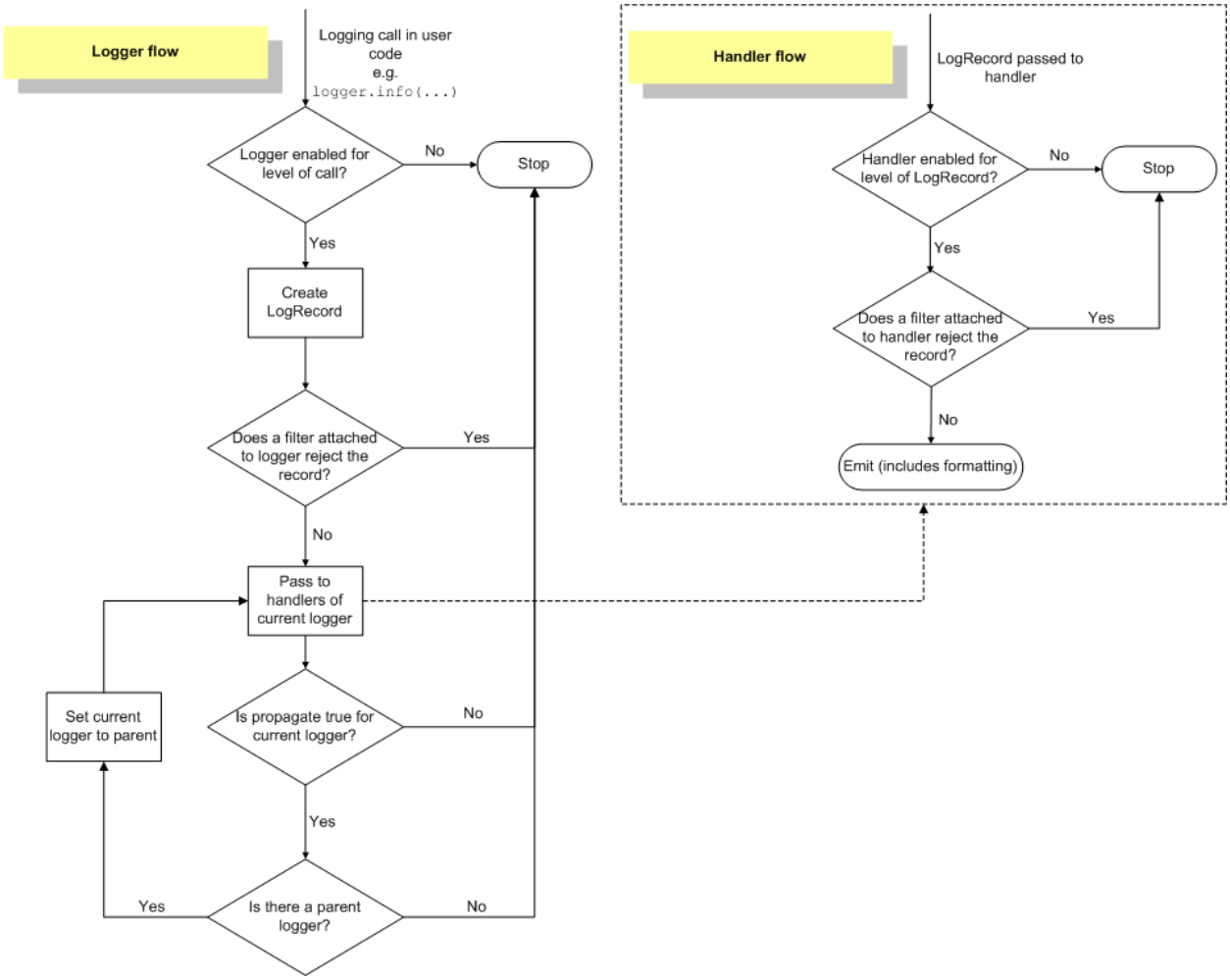
The default format set by `basicConfig()` for messages is:

```
severity:logger name:message
```

You can change this by passing a format string to `basicConfig()` with the *format* keyword argument. For all options regarding how a format string is constructed, see formatter-objects.

2.1 Logging Flow

The flow of log event information in loggers and handlers is illustrated in the following diagram.



2.2 Loggers

`Logger` objects have a threefold job. First, they expose several methods to application code so that applications can log messages at runtime. Second, logger objects determine which log messages to act upon based upon severity (the default filtering facility) or filter objects. Third, logger objects pass along relevant log messages to all interested log handlers.

The most widely used methods on logger objects fall into two categories: configuration and message sending.

These are the most common configuration methods:

- `Logger.setLevel()` specifies the lowest-severity log message a logger will handle, where debug is the lowest built-in severity level and critical is the highest built-in severity. For example, if the severity level is INFO, the logger will handle only INFO, WARNING, ERROR, and CRITICAL messages and will ignore DEBUG messages.
- `Logger.addHandler()` and `Logger.removeHandler()` add and remove handler objects from the logger object. Handlers are covered in more detail in *Handlers*.
- `Logger.addFilter()` and `Logger.removeFilter()` add and remove filter objects from the logger object. Filters are covered in more detail in filter.

You don't need to always call these methods on every logger you create. See the last two paragraphs in this section.

With the logger object configured, the following methods create log messages:

- `Logger.debug()`, `Logger.info()`, `Logger.warning()`, `Logger.error()`, and `Logger.critical()` all create log records with a message and a level that corresponds to their respective method names. The message is actually a format string, which may contain the standard string substitution syntax of `%s`, `%d`, `%f`, and so on. The rest of their arguments is a list of objects that correspond with the substitution fields in the message. With regard to `**kwargs`, the logging methods care only about a keyword of `exc_info` and use it to determine whether to log exception information.
- `Logger.exception()` creates a log message similar to `Logger.error()`. The difference is that `Logger.exception()` dumps a stack trace along with it. Call this method only from an exception handler.
- `Logger.log()` takes a log level as an explicit argument. This is a little more verbose for logging messages than using the log level convenience methods listed above, but this is how to log at custom log levels.

`getLogger()` returns a reference to a logger instance with the specified name if it is provided, or `root` if not. The names are period-separated hierarchical structures. Multiple calls to `getLogger()` with the same name will return a reference to the same logger object. Loggers that are further down in the hierarchical list are children of loggers higher up in the list. For example, given a logger with a name of `foo`, loggers with names of `foo.bar`, `foo.bar.baz`, and `foo.bam` are all descendants of `foo`.

Loggers have a concept of *effective level*. If a level is not explicitly set on a logger, the level of its parent is used instead as its effective level. If the parent has no explicit level set, *its* parent is examined, and so on - all ancestors are searched until an explicitly set level is found. The root logger always has an explicit level set (`WARNING` by default). When deciding whether to process an event, the effective level of the logger is used to determine whether the event is passed to the logger's handlers.

Child loggers propagate messages up to the handlers associated with their ancestor loggers. Because of this, it is unnecessary to define and configure handlers for all the loggers an application uses. It is sufficient to configure handlers for a top-level logger and create child loggers as needed. (You can, however, turn off propagation by setting the *propagate* attribute of a logger to `False`.)

2.3 Handlers

`Handler` objects are responsible for dispatching the appropriate log messages (based on the log messages' severity) to the handler's specified destination. `Logger` objects can add zero or more handler objects to themselves with an `addHandler()` method. As an example scenario, an application may want to send all log messages to a log file, all log messages of error or higher to stdout, and all messages of critical to an email address. This scenario requires three individual handlers where each handler is responsible for sending messages of a specific severity to a specific location.

The standard library includes quite a few handler types (see *Useful Handlers*); the tutorials use mainly `StreamHandler` and `FileHandler` in its examples.

There are very few methods in a handler for application developers to concern themselves with. The only handler methods that seem relevant for application developers who are using the built-in handler objects (that is, not creating custom handlers) are the following configuration methods:

- The `setLevel()` method, just as in logger objects, specifies the lowest severity that will be dispatched to the appropriate destination. Why are there two `setLevel()` methods? The level set in the logger determines which severity of messages it will pass to its handlers. The level set in each handler determines which messages that handler will send on.
- `setFormatter()` selects a Formatter object for this handler to use.
- `addFilter()` and `removeFilter()` respectively configure and deconfigure filter objects on handlers.

Application code should not directly instantiate and use instances of `Handler`. Instead, the `Handler` class is a base class that defines the interface that all handlers should have and establishes some default behavior that child classes can use (or override).

2.4 Formatters

Formatter objects configure the final order, structure, and contents of the log message. Unlike the base `logging.Handler` class, application code may instantiate formatter classes, although you could likely subclass the formatter if your application needs special behavior. The constructor takes three optional arguments – a message format string, a date format string and a style indicator.

`logging.Formatter.__init__`(*fmt=None*, *datefmt=None*, *style='%'*)

If there is no message format string, the default is to use the raw message. If there is no date format string, the default date format is:

```
%Y-%m-%d %H:%M:%S
```

with the milliseconds tacked on at the end. The `style` is one of `%`, '{' or '$'. If one of these is not specified, then '%' will be used.

If the `style` is '%', the message format string uses `%(<dictionary key>)s` styled string substitution; the possible keys are documented in logrecord-attributes. If the style is '{', the message format string is assumed to be compatible with `str.format()` (using keyword arguments), while if the style is '$' then the message format string should conform to what is expected by `string.Template.substitute()`.

Changed in version 3.2: Added the `style` parameter.

The following message format string will log the time in a human-readable format, the severity of the message, and the contents of the message, in that order:

```
'%(asctime)s - %(levelname)s - %(message)s'
```

Formatters use a user-configurable function to convert the creation time of a record to a tuple. By default, `time.localtime()` is used; to change this for a particular formatter instance, set the `converter` attribute of the instance to a function with the same signature as `time.localtime()` or `time.gmtime()`. To change it for all formatters, for example if you want all logging times to be shown in GMT, set the `converter` attribute in the Formatter class (to `time.gmtime` for GMT display).

2.5 Configuring Logging

Programmers can configure logging in three ways:

1. Creating loggers, handlers, and formatters explicitly using Python code that calls the configuration methods listed above.
2. Creating a logging config file and reading it using the `fileConfig()` function.

3. Creating a dictionary of configuration information and passing it to the `dictConfig()` function.

For the reference documentation on the last two options, see logging-config-api. The following example configures a very simple logger, a console handler, and a simple formatter using Python code:

```
import logging

# create logger
logger = logging.getLogger('simple_example')
logger.setLevel(logging.DEBUG)

# create console handler and set level to debug
ch = logging.StreamHandler()
ch.setLevel(logging.DEBUG)

# create formatter
formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s - %(message)s')

# add formatter to ch
ch.setFormatter(formatter)

# add ch to logger
logger.addHandler(ch)

# 'application' code
logger.debug('debug message')
logger.info('info message')
logger.warn('warn message')
logger.error('error message')
logger.critical('critical message')
```

Running this module from the command line produces the following output:

```
$ python simple_logging_module.py
2005-03-19 15:10:26,618 - simple_example - DEBUG - debug message
2005-03-19 15:10:26,620 - simple_example - INFO - info message
2005-03-19 15:10:26,695 - simple_example - WARNING - warn message
2005-03-19 15:10:26,697 - simple_example - ERROR - error message
2005-03-19 15:10:26,773 - simple_example - CRITICAL - critical message
```

The following Python module creates a logger, handler, and formatter nearly identical to those in the example listed above, with the only difference being the names of the objects:

```
import logging
import logging.config

logging.config.fileConfig('logging.conf')

# create logger
logger = logging.getLogger('simpleExample')

# 'application' code
logger.debug('debug message')
logger.info('info message')
logger.warn('warn message')
logger.error('error message')
logger.critical('critical message')
```

Here is the logging.conf file:

```
[loggers]
keys=root,simpleExample

[handlers]
keys=consoleHandler

[formatters]
keys=simpleFormatter

[logger_root]
level=DEBUG
handlers=consoleHandler

[logger_simpleExample]
level=DEBUG
handlers=consoleHandler
qualname=simpleExample
propagate=0

[handler_consoleHandler]
class=StreamHandler
level=DEBUG
formatter=simpleFormatter
args=(sys.stdout,)

[formatter_simpleFormatter]
format=%(asctime)s - %(name)s - %(levelname)s - %(message)s
datefmt=
```

The output is nearly identical to that of the non-config-file-based example:

```
$ python simple_logging_config.py
2005-03-19 15:38:55,977 - simpleExample - DEBUG - debug message
2005-03-19 15:38:55,979 - simpleExample - INFO - info message
2005-03-19 15:38:56,054 - simpleExample - WARNING - warn message
2005-03-19 15:38:56,055 - simpleExample - ERROR - error message
2005-03-19 15:38:56,130 - simpleExample - CRITICAL - critical message
```

You can see that the config file approach has a few advantages over the Python code approach, mainly separation of configuration and code and the ability of noncoders to easily modify the logging properties.

Warning: The `fileConfig()` function takes a default parameter, `disable_existing_loggers`, which defaults to `True` for reasons of backward compatibility. This may or may not be what you want, since it will cause any loggers existing before the `fileConfig()` call to be disabled unless they (or an ancestor) are explicitly named in the configuration. Please refer to the reference documentation for more information, and specify `False` for this parameter if you wish.

The dictionary passed to `dictConfig()` can also specify a Boolean value with key `disable_existing_loggers`, which if not specified explicitly in the dictionary also defaults to being interpreted as `True`. This leads to the logger-disabling behaviour described above, which may not be what you want - in which case, provide the key explicitly with a value of `False`.

Note that the class names referenced in config files need to be either relative to the logging module, or absolute values which can be resolved using normal import mechanisms. Thus, you could use either `WatchedFileHandler` (relative to the logging module) or `mypackage.mymodule.MyHandler` (for a class defined in package `mypackage` and module `mymodule`, where `mypackage` is available on the Python import

path).

In Python 3.2, a new means of configuring logging has been introduced, using dictionaries to hold configuration information. This provides a superset of the functionality of the config-file-based approach outlined above, and is the recommended configuration method for new applications and deployments. Because a Python dictionary is used to hold configuration information, and since you can populate that dictionary using different means, you have more options for configuration. For example, you can use a configuration file in JSON format, or, if you have access to YAML processing functionality, a file in YAML format, to populate the configuration dictionary. Or, of course, you can construct the dictionary in Python code, receive it in pickled form over a socket, or use whatever approach makes sense for your application.

Here's an example of the same configuration as above, in YAML format for the new dictionary-based approach:

```
version: 1
formatters:
  simple:
    format: '%(asctime)s - %(name)s - %(levelname)s - %(message)s'
handlers:
  console:
    class: logging.StreamHandler
    level: DEBUG
    formatter: simple
    stream: ext://sys.stdout
loggers:
  simpleExample:
    level: DEBUG
    handlers: [console]
    propagate: no
root:
  level: DEBUG
  handlers: [console]
```

For more information about logging using a dictionary, see logging-config-api.

2.6 What happens if no configuration is provided

If no logging configuration is provided, it is possible to have a situation where a logging event needs to be output, but no handlers can be found to output the event. The behaviour of the logging package in these circumstances is dependent on the Python version.

For versions of Python prior to 3.2, the behaviour is as follows:

- If *logging.raiseExceptions* is `False` (production mode), the event is silently dropped.
- If *logging.raiseExceptions* is `True` (development mode), a message 'No handlers could be found for logger X.Y.Z' is printed once.

In Python 3.2 and later, the behaviour is as follows:

- The event is output using a 'handler of last resort', stored in `logging.lastResort`. This internal handler is not associated with any logger, and acts like a `StreamHandler` which writes the event description message to the current value of `sys.stderr` (therefore respecting any redirections which may be in effect). No formatting is done on the message - just the bare event description message is printed. The handler's level is set to `WARNING`, so all events at this and greater severities will be output.

To obtain the pre-3.2 behaviour, `logging.lastResort` can be set to `None`.

2.7 Configuring Logging for a Library

When developing a library which uses logging, you should take care to document how the library uses logging - for example, the names of loggers used. Some consideration also needs to be given to its logging configuration. If the using application does not use logging, and library code makes logging calls, then (as described in the previous section) events of severity `WARNING` and greater will be printed to `sys.stderr`. This is regarded as the best default behaviour.

If for some reason you *don't* want these messages printed in the absence of any logging configuration, you can attach a do-nothing handler to the top-level logger for your library. This avoids the message being printed, since a handler will be always be found for the library's events: it just doesn't produce any output. If the library user configures logging for application use, presumably that configuration will add some handlers, and if levels are suitably configured then logging calls made in library code will send output to those handlers, as normal.

A do-nothing handler is included in the logging package: `NullHandler` (since Python 3.1). An instance of this handler could be added to the top-level logger of the logging namespace used by the library (*if* you want to prevent your library's logged events being output to `sys.stderr` in the absence of logging configuration). If all logging by a library *foo* is done using loggers with names matching 'foo.x', 'foo.x.y', etc. then the code:

```
import logging
logging.getLogger('foo').addHandler(logging.NullHandler())
```

should have the desired effect. If an organisation produces a number of libraries, then the logger name specified can be 'orgname.foo' rather than just 'foo'.

Note: It is strongly advised that you *do not add any handlers other than* `NullHandler` *to your library's loggers*. This is because the configuration of handlers is the prerogative of the application developer who uses your library. The application developer knows their target audience and what handlers are most appropriate for their application: if you add handlers 'under the hood', you might well interfere with their ability to carry out unit tests and deliver logs which suit their requirements.

---

3 Logging Levels

The numeric values of logging levels are given in the following table. These are primarily of interest if you want to define your own levels, and need them to have specific values relative to the predefined levels. If you define a level with the same numeric value, it overwrites the predefined value; the predefined name is lost.

Level	Numeric value
`CRITICAL`	50
`ERROR`	40
`WARNING`	30
`INFO`	20
`DEBUG`	10
`NOTSET`	0

Levels can also be associated with loggers, being set either by the developer or through loading a saved logging configuration. When a logging method is called on a logger, the logger compares its own level with the level associated with the method call. If the logger's level is higher than the method call's, no logging message is actually generated. This is the basic mechanism controlling the verbosity of logging output.

Logging messages are encoded as instances of the `LogRecord` class. When a logger decides to actually log an event, a `LogRecord` instance is created from the logging message.

Logging messages are subjected to a dispatch mechanism through the use of *handlers*, which are instances of subclasses of the `Handler` class. Handlers are responsible for ensuring that a logged message (in the form of a `LogRecord`) ends up in a particular location (or set of locations) which is useful for the target audience for that message (such as end users, support desk staff, system administrators, developers). Handlers are passed `LogRecord` instances intended for particular destinations. Each logger can have zero, one or more handlers associated with it (via the `addHandler()` method of `Logger`). In addition to any handlers directly associated with a logger, *all handlers associated with all ancestors of the logger* are called to dispatch the message (unless the *propagate* flag for a logger is set to a false value, at which point the passing to ancestor handlers stops).

Just as for loggers, handlers can have levels associated with them. A handler's level acts as a filter in the same way as a logger's level does. If a handler decides to actually dispatch an event, the `emit()` method is used to send the message to its destination. Most user-defined subclasses of `Handler` will need to override this `emit()`.

3.1 Custom Levels

Defining your own levels is possible, but should not be necessary, as the existing levels have been chosen on the basis of practical experience. However, if you are convinced that you need custom levels, great care should be exercised when doing this, and it is possibly *a very bad idea to define custom levels if you are developing a library*. That's because if multiple library authors all define their own custom levels, there is a chance that the logging output from such multiple libraries used together will be difficult for the using developer to control and/or interpret, because a given numeric value might mean different things for different libraries.

4 Useful Handlers

In addition to the base `Handler` class, many useful subclasses are provided:

1. `StreamHandler` instances send messages to streams (file-like objects).
2. `FileHandler` instances send messages to disk files.
3. `BaseRotatingHandler` is the base class for handlers that rotate log files at a certain point. It is not meant to be instantiated directly. Instead, use `RotatingFileHandler` or `TimedRotatingFileHandler`.
4. `RotatingFileHandler` instances send messages to disk files, with support for maximum log file sizes and log file rotation.
5. `TimedRotatingFileHandler` instances send messages to disk files, rotating the log file at certain timed intervals.
6. `SocketHandler` instances send messages to TCP/IP sockets. Since 3.4, Unix domain sockets are also supported.
7. `DatagramHandler` instances send messages to UDP sockets. Since 3.4, Unix domain sockets are also supported.
8. `SMTPHandler` instances send messages to a designated email address.
9. `SysLogHandler` instances send messages to a Unix syslog daemon, possibly on a remote machine.
10. `NTEventLogHandler` instances send messages to a Windows NT/2000/XP event log.
11. `MemoryHandler` instances send messages to a buffer in memory, which is flushed whenever specific criteria are met.
12. `HTTPHandler` instances send messages to an HTTP server using either `GET` or `POST` semantics.

13. `WatchedFileHandler` instances watch the file they are logging to. If the file changes, it is closed and reopened using the file name. This handler is only useful on Unix-like systems; Windows does not support the underlying mechanism used.

14. `QueueHandler` instances send messages to a queue, such as those implemented in the `queue` or `multiprocessing` modules.

15. `NullHandler` instances do nothing with error messages. They are used by library developers who want to use logging, but want to avoid the 'No handlers could be found for logger XXX' message which can be displayed if the library user has not configured logging. See *Configuring Logging for a Library* for more information.

New in version 3.1: The `NullHandler` class.

New in version 3.2: The `QueueHandler` class.

The `NullHandler`, `StreamHandler` and `FileHandler` classes are defined in the core logging package. The other handlers are defined in a sub- module, `logging.handlers`. (There is also another sub-module, `logging.config`, for configuration functionality.)

Logged messages are formatted for presentation through instances of the `Formatter` class. They are initialized with a format string suitable for use with the % operator and a dictionary.

For formatting multiple messages in a batch, instances of `BufferingFormatter` can be used. In addition to the format string (which is applied to each message in the batch), there is provision for header and trailer format strings.

When filtering based on logger level and/or handler level is not enough, instances of `Filter` can be added to both `Logger` and `Handler` instances (through their `addFilter()` method). Before deciding to process a message further, both loggers and handlers consult all their filters for permission. If any filter returns a false value, the message is not processed further.

The basic `Filter` functionality allows filtering by specific logger name. If this feature is used, messages sent to the named logger and its children are allowed through the filter, and all others dropped.

5 Exceptions raised during logging

The logging package is designed to swallow exceptions which occur while logging in production. This is so that errors which occur while handling logging events - such as logging misconfiguration, network or other similar errors - do not cause the application using logging to terminate prematurely.

`SystemExit` and `KeyboardInterrupt` exceptions are never swallowed. Other exceptions which occur during the `emit()` method of a `Handler` subclass are passed to its `handleError()` method.

The default implementation of `handleError()` in `Handler` checks to see if a module-level variable, `raiseExceptions`, is set. If set, a traceback is printed to `sys.stderr`. If not set, the exception is swallowed.

Note: The default value of `raiseExceptions` is `True`. This is because during development, you typically want to be notified of any exceptions that occur. It's advised that you set `raiseExceptions` to `False` for production usage.

---

6 Using arbitrary objects as messages

In the preceding sections and examples, it has been assumed that the message passed when logging the event is a string. However, this is not the only possibility. You can pass an arbitrary object as a message, and its `__str__()` method will be called when the logging system needs to convert it to a string representation.

In fact, if you want to, you can avoid computing a string representation altogether - for example, the `SocketHandler` emits an event by pickling it and sending it over the wire.

7 Optimization

Formatting of message arguments is deferred until it cannot be avoided. However, computing the arguments passed to the logging method can also be expensive, and you may want to avoid doing it if the logger will just throw away your event. To decide what to do, you can call the `isEnabledFor()` method which takes a level argument and returns true if the event would be created by the Logger for that level of call. You can write code like this:

```
if logger.isEnabledFor(logging.DEBUG):
    logger.debug('Message with %s, %s', expensive_func1(),
                                        expensive_func2())
```

so that if the logger's threshold is set above `DEBUG`, the calls to `expensive_func1()` and `expensive_func2()` are never made.

Note: In some cases, `isEnabledFor()` can itself be more expensive than you'd like (e.g. for deeply nested loggers where an explicit level is only set high up in the logger hierarchy). In such cases (or if you want to avoid calling a method in tight loops), you can cache the result of a call to `isEnabledFor()` in a local or instance variable, and use that instead of calling the method each time. Such a cached value would only need to be recomputed when the logging configuration changes dynamically while the application is running (which is not all that common).

There are other optimizations which can be made for specific applications which need more precise control over what logging information is collected. Here's a list of things you can do to avoid processing during logging which you don't need:

What you don't want to collect	How to avoid collecting it
Information about where calls were made from.	Set `logging._srcfile` to `None`. This avoids calling `sys._getframe()`, which may help to speed up your code in environments like PyPy (which can't speed up code that uses `sys._getframe()`), if and when PyPy supports Python 3.x.
Threading information.	Set `logging.logThreads` to `0`.
Process information.	Set `logging.logProcesses` to `0`.

Also note that the core logging module only includes the basic handlers. If you don't import `logging.handlers` and `logging.config`, they won't take up any memory.

See also:

Module `logging` API reference for the logging module.

Module `logging.config` Configuration API for the logging module.

Module `logging.handlers` Useful handlers included with the logging module.

A logging cookbook

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An introduction to the ipaddress module

Release 3.7.0

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and the Python development team

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Overview

This document aims to provide a gentle introduction to the `ipaddress` module. It is aimed primarily at users that aren't already familiar with IP networking terminology, but may also be useful to network engineers wanting an overview of how `ipaddress` represents IP network addressing concepts.

1 Creating Address/Network/Interface objects

Since `ipaddress` is a module for inspecting and manipulating IP addresses, the first thing you'll want to do is create some objects. You can use `ipaddress` to create objects from strings and integers.

1.1 A Note on IP Versions

For readers that aren't particularly familiar with IP addressing, it's important to know that the Internet Protocol is currently in the process of moving from version 4 of the protocol to version 6. This transition is occurring largely because version 4 of the protocol doesn't provide enough addresses to handle the needs of the whole world, especially given the increasing number of devices with direct connections to the internet.

Explaining the details of the differences between the two versions of the protocol is beyond the scope of this introduction, but readers need to at least be aware that these two versions exist, and it will sometimes be necessary to force the use of one version or the other.

1.2 IP Host Addresses

Addresses, often referred to as "host addresses" are the most basic unit when working with IP addressing. The simplest way to create addresses is to use the `ipaddress.ip_address()` factory function, which automatically determines whether to create an IPv4 or IPv6 address based on the passed in value:

```
>>> ipaddress.ip_address('192.0.2.1')
IPv4Address('192.0.2.1')
>>> ipaddress.ip_address('2001:DB8::1')
IPv6Address('2001:db8::1')
```

Addresses can also be created directly from integers. Values that will fit within 32 bits are assumed to be IPv4 addresses:

```
>>> ipaddress.ip_address(3221225985)
IPv4Address('192.0.2.1')
>>> ipaddress.ip_address(42540766411282592856903984951653826561)
IPv6Address('2001:db8::1')
```

To force the use of IPv4 or IPv6 addresses, the relevant classes can be invoked directly. This is particularly useful to force creation of IPv6 addresses for small integers:

```
>>> ipaddress.ip_address(1)
IPv4Address('0.0.0.1')
>>> ipaddress.IPv4Address(1)
IPv4Address('0.0.0.1')
>>> ipaddress.IPv6Address(1)
IPv6Address('::1')
```

1.3 Defining Networks

Host addresses are usually grouped together into IP networks, so `ipaddress` provides a way to create, inspect and manipulate network definitions. IP network objects are constructed from strings that define the range of host addresses that are part of that network. The simplest form for that information is a "network address/network prefix" pair, where the prefix defines the number of leading bits that are compared to determine whether or not an address is part of the network and the network address defines the expected value of those bits.

As for addresses, a factory function is provided that determines the correct IP version automatically:

```
>>> ipaddress.ip_network('192.0.2.0/24')
IPv4Network('192.0.2.0/24')
>>> ipaddress.ip_network('2001:db8::0/96')
IPv6Network('2001:db8::/96')
```

Network objects cannot have any host bits set. The practical effect of this is that `192.0.2.1/24` does not describe a network. Such definitions are referred to as interface objects since the ip-on-a-network notation is commonly used to describe network interfaces of a computer on a given network and are described further in the next section.

By default, attempting to create a network object with host bits set will result in `ValueError` being raised. To request that the additional bits instead be coerced to zero, the flag `strict=False` can be passed to the constructor:

```
>>> ipaddress.ip_network('192.0.2.1/24')
Traceback (most recent call last):
  ...
ValueError: 192.0.2.1/24 has host bits set
>>> ipaddress.ip_network('192.0.2.1/24', strict=False)
IPv4Network('192.0.2.0/24')
```

While the string form offers significantly more flexibility, networks can also be defined with integers, just like host addresses. In this case, the network is considered to contain only the single address identified by the integer, so the network prefix includes the entire network address:

```
>>> ipaddress.ip_network(3221225984)
IPv4Network('192.0.2.0/32')
>>> ipaddress.ip_network(42540766411282592856903984951653826560)
IPv6Network('2001:db8::/128')
```

As with addresses, creation of a particular kind of network can be forced by calling the class constructor directly instead of using the factory function.

1.4 Host Interfaces

As mentioned just above, if you need to describe an address on a particular network, neither the address nor the network classes are sufficient. Notation like `192.0.2.1/24` is commonly used by network engineers and the people who write tools for firewalls and routers as shorthand for "the host `192.0.2.1` on the network `192.0.2.0/24`", Accordingly, `ipaddress` provides a set of hybrid classes that associate an address with a particular network. The interface for creation is identical to that for defining network objects, except that the address portion isn't constrained to being a network address.

```
>>> ipaddress.ip_interface('192.0.2.1/24')
IPv4Interface('192.0.2.1/24')
>>> ipaddress.ip_interface('2001:db8::1/96')
IPv6Interface('2001:db8::1/96')
```

Integer inputs are accepted (as with networks), and use of a particular IP version can be forced by calling the relevant constructor directly.

2 Inspecting Address/Network/Interface Objects

You've gone to the trouble of creating an IPv(4|6)(Address|Network|Interface) object, so you probably want to get information about it. `ipaddress` tries to make doing this easy and intuitive.

Extracting the IP version:

```
>>> addr4 = ipaddress.ip_address('192.0.2.1')
>>> addr6 = ipaddress.ip_address('2001:db8::1')
>>> addr6.version
6
>>> addr4.version
4
```

Obtaining the network from an interface:

```
>>> host4 = ipaddress.ip_interface('192.0.2.1/24')
>>> host4.network
IPv4Network('192.0.2.0/24')
>>> host6 = ipaddress.ip_interface('2001:db8::1/96')
>>> host6.network
IPv6Network('2001:db8::/96')
```

Finding out how many individual addresses are in a network:

```
>>> net4 = ipaddress.ip_network('192.0.2.0/24')
>>> net4.num_addresses
256
>>> net6 = ipaddress.ip_network('2001:db8::0/96')
>>> net6.num_addresses
4294967296
```

Iterating through the "usable" addresses on a network:

```
>>> net4 = ipaddress.ip_network('192.0.2.0/24')
>>> for x in net4.hosts():
...     print(x)
192.0.2.1
192.0.2.2
192.0.2.3
192.0.2.4
...
192.0.2.252
192.0.2.253
192.0.2.254
```

Obtaining the netmask (i.e. set bits corresponding to the network prefix) or the hostmask (any bits that are not part of the netmask):

```
>>> net4 = ipaddress.ip_network('192.0.2.0/24')
>>> net4.netmask
IPv4Address('255.255.255.0')
>>> net4.hostmask
IPv4Address('0.0.0.255')
>>> net6 = ipaddress.ip_network('2001:db8::0/96')
>>> net6.netmask
IPv6Address('ffff:ffff:ffff:ffff:ffff:ffff::')
```

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```
>>> net6.hostmask
IPv6Address('::ffff:ffff')
```

Exploding or compressing the address:

```
>>> addr6.exploded
'2001:0db8:0000:0000:0000:0000:0000:0001'
>>> addr6.compressed
'2001:db8::1'
>>> net6.exploded
'2001:0db8:0000:0000:0000:0000:0000:0000/96'
>>> net6.compressed
'2001:db8::/96'
```

While IPv4 doesn't support explosion or compression, the associated objects still provide the relevant properties so that version neutral code can easily ensure the most concise or most verbose form is used for IPv6 addresses while still correctly handling IPv4 addresses.

3 Networks as lists of Addresses

It's sometimes useful to treat networks as lists. This means it is possible to index them like this:

```
>>> net4[1]
IPv4Address('192.0.2.1')
>>> net4[-1]
IPv4Address('192.0.2.255')
>>> net6[1]
IPv6Address('2001:db8::1')
>>> net6[-1]
IPv6Address('2001:db8::ffff:ffff')
```

It also means that network objects lend themselves to using the list membership test syntax like this:

```
if address in network:
    # do something
```

Containment testing is done efficiently based on the network prefix:

```
>>> addr4 = ipaddress.ip_address('192.0.2.1')
>>> addr4 in ipaddress.ip_network('192.0.2.0/24')
True
>>> addr4 in ipaddress.ip_network('192.0.3.0/24')
False
```

4 Comparisons

`ipaddress` provides some simple, hopefully intuitive ways to compare objects, where it makes sense:

```
>>> ipaddress.ip_address('192.0.2.1') < ipaddress.ip_address('192.0.2.2')
True
```

A `TypeError` exception is raised if you try to compare objects of different versions or different types.

5 Using IP Addresses with other modules

Other modules that use IP addresses (such as `socket`) usually won't accept objects from this module directly. Instead, they must be coerced to an integer or string that the other module will accept:

```
>>> addr4 = ipaddress.ip_address('192.0.2.1')
>>> str(addr4)
'192.0.2.1'
>>> int(addr4)
3221225985
```

6 Getting more detail when instance creation fails

When creating address/network/interface objects using the version-agnostic factory functions, any errors will be reported as `ValueError` with a generic error message that simply says the passed in value was not recognized as an object of that type. The lack of a specific error is because it's necessary to know whether the value is *supposed* to be IPv4 or IPv6 in order to provide more detail on why it has been rejected.

To support use cases where it is useful to have access to this additional detail, the individual class constructors actually raise the `ValueError` subclasses `ipaddress.AddressValueError` and `ipaddress.NetmaskValueError` to indicate exactly which part of the definition failed to parse correctly.

The error messages are significantly more detailed when using the class constructors directly. For example:

```
>>> ipaddress.ip_address("192.168.0.256")
Traceback (most recent call last):
  ...
ValueError: '192.168.0.256' does not appear to be an IPv4 or IPv6 address
>>> ipaddress.IPv4Address("192.168.0.256")
Traceback (most recent call last):
  ...
ipaddress.AddressValueError: Octet 256 (> 255) not permitted in '192.168.0.256'

>>> ipaddress.ip_network("192.168.0.1/64")
Traceback (most recent call last):
  ...
ValueError: '192.168.0.1/64' does not appear to be an IPv4 or IPv6 network
>>> ipaddress.IPv4Network("192.168.0.1/64")
Traceback (most recent call last):
  ...
ipaddress.NetmaskValueError: '64' is not a valid netmask
```

However, both of the module specific exceptions have `ValueError` as their parent class, so if you're not concerned with the particular type of error, you can still write code like the following:

```
try:
    network = ipaddress.IPv4Network(address)
except ValueError:
    print('address/netmask is invalid for IPv4:', address)
```

Instrumenting CPython with DTrace and SystemTap

Release 3.7.0

Guido van Rossum
and the Python development team

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Python Software Foundation
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DTrace and SystemTap are monitoring tools, each providing a way to inspect what the processes on a computer system are doing. They both use domain-specific languages allowing a user to write scripts which:

- filter which processes are to be observed
- gather data from the processes of interest
- generate reports on the data

As of Python 3.6, CPython can be built with embedded "markers", also known as "probes", that can be observed by a DTrace or SystemTap script, making it easier to monitor what the CPython processes on a system are doing.

CPython implementation detail: DTrace markers are implementation details of the CPython interpreter. No guarantees are made about probe compatibility between versions of CPython. DTrace scripts can stop working or work incorrectly without warning when changing CPython versions.

1 Enabling the static markers

macOS comes with built-in support for DTrace. On Linux, in order to build CPython with the embedded markers for SystemTap, the SystemTap development tools must be installed.

On a Linux machine, this can be done via:

```
$ yum install systemtap-sdt-devel
```

or:

```
$ sudo apt-get install systemtap-sdt-dev
```

CPython must then be configured `--with-dtrace`:

```
checking for --with-dtrace... yes
```

On macOS, you can list available DTrace probes by running a Python process in the background and listing all probes made available by the Python provider:

```
$ python3.6 -q &
$ sudo dtrace -l -P python$!  # or: dtrace -l -m python3.6

   ID   PROVIDER            MODULE                          FUNCTION NAME
29564 python18035        python3.6          _PyEval_EvalFrameDefault function-entry
29565 python18035        python3.6             dtrace_function_entry function-entry
29566 python18035        python3.6          _PyEval_EvalFrameDefault function-return
29567 python18035        python3.6            dtrace_function_return function-return
29568 python18035        python3.6                           collect gc-done
29569 python18035        python3.6                           collect gc-start
29570 python18035        python3.6          _PyEval_EvalFrameDefault line
29571 python18035        python3.6                 maybe_dtrace_line line
```

On Linux, you can verify if the SystemTap static markers are present in the built binary by seeing if it contains a ".note.stapsdt" section.

```
$ readelf -S ./python | grep .note.stapsdt
[30] .note.stapsdt        NOTE         0000000000000000 00308d78
```

If you've built Python as a shared library (with –enable-shared), you need to look instead within the shared library. For example:

```
$ readelf -S libpython3.3dm.so.1.0 | grep .note.stapsdt
[29] .note.stapsdt        NOTE         0000000000000000 00365b68
```

Sufficiently modern readelf can print the metadata:

```
$ readelf -n ./python

Displaying notes found at file offset 0x00000254 with length 0x00000020:
    Owner                 Data size          Description
    GNU                   0x00000010         NT_GNU_ABI_TAG (ABI version tag)
```

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```
        OS: Linux, ABI: 2.6.32

Displaying notes found at file offset 0x00000274 with length 0x00000024:
    Owner                 Data size          Description
    GNU                   0x00000014         NT_GNU_BUILD_ID (unique build ID bitstring)
        Build ID: df924a2b08a7e89f6e11251d4602022977af2670

Displaying notes found at file offset 0x002d6c30 with length 0x00000144:
    Owner                 Data size          Description
    stapsdt               0x00000031         NT_STAPSDT (SystemTap probe descriptors)
        Provider: python
        Name: gc__start
        Location: 0x00000000004371c3, Base: 0x0000000000630ce2, Semaphore: 0x00000000008d6bf6
        Arguments: -4@%ebx
    stapsdt               0x00000030         NT_STAPSDT (SystemTap probe descriptors)
        Provider: python
        Name: gc__done
        Location: 0x00000000004374e1, Base: 0x0000000000630ce2, Semaphore: 0x00000000008d6bf8
        Arguments: -8@%rax
    stapsdt               0x00000045         NT_STAPSDT (SystemTap probe descriptors)
        Provider: python
        Name: function__entry
        Location: 0x000000000053db6c, Base: 0x0000000000630ce2, Semaphore: 0x00000000008d6be8
        Arguments: 8@%rbp 8@%r12 -4@%eax
    stapsdt               0x00000046         NT_STAPSDT (SystemTap probe descriptors)
        Provider: python
        Name: function__return
        Location: 0x000000000053dba8, Base: 0x0000000000630ce2, Semaphore: 0x00000000008d6bea
        Arguments: 8@%rbp 8@%r12 -4@%eax
```

The above metadata contains information for SystemTap describing how it can patch strategically-placed machine code instructions to enable the tracing hooks used by a SystemTap script.

2 Static DTrace probes

The following example DTrace script can be used to show the call/return hierarchy of a Python script, only tracing within the invocation of a function called “start”. In other words, import-time function invocations are not going to be listed:

```
self int indent;

python$target:::function-entry
/copyinstr(arg1) == "start"/
{
        self->trace = 1;
}

python$target:::function-entry
/self->trace/
{
        printf("%d\t%*s:", timestamp, 15, probename);
        printf("%*s", self->indent, "");
        printf("%s:%s:%d\n", basename(copyinstr(arg0)), copyinstr(arg1), arg2);
        self->indent++;
```

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```
}

python$target:::function-return
/self->trace/
{
        self->indent--;
        printf("%d\t%*s:", timestamp, 15, probename);
        printf("%*s", self->indent, "");
        printf("%s:%s:%d\n", basename(copyinstr(arg0)), copyinstr(arg1), arg2);
}

python$target:::function-return
/copyinstr(arg1) == "start"/
{
        self->trace = 0;
}
```

It can be invoked like this:

```
$ sudo dtrace -q -s call_stack.d -c "python3.6 script.py"
```

The output looks like this:

```
156641360502280  function-entry:call_stack.py:start:23
156641360518804  function-entry: call_stack.py:function_1:1
156641360532797  function-entry:  call_stack.py:function_3:9
156641360546807 function-return:  call_stack.py:function_3:10
156641360563367 function-return: call_stack.py:function_1:2
156641360578365  function-entry: call_stack.py:function_2:5
156641360591757  function-entry:  call_stack.py:function_1:1
156641360605556  function-entry:   call_stack.py:function_3:9
156641360617482 function-return:   call_stack.py:function_3:10
156641360629814 function-return:  call_stack.py:function_1:2
156641360642285 function-return: call_stack.py:function_2:6
156641360656770  function-entry: call_stack.py:function_3:9
156641360669707 function-return: call_stack.py:function_3:10
156641360687853  function-entry: call_stack.py:function_4:13
156641360700719 function-return: call_stack.py:function_4:14
156641360719640  function-entry: call_stack.py:function_5:18
156641360732567 function-return: call_stack.py:function_5:21
156641360747370 function-return:call_stack.py:start:28
```

3 Static SystemTap markers

The low-level way to use the SystemTap integration is to use the static markers directly. This requires you to explicitly state the binary file containing them.

For example, this SystemTap script can be used to show the call/return hierarchy of a Python script:

```
probe process("python").mark("function__entry") {
     filename = user_string($arg1);
     funcname = user_string($arg2);
     lineno = $arg3;
```

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```
    printf("%s => %s in %s:%d\\n",
           thread_indent(1), funcname, filename, lineno);
}

probe process("python").mark("function__return") {
    filename = user_string($arg1);
    funcname = user_string($arg2);
    lineno = $arg3;

    printf("%s <= %s in %s:%d\\n",
           thread_indent(-1), funcname, filename, lineno);
}
```

It can be invoked like this:

```
$ stap \
  show-call-hierarchy.stp \
  -c "./python test.py"
```

The output looks like this:

```
11408 python(8274):        => __contains__ in Lib/_abcoll.py:362
11414 python(8274):         => __getitem__ in Lib/os.py:425
11418 python(8274):          => encode in Lib/os.py:490
11424 python(8274):          <= encode in Lib/os.py:493
11428 python(8274):         <= __getitem__ in Lib/os.py:426
11433 python(8274):        <= __contains__ in Lib/_abcoll.py:366
```

where the columns are:

- time in microseconds since start of script
- name of executable
- PID of process

and the remainder indicates the call/return hierarchy as the script executes.

For a *–enable-shared* build of CPython, the markers are contained within the libpython shared library, and the probe's dotted path needs to reflect this. For example, this line from the above example:

```
probe process("python").mark("function__entry") {
```

should instead read:

```
probe process("python").library("libpython3.6dm.so.1.0").mark("function__entry") {
```

(assuming a debug build of CPython 3.6)

4 Available static markers

function__entry(str *filename*, str *funcname*, int *lineno*)

This marker indicates that execution of a Python function has begun. It is only triggered for pure-Python (bytecode) functions.

The filename, function name, and line number are provided back to the tracing script as positional arguments, which must be accessed using `$arg1`, `$arg2`, `$arg3`:

- `$arg1` : `(const char *)` filename, accessible using `user_string($arg1)`
- `$arg2` : `(const char *)` function name, accessible using `user_string($arg2)`
- `$arg3` : `int` line number

function__return(str *filename*, str *funcname*, int *lineno*)
This marker is the converse of *function__entry()*, and indicates that execution of a Python function has ended (either via `return`, or via an exception). It is only triggered for pure-Python (bytecode) functions.

The arguments are the same as for *function__entry()*

line(str *filename*, str *funcname*, int *lineno*)
This marker indicates a Python line is about to be executed. It is the equivalent of line-by-line tracing with a Python profiler. It is not triggered within C functions.

The arguments are the same as for *function__entry()*.

gc__start(int *generation*)
Fires when the Python interpreter starts a garbage collection cycle. `arg0` is the generation to scan, like `gc.collect()`.

gc__done(long *collected*)
Fires when the Python interpreter finishes a garbage collection cycle. `arg0` is the number of collected objects.

import__find__load__start(str *modulename*)
Fires before `importlib` attempts to find and load the module. `arg0` is the module name.

New in version 3.7.

import__find__load__done(str *modulename*, int *found*)
Fires after `importlib`'s find_and_load function is called. `arg0` is the module name, `arg1` indicates if module was successfully loaded.

New in version 3.7.

5 SystemTap Tapsets

The higher-level way to use the SystemTap integration is to use a "tapset": SystemTap's equivalent of a library, which hides some of the lower-level details of the static markers.

Here is a tapset file, based on a non-shared build of CPython:

```
/*
   Provide a higher-level wrapping around the function__entry and
   function__return markers:
 \*/
probe python.function.entry = process("python").mark("function__entry")
{
    filename = user_string($arg1);
    funcname = user_string($arg2);
    lineno = $arg3;
    frameptr = $arg4
}
probe python.function.return = process("python").mark("function__return")
{
    filename = user_string($arg1);
    funcname = user_string($arg2);
    lineno = $arg3;
```

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```
    frameptr = $arg4
}
```

If this file is installed in SystemTap's tapset directory (e.g. `/usr/share/systemtap/tapset`), then these additional probepoints become available:

python.function.entry(str *filename*, str *funcname*, int *lineno*, frameptr)
This probe point indicates that execution of a Python function has begun. It is only triggered for pure-python (bytecode) functions.

python.function.return(str *filename*, str *funcname*, int *lineno*, frameptr)
This probe point is the converse of *python.function.return()*, and indicates that execution of a Python function has ended (either via `return`, or via an exception). It is only triggered for pure-python (bytecode) functions.

6 Examples

This SystemTap script uses the tapset above to more cleanly implement the example given above of tracing the Python function-call hierarchy, without needing to directly name the static markers:

```
probe python.function.entry
{
  printf("%s => %s in %s:%d\n",
         thread_indent(1), funcname, filename, lineno);
}

probe python.function.return
{
  printf("%s <= %s in %s:%d\n",
         thread_indent(-1), funcname, filename, lineno);
}
```

The following script uses the tapset above to provide a top-like view of all running CPython code, showing the top 20 most frequently-entered bytecode frames, each second, across the whole system:

```
global fn_calls;

probe python.function.entry
{
    fn_calls[pid(), filename, funcname, lineno] += 1;
}

probe timer.ms(1000) {
    printf("\033[2J\033[1;1H") /* clear screen \*/
    printf("%6s %80s %6s %30s %6s\n",
           "PID", "FILENAME", "LINE", "FUNCTION", "CALLS")
    foreach ([pid, filename, funcname, lineno] in fn_calls- limit 20) {
        printf("%6d %80s %6d %30s %6d\n",
            pid, filename, lineno, funcname,
            fn_calls[pid, filename, funcname, lineno]);
    }
    delete fn_calls;
}
```

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Functional Programming HOWTO

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In this document, we'll take a tour of Python's features suitable for implementing programs in a functional style. After an introduction to the concepts of functional programming, we'll look at language features such as iterators and generators and relevant library modules such as `itertools` and `functools`.

1 Introduction

This section explains the basic concept of functional programming; if you're just interested in learning about Python language features, skip to the next section on *Iterators*.

Programming languages support decomposing problems in several different ways:

- Most programming languages are **procedural**: programs are lists of instructions that tell the computer what to do with the program's input. C, Pascal, and even Unix shells are procedural languages.
- In **declarative** languages, you write a specification that describes the problem to be solved, and the language implementation figures out how to perform the computation efficiently. SQL is the declarative language you're most likely to be familiar with; a SQL query describes the data set you want to retrieve, and the SQL engine decides whether to scan tables or use indexes, which subclauses should be performed first, etc.
- **Object-oriented** programs manipulate collections of objects. Objects have internal state and support methods that query or modify this internal state in some way. Smalltalk and Java are object-oriented languages. C++ and Python are languages that support object-oriented programming, but don't force the use of object-oriented features.
- **Functional** programming decomposes a problem into a set of functions. Ideally, functions only take inputs and produce outputs, and don't have any internal state that affects the output produced for a given input. Well-known functional languages include the ML family (Standard ML, OCaml, and other variants) and Haskell.

The designers of some computer languages choose to emphasize one particular approach to programming. This often makes it difficult to write programs that use a different approach. Other languages are multi-paradigm languages that support several different approaches. Lisp, C++, and Python are multi-paradigm; you can write programs or libraries that are largely procedural, object-oriented, or functional in all of these languages. In a large program, different sections might be written using different approaches; the GUI might be object-oriented while the processing logic is procedural or functional, for example.

In a functional program, input flows through a set of functions. Each function operates on its input and produces some output. Functional style discourages functions with side effects that modify internal state or make other changes that aren't visible in the function's return value. Functions that have no side effects at all are called **purely functional**. Avoiding side effects means not using data structures that get updated as a program runs; every function's output must only depend on its input.

Some languages are very strict about purity and don't even have assignment statements such as `a=3` or `c = a + b`, but it's difficult to avoid all side effects. Printing to the screen or writing to a disk file are side effects, for example. For example, in Python a call to the `print()` or `time.sleep()` function both return no useful value; they're only called for their side effects of sending some text to the screen or pausing execution for a second.

Python programs written in functional style usually won't go to the extreme of avoiding all I/O or all assignments; instead, they'll provide a functional-appearing interface but will use non-functional features internally. For example, the implementation of a function will still use assignments to local variables, but won't modify global variables or have other side effects.

Functional programming can be considered the opposite of object-oriented programming. Objects are little capsules containing some internal state along with a collection of method calls that let you modify this state, and programs consist of making the right set of state changes. Functional programming wants to avoid state changes as much as possible and works with data flowing between functions. In Python you might combine the two approaches by writing functions that take and return instances representing objects in your application (e-mail messages, transactions, etc.).

Functional design may seem like an odd constraint to work under. Why should you avoid objects and side effects? There are theoretical and practical advantages to the functional style:

- Formal provability.
- Modularity.
- Composability.
- Ease of debugging and testing.

1.1 Formal provability

A theoretical benefit is that it's easier to construct a mathematical proof that a functional program is correct.

For a long time researchers have been interested in finding ways to mathematically prove programs correct. This is different from testing a program on numerous inputs and concluding that its output is usually correct, or reading a program's source code and concluding that the code looks right; the goal is instead a rigorous proof that a program produces the right result for all possible inputs.

The technique used to prove programs correct is to write down **invariants**, properties of the input data and of the program's variables that are always true. For each line of code, you then show that if invariants X and Y are true **before** the line is executed, the slightly different invariants X' and Y' are true **after** the line is executed. This continues until you reach the end of the program, at which point the invariants should match the desired conditions on the program's output.

Functional programming's avoidance of assignments arose because assignments are difficult to handle with this technique; assignments can break invariants that were true before the assignment without producing any new invariants that can be propagated onward.

Unfortunately, proving programs correct is largely impractical and not relevant to Python software. Even trivial programs require proofs that are several pages long; the proof of correctness for a moderately complicated program would be enormous, and few or none of the programs you use daily (the Python interpreter, your XML parser, your web browser) could be proven correct. Even if you wrote down or generated a proof, there would then be the question of verifying the proof; maybe there's an error in it, and you wrongly believe you've proved the program correct.

1.2 Modularity

A more practical benefit of functional programming is that it forces you to break apart your problem into small pieces. Programs are more modular as a result. It's easier to specify and write a small function that does one thing than a large function that performs a complicated transformation. Small functions are also easier to read and to check for errors.

1.3 Ease of debugging and testing

Testing and debugging a functional-style program is easier.

Debugging is simplified because functions are generally small and clearly specified. When a program doesn't work, each function is an interface point where you can check that the data are correct. You can look at the intermediate inputs and outputs to quickly isolate the function that's responsible for a bug.

Testing is easier because each function is a potential subject for a unit test. Functions don't depend on system state that needs to be replicated before running a test; instead you only have to synthesize the right input and then check that the output matches expectations.

1.4 Composability

As you work on a functional-style program, you'll write a number of functions with varying inputs and outputs. Some of these functions will be unavoidably specialized to a particular application, but others will be useful in a wide variety of programs. For example, a function that takes a directory path and returns all the XML files in the directory, or a function that takes a filename and returns its contents, can be applied to many different situations.

Over time you'll form a personal library of utilities. Often you'll assemble new programs by arranging existing functions in a new configuration and writing a few functions specialized for the current task.

2 Iterators

I'll start by looking at a Python language feature that's an important foundation for writing functional-style programs: iterators.

An iterator is an object representing a stream of data; this object returns the data one element at a time. A Python iterator must support a method called `__next__()` that takes no arguments and always returns the next element of the stream. If there are no more elements in the stream, `__next__()` must raise the `StopIteration` exception. Iterators don't have to be finite, though; it's perfectly reasonable to write an iterator that produces an infinite stream of data.

The built-in `iter()` function takes an arbitrary object and tries to return an iterator that will return the object's contents or elements, raising `TypeError` if the object doesn't support iteration. Several of Python's built-in data types support iteration, the most common being lists and dictionaries. An object is called iterable if you can get an iterator for it.

You can experiment with the iteration interface manually:

```
>>> L = [1,2,3]
>>> it = iter(L)
>>> it
<...iterator object at ...>
>>> it.__next__()  # same as next(it)
1
>>> next(it)
2
>>> next(it)
3
>>> next(it)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
>>>
```

Python expects iterable objects in several different contexts, the most important being the `for` statement. In the statement `for X in Y`, Y must be an iterator or some object for which `iter()` can create an iterator. These two statements are equivalent:

```
for i in iter(obj):
    print(i)

for i in obj:
    print(i)
```

Iterators can be materialized as lists or tuples by using the `list()` or `tuple()` constructor functions:

```
>>> L = [1,2,3]
>>> iterator = iter(L)
>>> t = tuple(iterator)
>>> t
(1, 2, 3)
```

Sequence unpacking also supports iterators: if you know an iterator will return N elements, you can unpack them into an N-tuple:

```
>>> L = [1,2,3]
>>> iterator = iter(L)
>>> a,b,c = iterator
>>> a,b,c
(1, 2, 3)
```

Built-in functions such as `max()` and `min()` can take a single iterator argument and will return the largest or smallest element. The `"in"` and `"not in"` operators also support iterators: `X in iterator` is true if X is found in the stream returned by the iterator. You'll run into obvious problems if the iterator is infinite; `max()`, `min()` will never return, and if the element X never appears in the stream, the `"in"` and `"not in"` operators won't return either.

Note that you can only go forward in an iterator; there's no way to get the previous element, reset the iterator, or make a copy of it. Iterator objects can optionally provide these additional capabilities, but the iterator protocol only specifies the `__next__()` method. Functions may therefore consume all of the iterator's output, and if you need to do something different with the same stream, you'll have to create a new iterator.

2.1 Data Types That Support Iterators

We've already seen how lists and tuples support iterators. In fact, any Python sequence type, such as strings, will automatically support creation of an iterator.

Calling `iter()` on a dictionary returns an iterator that will loop over the dictionary's keys:

```
>>> m = {'Jan': 1, 'Feb': 2, 'Mar': 3, 'Apr': 4, 'May': 5, 'Jun': 6,
...      'Jul': 7, 'Aug': 8, 'Sep': 9, 'Oct': 10, 'Nov': 11, 'Dec': 12}
>>> for key in m:
...     print(key, m[key])
Mar 3
Feb 2
Aug 8
Sep 9
Apr 4
Jun 6
Jul 7
```

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```
Jan 1
May 5
Nov 11
Dec 12
Oct 10
```

Note that the order is essentially random, because it's based on the hash ordering of the objects in the dictionary.

Applying `iter()` to a dictionary always loops over the keys, but dictionaries have methods that return other iterators. If you want to iterate over values or key/value pairs, you can explicitly call the `values()` or `items()` methods to get an appropriate iterator.

The `dict()` constructor can accept an iterator that returns a finite stream of `(key, value)` tuples:

```
>>> L = [('Italy', 'Rome'), ('France', 'Paris'), ('US', 'Washington DC')]
>>> dict(iter(L))
{'Italy': 'Rome', 'US': 'Washington DC', 'France': 'Paris'}
```

Files also support iteration by calling the `readline()` method until there are no more lines in the file. This means you can read each line of a file like this:

```
for line in file:
    # do something for each line
    ...
```

Sets can take their contents from an iterable and let you iterate over the set's elements:

```
S = {2, 3, 5, 7, 11, 13}
for i in S:
    print(i)
```

3 Generator expressions and list comprehensions

Two common operations on an iterator's output are 1) performing some operation for every element, 2) selecting a subset of elements that meet some condition. For example, given a list of strings, you might want to strip off trailing whitespace from each line or extract all the strings containing a given substring.

List comprehensions and generator expressions (short form: "listcomps" and "genexps") are a concise notation for such operations, borrowed from the functional programming language Haskell (https://www.haskell.org/). You can strip all the whitespace from a stream of strings with the following code:

```
line_list = ['  line 1\n', 'line 2  \n', ...]

# Generator expression -- returns iterator
stripped_iter = (line.strip() for line in line_list)

# List comprehension -- returns list
stripped_list = [line.strip() for line in line_list]
```

You can select only certain elements by adding an `"if"` condition:

```
stripped_list = [line.strip() for line in line_list
                 if line != ""]
```

With a list comprehension, you get back a Python list; `stripped_list` is a list containing the resulting lines, not an iterator. Generator expressions return an iterator that computes the values as necessary, not needing to materialize all the values at once. This means that list comprehensions aren't useful if you're working with iterators that return an infinite stream or a very large amount of data. Generator expressions are preferable in these situations.

Generator expressions are surrounded by parentheses ("()") and list comprehensions are surrounded by square brackets ("[]"). Generator expressions have the form:

```
( expression for expr in sequence1
              if condition1
              for expr2 in sequence2
              if condition2
              for expr3 in sequence3 ...
              if condition3
              for exprN in sequenceN
              if conditionN )
```

Again, for a list comprehension only the outside brackets are different (square brackets instead of parentheses).

The elements of the generated output will be the successive values of `expression`. The `if` clauses are all optional; if present, `expression` is only evaluated and added to the result when `condition` is true.

Generator expressions always have to be written inside parentheses, but the parentheses signalling a function call also count. If you want to create an iterator that will be immediately passed to a function you can write:

```
obj_total = sum(obj.count for obj in list_all_objects())
```

The `for...in` clauses contain the sequences to be iterated over. The sequences do not have to be the same length, because they are iterated over from left to right, **not** in parallel. For each element in `sequence1`, `sequence2` is looped over from the beginning. `sequence3` is then looped over for each resulting pair of elements from `sequence1` and `sequence2`.

To put it another way, a list comprehension or generator expression is equivalent to the following Python code:

```
for expr1 in sequence1:
    if not (condition1):
        continue   # Skip this element
    for expr2 in sequence2:
        if not (condition2):
            continue   # Skip this element
        ...
        for exprN in sequenceN:
            if not (conditionN):
                continue   # Skip this element

            # Output the value of
            # the expression.
```

This means that when there are multiple `for...in` clauses but no `if` clauses, the length of the resulting output will be equal to the product of the lengths of all the sequences. If you have two lists of length 3, the output list is 9 elements long:

```
>>> seq1 = 'abc'
>>> seq2 = (1,2,3)
>>> [(x, y) for x in seq1 for y in seq2]
[('a', 1), ('a', 2), ('a', 3),
```

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```
 ('b', 1), ('b', 2), ('b', 3),
 ('c', 1), ('c', 2), ('c', 3)]
```

To avoid introducing an ambiguity into Python's grammar, if `expression` is creating a tuple, it must be surrounded with parentheses. The first list comprehension below is a syntax error, while the second one is correct:

```
# Syntax error
[x, y for x in seq1 for y in seq2]
# Correct
[(x, y) for x in seq1 for y in seq2]
```

4 Generators

Generators are a special class of functions that simplify the task of writing iterators. Regular functions compute a value and return it, but generators return an iterator that returns a stream of values.

You're doubtless familiar with how regular function calls work in Python or C. When you call a function, it gets a private namespace where its local variables are created. When the function reaches a `return` statement, the local variables are destroyed and the value is returned to the caller. A later call to the same function creates a new private namespace and a fresh set of local variables. But, what if the local variables weren't thrown away on exiting a function? What if you could later resume the function where it left off? This is what generators provide; they can be thought of as resumable functions.

Here's the simplest example of a generator function:

```
>>> def generate_ints(N):
...     for i in range(N):
...         yield i
```

Any function containing a `yield` keyword is a generator function; this is detected by Python's bytecode compiler which compiles the function specially as a result.

When you call a generator function, it doesn't return a single value; instead it returns a generator object that supports the iterator protocol. On executing the `yield` expression, the generator outputs the value of `i`, similar to a `return` statement. The big difference between `yield` and a `return` statement is that on reaching a `yield` the generator's state of execution is suspended and local variables are preserved. On the next call to the generator's `__next__()` method, the function will resume executing.

Here's a sample usage of the `generate_ints()` generator:

```
>>> gen = generate_ints(3)
>>> gen
<generator object generate_ints at ...>
>>> next(gen)
0
>>> next(gen)
1
>>> next(gen)
2
>>> next(gen)
Traceback (most recent call last):
  File "stdin", line 1, in <module>
  File "stdin", line 2, in generate_ints
StopIteration
```

You could equally write `for i in generate_ints(5)`, or `a,b,c = generate_ints(3)`.

Inside a generator function, `return value` causes `StopIteration(value)` to be raised from the `__next__()` method. Once this happens, or the bottom of the function is reached, the procession of values ends and the generator cannot yield any further values.

You could achieve the effect of generators manually by writing your own class and storing all the local variables of the generator as instance variables. For example, returning a list of integers could be done by setting `self.count` to 0, and having the `__next__()` method increment `self.count` and return it. However, for a moderately complicated generator, writing a corresponding class can be much messier.

The test suite included with Python's library, Lib/test/test_generators.py, contains a number of more interesting examples. Here's one generator that implements an in-order traversal of a tree using generators recursively.

```
# A recursive generator that generates Tree leaves in in-order.
def inorder(t):
    if t:
        for x in inorder(t.left):
            yield x

        yield t.label

        for x in inorder(t.right):
            yield x
```

Two other examples in `test_generators.py` produce solutions for the N-Queens problem (placing N queens on an NxN chess board so that no queen threatens another) and the Knight's Tour (finding a route that takes a knight to every square of an NxN chessboard without visiting any square twice).

4.1 Passing values into a generator

In Python 2.4 and earlier, generators only produced output. Once a generator's code was invoked to create an iterator, there was no way to pass any new information into the function when its execution is resumed. You could hack together this ability by making the generator look at a global variable or by passing in some mutable object that callers then modify, but these approaches are messy.

In Python 2.5 there's a simple way to pass values into a generator. `yield` became an expression, returning a value that can be assigned to a variable or otherwise operated on:

```
val = (yield i)
```

I recommend that you **always** put parentheses around a `yield` expression when you're doing something with the returned value, as in the above example. The parentheses aren't always necessary, but it's easier to always add them instead of having to remember when they're needed.

(**PEP 342** explains the exact rules, which are that a `yield`-expression must always be parenthesized except when it occurs at the top-level expression on the right-hand side of an assignment. This means you can write `val = yield i` but have to use parentheses when there's an operation, as in `val = (yield i) + 12`.)

Values are sent into a generator by calling its `send(value)` method. This method resumes the generator's code and the `yield` expression returns the specified value. If the regular `__next__()` method is called, the `yield` returns `None`.

Here's a simple counter that increments by 1 and allows changing the value of the internal counter.

```
def counter(maximum):
    i = 0
```

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```
    while i < maximum:
        val = (yield i)
        # If value provided, change counter
        if val is not None:
            i = val
        else:
            i += 1
```

And here's an example of changing the counter:

```
>>> it = counter(10)
>>> next(it)
0
>>> next(it)
1
>>> it.send(8)
8
>>> next(it)
9
>>> next(it)
Traceback (most recent call last):
  File "t.py", line 15, in <module>
    it.next()
StopIteration
```

Because `yield` will often be returning `None`, you should always check for this case. Don't just use its value in expressions unless you're sure that the `send()` method will be the only method used to resume your generator function.

In addition to `send()`, there are two other methods on generators:

- `throw(type, value=None, traceback=None)` is used to raise an exception inside the generator; the exception is raised by the `yield` expression where the generator's execution is paused.
- `close()` raises a `GeneratorExit` exception inside the generator to terminate the iteration. On receiving this exception, the generator's code must either raise `GeneratorExit` or `StopIteration`; catching the exception and doing anything else is illegal and will trigger a `RuntimeError`. `close()` will also be called by Python's garbage collector when the generator is garbage-collected.

  If you need to run cleanup code when a `GeneratorExit` occurs, I suggest using a `try: ... finally:` suite instead of catching `GeneratorExit`.

The cumulative effect of these changes is to turn generators from one-way producers of information into both producers and consumers.

Generators also become **coroutines**, a more generalized form of subroutines. Subroutines are entered at one point and exited at another point (the top of the function, and a `return` statement), but coroutines can be entered, exited, and resumed at many different points (the `yield` statements).

5 Built-in functions

Let's look in more detail at built-in functions often used with iterators.

Two of Python's built-in functions, `map()` and `filter()` duplicate the features of generator expressions:

`map(f, iterA, iterB, ...)` returns an iterator over the sequence `f(iterA[0], iterB[0]), f(iterA[1], iterB[1]), f(iterA[2], iterB[2]), ...`.

```
>>> def upper(s):
...     return s.upper()
```

```
>>> list(map(upper, ['sentence', 'fragment']))
['SENTENCE', 'FRAGMENT']
>>> [upper(s) for s in ['sentence', 'fragment']]
['SENTENCE', 'FRAGMENT']
```

You can of course achieve the same effect with a list comprehension.

`filter(predicate, iter)` returns an iterator over all the sequence elements that meet a certain condition, and is similarly duplicated by list comprehensions. A **predicate** is a function that returns the truth value of some condition; for use with `filter()`, the predicate must take a single value.

```
>>> def is_even(x):
...     return (x % 2) == 0
```

```
>>> list(filter(is_even, range(10)))
[0, 2, 4, 6, 8]
```

This can also be written as a list comprehension:

```
>>> list(x for x in range(10) if is_even(x))
[0, 2, 4, 6, 8]
```

`enumerate(iter, start=0)` counts off the elements in the iterable returning 2-tuples containing the count (from *start*) and each element.

```
>>> for item in enumerate(['subject', 'verb', 'object']):
...     print(item)
(0, 'subject')
(1, 'verb')
(2, 'object')
```

`enumerate()` is often used when looping through a list and recording the indexes at which certain conditions are met:

```
f = open('data.txt', 'r')
for i, line in enumerate(f):
    if line.strip() == '':
        print('Blank line at line #%i' % i)
```

`sorted(iterable, key=None, reverse=False)` collects all the elements of the iterable into a list, sorts the list, and returns the sorted result. The *key* and *reverse* arguments are passed through to the constructed list's `sort()` method.

```
>>> import random
>>> # Generate 8 random numbers between [0, 10000)
>>> rand_list = random.sample(range(10000), 8)
>>> rand_list
[769, 7953, 9828, 6431, 8442, 9878, 6213, 2207]
>>> sorted(rand_list)
[769, 2207, 6213, 6431, 7953, 8442, 9828, 9878]
>>> sorted(rand_list, reverse=True)
[9878, 9828, 8442, 7953, 6431, 6213, 2207, 769]
```

(For a more detailed discussion of sorting, see the sortinghowto.)

The `any(iter)` and `all(iter)` built-ins look at the truth values of an iterable's contents. `any()` returns `True` if any element in the iterable is a true value, and `all()` returns `True` if all of the elements are true values:

```
>>> any([0,1,0])
True
>>> any([0,0,0])
False
>>> any([1,1,1])
True
>>> all([0,1,0])
False
>>> all([0,0,0])
False
>>> all([1,1,1])
True
```

`zip(iterA, iterB, ...)` takes one element from each iterable and returns them in a tuple:

```
zip(['a', 'b', 'c'], (1, 2, 3)) =>
  ('a', 1), ('b', 2), ('c', 3)
```

It doesn't construct an in-memory list and exhaust all the input iterators before returning; instead tuples are constructed and returned only if they're requested. (The technical term for this behaviour is lazy evaluation.)

This iterator is intended to be used with iterables that are all of the same length. If the iterables are of different lengths, the resulting stream will be the same length as the shortest iterable.

```
zip(['a', 'b'], (1, 2, 3)) =>
  ('a', 1), ('b', 2)
```

You should avoid doing this, though, because an element may be taken from the longer iterators and discarded. This means you can't go on to use the iterators further because you risk skipping a discarded element.

6 The itertools module

The `itertools` module contains a number of commonly-used iterators as well as functions for combining several iterators. This section will introduce the module's contents by showing small examples.

The module's functions fall into a few broad classes:

- Functions that create a new iterator based on an existing iterator.
- Functions for treating an iterator's elements as function arguments.
- Functions for selecting portions of an iterator's output.
- A function for grouping an iterator's output.

6.1 Creating new iterators

`itertools.count(start, step)` returns an infinite stream of evenly spaced values. You can optionally supply the starting number, which defaults to 0, and the interval between numbers, which defaults to 1:

```
itertools.count() =>
  0, 1, 2, 3, 4, 5, 6, 7, 8, 9, ...
itertools.count(10) =>
  10, 11, 12, 13, 14, 15, 16, 17, 18, 19, ...
itertools.count(10, 5) =>
  10, 15, 20, 25, 30, 35, 40, 45, 50, 55, ...
```

`itertools.cycle(iter)` saves a copy of the contents of a provided iterable and returns a new iterator that returns its elements from first to last. The new iterator will repeat these elements infinitely.

```
itertools.cycle([1,2,3,4,5]) =>
  1, 2, 3, 4, 5, 1, 2, 3, 4, 5, ...
```

`itertools.repeat(elem, [n])` returns the provided element n times, or returns the element endlessly if n is not provided.

```
itertools.repeat('abc') =>
  abc, abc, abc, abc, abc, abc, abc, abc, abc, abc, ...
itertools.repeat('abc', 5) =>
  abc, abc, abc, abc, abc
```

`itertools.chain(iterA, iterB, ...)` takes an arbitrary number of iterables as input, and returns all the elements of the first iterator, then all the elements of the second, and so on, until all of the iterables have been exhausted.

```
itertools.chain(['a', 'b', 'c'], (1, 2, 3)) =>
  a, b, c, 1, 2, 3
```

`itertools.islice(iter, [start], stop, [step])` returns a stream that's a slice of the iterator. With a single *stop* argument, it will return the first *stop* elements. If you supply a starting index, you'll get *stop-start* elements, and if you supply a value for *step*, elements will be skipped accordingly. Unlike Python's string and list slicing, you can't use negative values for *start*, *stop*, or *step*.

```
itertools.islice(range(10), 8) =>
  0, 1, 2, 3, 4, 5, 6, 7
itertools.islice(range(10), 2, 8) =>
  2, 3, 4, 5, 6, 7
itertools.islice(range(10), 2, 8, 2) =>
  2, 4, 6
```

`itertools.tee(iter, [n])` replicates an iterator; it returns n independent iterators that will all return the contents of the source iterator. If you don't supply a value for n, the default is 2. Replicating iterators requires saving some of the contents of the source iterator, so this can consume significant memory if the iterator is large and one of the new iterators is consumed more than the others.

```
itertools.tee( itertools.count() ) =>
   iterA, iterB

where iterA ->
   0, 1, 2, 3, 4, 5, 6, 7, 8, 9, ...

and   iterB ->
   0, 1, 2, 3, 4, 5, 6, 7, 8, 9, ...
```

6.2 Calling functions on elements

The `operator` module contains a set of functions corresponding to Python's operators. Some examples are `operator.add(a, b)` (adds two values), `operator.ne(a, b)` (same as `a != b`), and `operator.attrgetter('id')` (returns a callable that fetches the `.id` attribute).

`itertools.starmap(func, iter)` assumes that the iterable will return a stream of tuples, and calls *func* using these tuples as the arguments:

```
itertools.starmap(os.path.join,
                  [('/bin', 'python'), ('/usr', 'bin', 'java'),
                   ('/usr', 'bin', 'perl'), ('/usr', 'bin', 'ruby')])
=>
  /bin/python, /usr/bin/java, /usr/bin/perl, /usr/bin/ruby
```

6.3 Selecting elements

Another group of functions chooses a subset of an iterator's elements based on a predicate.

`itertools.filterfalse(predicate, iter)` is the opposite of `filter()`, returning all elements for which the predicate returns false:

```
itertools.filterfalse(is_even, itertools.count()) =>
  1, 3, 5, 7, 9, 11, 13, 15, ...
```

`itertools.takewhile(predicate, iter)` returns elements for as long as the predicate returns true. Once the predicate returns false, the iterator will signal the end of its results.

```
def less_than_10(x):
    return x < 10

itertools.takewhile(less_than_10, itertools.count()) =>
  0, 1, 2, 3, 4, 5, 6, 7, 8, 9

itertools.takewhile(is_even, itertools.count()) =>
  0
```

`itertools.dropwhile(predicate, iter)` discards elements while the predicate returns true, and then returns the rest of the iterable's results.

```
itertools.dropwhile(less_than_10, itertools.count()) =>
  10, 11, 12, 13, 14, 15, 16, 17, 18, 19, ...

itertools.dropwhile(is_even, itertools.count()) =>
  1, 2, 3, 4, 5, 6, 7, 8, 9, 10, ...
```

`itertools.compress(data, selectors)` takes two iterators and returns only those elements of *data* for which the corresponding element of *selectors* is true, stopping whenever either one is exhausted:

```
itertools.compress([1,2,3,4,5], [True, True, False, False, True]) =>
   1, 2, 5
```

6.4 Combinatoric functions

The `itertools.combinations(iterable, r)` returns an iterator giving all possible r-tuple combinations of the elements contained in *iterable*.

```
itertools.combinations([1, 2, 3, 4, 5], 2) =>
  (1, 2), (1, 3), (1, 4), (1, 5),
  (2, 3), (2, 4), (2, 5),
  (3, 4), (3, 5),
  (4, 5)

itertools.combinations([1, 2, 3, 4, 5], 3) =>
  (1, 2, 3), (1, 2, 4), (1, 2, 5), (1, 3, 4), (1, 3, 5), (1, 4, 5),
  (2, 3, 4), (2, 3, 5), (2, 4, 5),
  (3, 4, 5)
```

The elements within each tuple remain in the same order as *iterable* returned them. For example, the number 1 is always before 2, 3, 4, or 5 in the examples above. A similar function, `itertools.permutations(iterable, r=None)`, removes this constraint on the order, returning all possible arrangements of length *r*:

```
itertools.permutations([1, 2, 3, 4, 5], 2) =>
  (1, 2), (1, 3), (1, 4), (1, 5),
  (2, 1), (2, 3), (2, 4), (2, 5),
  (3, 1), (3, 2), (3, 4), (3, 5),
  (4, 1), (4, 2), (4, 3), (4, 5),
  (5, 1), (5, 2), (5, 3), (5, 4)

itertools.permutations([1, 2, 3, 4, 5]) =>
  (1, 2, 3, 4, 5), (1, 2, 3, 5, 4), (1, 2, 4, 3, 5),
  ...
  (5, 4, 3, 2, 1)
```

If you don't supply a value for *r* the length of the iterable is used, meaning that all the elements are permuted.

Note that these functions produce all of the possible combinations by position and don't require that the contents of *iterable* are unique:

```
itertools.permutations('aba', 3) =>
  ('a', 'b', 'a'), ('a', 'a', 'b'), ('b', 'a', 'a'),
  ('b', 'a', 'a'), ('a', 'a', 'b'), ('a', 'b', 'a')
```

The identical tuple `('a', 'a', 'b')` occurs twice, but the two 'a' strings came from different positions.

The `itertools.combinations_with_replacement(iterable, r)` function relaxes a different constraint: elements can be repeated within a single tuple. Conceptually an element is selected for the first position of each tuple and then is replaced before the second element is selected.

```
itertools.combinations_with_replacement([1, 2, 3, 4, 5], 2) =>
  (1, 1), (1, 2), (1, 3), (1, 4), (1, 5),
  (2, 2), (2, 3), (2, 4), (2, 5),
  (3, 3), (3, 4), (3, 5),
  (4, 4), (4, 5),
  (5, 5)
```

6.5 Grouping elements

The last function I'll discuss, `itertools.groupby(iter, key_func=None)`, is the most complicated. `key_func(elem)` is a function that can compute a key value for each element returned by the iterable. If you don't supply a key function, the key is simply each element itself.

`groupby()` collects all the consecutive elements from the underlying iterable that have the same key value, and returns a stream of 2-tuples containing a key value and an iterator for the elements with that key.

```
city_list = [('Decatur', 'AL'), ('Huntsville', 'AL'), ('Selma', 'AL'),
             ('Anchorage', 'AK'), ('Nome', 'AK'),
             ('Flagstaff', 'AZ'), ('Phoenix', 'AZ'), ('Tucson', 'AZ'),
             ...
            ]

def get_state(city_state):
    return city_state[1]

itertools.groupby(city_list, get_state) =>
  ('AL', iterator-1),
  ('AK', iterator-2),
  ('AZ', iterator-3), ...

where
iterator-1 =>
  ('Decatur', 'AL'), ('Huntsville', 'AL'), ('Selma', 'AL')
iterator-2 =>
  ('Anchorage', 'AK'), ('Nome', 'AK')
iterator-3 =>
  ('Flagstaff', 'AZ'), ('Phoenix', 'AZ'), ('Tucson', 'AZ')
```

`groupby()` assumes that the underlying iterable's contents will already be sorted based on the key. Note that the returned iterators also use the underlying iterable, so you have to consume the results of iterator-1 before requesting iterator-2 and its corresponding key.

7 The functools module

The `functools` module in Python 2.5 contains some higher-order functions. A **higher-order function** takes one or more functions as input and returns a new function. The most useful tool in this module is the `functools.partial()` function.

For programs written in a functional style, you'll sometimes want to construct variants of existing functions that have some of the parameters filled in. Consider a Python function `f(a, b, c)`; you may wish to create a new function `g(b, c)` that's equivalent to `f(1, b, c)`; you're filling in a value for one of `f()`'s parameters. This is called "partial function application".

The constructor for `partial()` takes the arguments `(function, arg1, arg2, ..., kwarg1=value1, kwarg2=value2)`. The resulting object is callable, so you can just call it to invoke `function` with the filled-in arguments.

Here's a small but realistic example:

```
import functools

def log(message, subsystem):
    """Write the contents of 'message' to the specified subsystem."""
    print('%s: %s' % (subsystem, message))
    ...

server_log = functools.partial(log, subsystem='server')
server_log('Unable to open socket')
```

`functools.reduce(func, iter, [initial_value])` cumulatively performs an operation on all the iterable's elements and, therefore, can't be applied to infinite iterables. *func* must be a function that takes two elements and returns a single value. `functools.reduce()` takes the first two elements A and B returned by the iterator and calculates `func(A, B)`. It then requests the third element, C, calculates `func(func(A, B), C)`, combines this result with the fourth element returned, and continues until the iterable is exhausted. If the iterable returns no values at all, a `TypeError` exception is raised. If the initial value is supplied, it's used as a starting point and `func(initial_value, A)` is the first calculation.

```
>>> import operator, functools
>>> functools.reduce(operator.concat, ['A', 'BB', 'C'])
'ABBC'
>>> functools.reduce(operator.concat, [])
Traceback (most recent call last):
  ...
TypeError: reduce() of empty sequence with no initial value
>>> functools.reduce(operator.mul, [1,2,3], 1)
6
>>> functools.reduce(operator.mul, [], 1)
1
```

If you use `operator.add()` with `functools.reduce()`, you'll add up all the elements of the iterable. This case is so common that there's a special built-in called `sum()` to compute it:

```
>>> import functools, operator
>>> functools.reduce(operator.add, [1,2,3,4], 0)
10
>>> sum([1,2,3,4])
10
>>> sum([])
0
```

For many uses of `functools.reduce()`, though, it can be clearer to just write the obvious `for` loop:

```
import functools
# Instead of:
product = functools.reduce(operator.mul, [1,2,3], 1)

# You can write:
product = 1
for i in [1,2,3]:
    product *= i
```

A related function is `itertools.accumulate(iterable, func=operator.add)`. It performs the same calculation, but instead of returning only the final result, `accumulate()` returns an iterator that also yields each partial result:

```
itertools.accumulate([1,2,3,4,5]) =>
  1, 3, 6, 10, 15

itertools.accumulate([1,2,3,4,5], operator.mul) =>
  1, 2, 6, 24, 120
```

7.1 The operator module

The `operator` module was mentioned earlier. It contains a set of functions corresponding to Python's operators. These functions are often useful in functional-style code because they save you from writing trivial functions that perform a single operation.

Some of the functions in this module are:

- Math operations: `add()`, `sub()`, `mul()`, `floordiv()`, `abs()`, …
- Logical operations: `not_()`, `truth()`.
- Bitwise operations: `and_()`, `or_()`, `invert()`.
- Comparisons: `eq()`, `ne()`, `lt()`, `le()`, `gt()`, and `ge()`.
- Object identity: `is_()`, `is_not()`.

Consult the operator module's documentation for a complete list.

8 Small functions and the lambda expression

When writing functional-style programs, you'll often need little functions that act as predicates or that combine elements in some way.

If there's a Python built-in or a module function that's suitable, you don't need to define a new function at all:

```
stripped_lines = [line.strip() for line in lines]
existing_files = filter(os.path.exists, file_list)
```

If the function you need doesn't exist, you need to write it. One way to write small functions is to use the `lambda` statement. `lambda` takes a number of parameters and an expression combining these parameters, and creates an anonymous function that returns the value of the expression:

```
adder = lambda x, y: x+y

print_assign = lambda name, value: name + '=' + str(value)
```

An alternative is to just use the `def` statement and define a function in the usual way:

```
def adder(x, y):
    return x + y

def print_assign(name, value):
    return name + '=' + str(value)
```

Which alternative is preferable? That's a style question; my usual course is to avoid using `lambda`.

One reason for my preference is that `lambda` is quite limited in the functions it can define. The result has to be computable as a single expression, which means you can't have multiway `if... elif... else` comparisons or `try... except` statements. If you try to do too much in a `lambda` statement, you'll end up with an overly complicated expression that's hard to read. Quick, what's the following code doing?

```
import functools
total = functools.reduce(lambda a, b: (0, a[1] + b[1]), items)[1]
```

You can figure it out, but it takes time to disentangle the expression to figure out what's going on. Using a short nested `def` statements makes things a little bit better:

```
import functools
def combine(a, b):
    return 0, a[1] + b[1]

total = functools.reduce(combine, items)[1]
```

But it would be best of all if I had simply used a `for` loop:

```
total = 0
for a, b in items:
    total += b
```

Or the `sum()` built-in and a generator expression:

```
total = sum(b for a,b in items)
```

Many uses of `functools.reduce()` are clearer when written as `for` loops.

Fredrik Lundh once suggested the following set of rules for refactoring uses of `lambda`:

1. Write a lambda function.
2. Write a comment explaining what the heck that lambda does.
3. Study the comment for a while, and think of a name that captures the essence of the comment.
4. Convert the lambda to a def statement, using that name.
5. Remove the comment.

I really like these rules, but you're free to disagree about whether this lambda-free style is better.

9 Revision History and Acknowledgements

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Version 0.1: posted June 30 2006.

Version 0.11: posted July 1 2006. Typo fixes.

Version 0.2: posted July 10 2006. Merged genexp and listcomp sections into one. Typo fixes.

Version 0.21: Added more references suggested on the tutor mailing list.

Version 0.30: Adds a section on the `functional` module written by Collin Winter; adds short section on the operator module; a few other edits.

10 References

10.1 General

Structure and Interpretation of Computer Programs, by Harold Abelson and Gerald Jay Sussman with Julie Sussman. Full text at https://mitpress.mit.edu/sicp/. In this classic textbook of computer science, chapters 2 and 3 discuss the use of sequences and streams to organize the data flow inside a program. The book uses Scheme for its examples, but many of the design approaches described in these chapters are applicable to functional-style Python code.

http://www.defmacro.org/ramblings/fp.html: A general introduction to functional programming that uses Java examples and has a lengthy historical introduction.

https://en.wikipedia.org/wiki/Functional_programming: General Wikipedia entry describing functional programming.

https://en.wikipedia.org/wiki/Coroutine: Entry for coroutines.

https://en.wikipedia.org/wiki/Currying: Entry for the concept of currying.

10.2 Python-specific

http://gnosis.cx/TPiP/: The first chapter of David Mertz's book *Text Processing in Python* discusses functional programming for text processing, in the section titled "Utilizing Higher-Order Functions in Text Processing".

Mertz also wrote a 3-part series of articles on functional programming for IBM's DeveloperWorks site; see part 1, part 2, and part 3,

10.3 Python documentation

Documentation for the `itertools` module.

Documentation for the `functools` module.

Documentation for the `operator` module.

PEP 289: "Generator Expressions"

PEP 342: "Coroutines via Enhanced Generators" describes the new generator features in Python 2.5.

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Descriptor HowTo Guide

Release 3.7.0

Guido van Rossum
and the Python development team

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1 Abstract

Defines descriptors, summarizes the protocol, and shows how descriptors are called. Examines a custom descriptor and several built-in python descriptors including functions, properties, static methods, and class methods. Shows how each works by giving a pure Python equivalent and a sample application.

Learning about descriptors not only provides access to a larger toolset, it creates a deeper understanding of how Python works and an appreciation for the elegance of its design.

2 Definition and Introduction

In general, a descriptor is an object attribute with "binding behavior", one whose attribute access has been overridden by methods in the descriptor protocol. Those methods are `__get__()`, `__set__()`, and `__delete__()`. If any of those methods are defined for an object, it is said to be a descriptor.

The default behavior for attribute access is to get, set, or delete the attribute from an object's dictionary. For instance, `a.x` has a lookup chain starting with `a.__dict__['x']`, then `type(a).__dict__['x']`, and continuing through the base classes of `type(a)` excluding metaclasses. If the looked-up value is an object defining one of the descriptor methods, then Python may override the default behavior and invoke the descriptor method instead. Where this occurs in the precedence chain depends on which descriptor methods were defined.

Descriptors are a powerful, general purpose protocol. They are the mechanism behind properties, methods, static methods, class methods, and `super()`. They are used throughout Python itself to implement the new style classes introduced in version 2.2. Descriptors simplify the underlying C-code and offer a flexible set of new tools for everyday Python programs.

3 Descriptor Protocol

```
descr.__get__(self, obj, type=None) --> value

descr.__set__(self, obj, value) --> None

descr.__delete__(self, obj) --> None
```

That is all there is to it. Define any of these methods and an object is considered a descriptor and can override default behavior upon being looked up as an attribute.

If an object defines both `__get__()` and `__set__()`, it is considered a data descriptor. Descriptors that only define `__get__()` are called non-data descriptors (they are typically used for methods but other uses are possible).

Data and non-data descriptors differ in how overrides are calculated with respect to entries in an instance's dictionary. If an instance's dictionary has an entry with the same name as a data descriptor, the data descriptor takes precedence. If an instance's dictionary has an entry with the same name as a non-data descriptor, the dictionary entry takes precedence.

To make a read-only data descriptor, define both `__get__()` and `__set__()` with the `__set__()` raising an `AttributeError` when called. Defining the `__set__()` method with an exception raising placeholder is enough to make it a data descriptor.

4 Invoking Descriptors

A descriptor can be called directly by its method name. For example, `d.__get__(obj)`.

Alternatively, it is more common for a descriptor to be invoked automatically upon attribute access. For example, `obj.d` looks up `d` in the dictionary of `obj`. If `d` defines the method `__get__()`, then `d.__get__(obj)` is invoked according to the precedence rules listed below.

The details of invocation depend on whether `obj` is an object or a class.

For objects, the machinery is in `object.__getattribute__()` which transforms `b.x` into `type(b).__dict__['x'].__get__(b, type(b))`. The implementation works through a precedence chain that gives data descriptors priority over instance variables, instance variables priority over non-data descriptors, and assigns lowest priority to `__getattr__()` if provided. The full C implementation can be found in `PyObject_GenericGetAttr()` in Objects/object.c.

For classes, the machinery is in `type.__getattribute__()` which transforms `B.x` into `B.__dict__['x'].__get__(None, B)`. In pure Python, it looks like:

```
def __getattribute__(self, key):
    "Emulate type_getattro() in Objects/typeobject.c"
    v = object.__getattribute__(self, key)
    if hasattr(v, '__get__'):
        return v.__get__(None, self)
    return v
```

The important points to remember are:

- descriptors are invoked by the `__getattribute__()` method
- overriding `__getattribute__()` prevents automatic descriptor calls
- `object.__getattribute__()` and `type.__getattribute__()` make different calls to `__get__()`.
- data descriptors always override instance dictionaries.
- non-data descriptors may be overridden by instance dictionaries.

The object returned by `super()` also has a custom `__getattribute__()` method for invoking descriptors. The call `super(B, obj).m()` searches `obj.__class__.__mro__` for the base class `A` immediately following `B` and then returns `A.__dict__['m'].__get__(obj, B)`. If not a descriptor, `m` is returned unchanged. If not in the dictionary, `m` reverts to a search using `object.__getattribute__()`.

The implementation details are in `super_getattro()` in Objects/typeobject.c. and a pure Python equivalent can be found in Guido's Tutorial.

The details above show that the mechanism for descriptors is embedded in the `__getattribute__()` methods for `object`, `type`, and `super()`. Classes inherit this machinery when they derive from `object` or if they have a meta-class providing similar functionality. Likewise, classes can turn-off descriptor invocation by overriding `__getattribute__()`.

5 Descriptor Example

The following code creates a class whose objects are data descriptors which print a message for each get or set. Overriding `__getattribute__()` is alternate approach that could do this for every attribute. However,

this descriptor is useful for monitoring just a few chosen attributes:

```
class RevealAccess(object):
    """A data descriptor that sets and returns values
       normally and prints a message logging their access.
    """

    def __init__(self, initval=None, name='var'):
        self.val = initval
        self.name = name

    def __get__(self, obj, objtype):
        print('Retrieving', self.name)
        return self.val

    def __set__(self, obj, val):
        print('Updating', self.name)
        self.val = val

>>> class MyClass(object):
...     x = RevealAccess(10, 'var "x"')
...     y = 5
...
>>> m = MyClass()
>>> m.x
Retrieving var "x"
10
>>> m.x = 20
Updating var "x"
>>> m.x
Retrieving var "x"
20
>>> m.y
5
```

The protocol is simple and offers exciting possibilities. Several use cases are so common that they have been packaged into individual function calls. Properties, bound methods, static methods, and class methods are all based on the descriptor protocol.

6 Properties

Calling `property()` is a succinct way of building a data descriptor that triggers function calls upon access to an attribute. Its signature is:

```
property(fget=None, fset=None, fdel=None, doc=None) -> property attribute
```

The documentation shows a typical use to define a managed attribute `x`:

```
class C(object):
    def getx(self): return self.__x
    def setx(self, value): self.__x = value
    def delx(self): del self.__x
    x = property(getx, setx, delx, "I'm the 'x' property.")
```

To see how `property()` is implemented in terms of the descriptor protocol, here is a pure Python equivalent:

```
class Property(object):
    "Emulate PyProperty_Type() in Objects/descrobject.c"

    def __init__(self, fget=None, fset=None, fdel=None, doc=None):
        self.fget = fget
        self.fset = fset
        self.fdel = fdel
        if doc is None and fget is not None:
            doc = fget.__doc__
        self.__doc__ = doc

    def __get__(self, obj, objtype=None):
        if obj is None:
            return self
        if self.fget is None:
            raise AttributeError("unreadable attribute")
        return self.fget(obj)

    def __set__(self, obj, value):
        if self.fset is None:
            raise AttributeError("can't set attribute")
        self.fset(obj, value)

    def __delete__(self, obj):
        if self.fdel is None:
            raise AttributeError("can't delete attribute")
        self.fdel(obj)

    def getter(self, fget):
        return type(self)(fget, self.fset, self.fdel, self.__doc__)

    def setter(self, fset):
        return type(self)(self.fget, fset, self.fdel, self.__doc__)

    def deleter(self, fdel):
        return type(self)(self.fget, self.fset, fdel, self.__doc__)
```

The `property()` builtin helps whenever a user interface has granted attribute access and then subsequent changes require the intervention of a method.

For instance, a spreadsheet class may grant access to a cell value through `Cell('b10').value`. Subsequent improvements to the program require the cell to be recalculated on every access; however, the programmer does not want to affect existing client code accessing the attribute directly. The solution is to wrap access to the value attribute in a property data descriptor:

```
class Cell(object):
    . . .
    def getvalue(self):
        "Recalculate the cell before returning value"
        self.recalc()
        return self._value
    value = property(getvalue)
```

7 Functions and Methods

Python's object oriented features are built upon a function based environment. Using non-data descriptors, the two are merged seamlessly.

Class dictionaries store methods as functions. In a class definition, methods are written using `def` or `lambda`, the usual tools for creating functions. Methods only differ from regular functions in that the first argument is reserved for the object instance. By Python convention, the instance reference is called *self* but may be called *this* or any other variable name.

To support method calls, functions include the `__get__()` method for binding methods during attribute access. This means that all functions are non-data descriptors which return bound methods when they are invoked from an object. In pure python, it works like this:

```
class Function(object):
    . . .
    def __get__(self, obj, objtype=None):
        "Simulate func_descr_get() in Objects/funcobject.c"
        if obj is None:
            return self
        return types.MethodType(self, obj)
```

Running the interpreter shows how the function descriptor works in practice:

```
>>> class D(object):
...     def f(self, x):
...         return x
...
>>> d = D()

# Access through the class dictionary does not invoke __get__.
# It just returns the underlying function object.
>>> D.__dict__['f']
<function D.f at 0x00C45070>

# Dotted access from a class calls __get__() which just returns
# the underlying function unchanged.
>>> D.f
<function D.f at 0x00C45070>

# The function has a __qualname__ attribute to support introspection
>>> D.f.__qualname__
'D.f'

# Dotted access from an instance calls __get__() which returns the
# function wrapped in a bound method object
>>> d.f
<bound method D.f of <__main__.D object at 0x00B18C90>>

# Internally, the bound method stores the underlying function,
# the bound instance, and the class of the bound instance.
>>> d.f.__func__
<function D.f at 0x1012e5ae8>
>>> d.f.__self__
<__main__.D object at 0x1012e1f98>
>>> d.f.__class__
<class 'method'>
```

8 Static Methods and Class Methods

Non-data descriptors provide a simple mechanism for variations on the usual patterns of binding functions into methods.

To recap, functions have a `__get__()` method so that they can be converted to a method when accessed as attributes. The non-data descriptor transforms an `obj.f(*args)` call into `f(obj, *args)`. Calling `klass.f(*args)` becomes `f(*args)`.

This chart summarizes the binding and its two most useful variants:

Transformation	Called from an Object	Called from a Class
function	f(obj, *args)	f(*args)
staticmethod	f(*args)	f(*args)
classmethod	f(type(obj), *args)	f(klass, *args)

Static methods return the underlying function without changes. Calling either `c.f` or `C.f` is the equivalent of a direct lookup into `object.__getattribute__(c, "f")` or `object.__getattribute__(C, "f")`. As a result, the function becomes identically accessible from either an object or a class.

Good candidates for static methods are methods that do not reference the `self` variable.

For instance, a statistics package may include a container class for experimental data. The class provides normal methods for computing the average, mean, median, and other descriptive statistics that depend on the data. However, there may be useful functions which are conceptually related but do not depend on the data. For instance, `erf(x)` is handy conversion routine that comes up in statistical work but does not directly depend on a particular dataset. It can be called either from an object or the class: `s.erf(1.5) --> .9332` or `Sample.erf(1.5) --> .9332`.

Since staticmethods return the underlying function with no changes, the example calls are unexciting:

```
>>> class E(object):
...     def f(x):
...         print(x)
...     f = staticmethod(f)
...
>>> print(E.f(3))
3
>>> print(E().f(3))
3
```

Using the non-data descriptor protocol, a pure Python version of `staticmethod()` would look like this:

```
class StaticMethod(object):
    "Emulate PyStaticMethod_Type() in Objects/funcobject.c"

    def __init__(self, f):
        self.f = f

    def __get__(self, obj, objtype=None):
        return self.f
```

Unlike static methods, class methods prepend the class reference to the argument list before calling the function. This format is the same for whether the caller is an object or a class:

```
>>> class E(object):
...     def f(klass, x):
```

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```
...         return klass.__name__, x
...     f = classmethod(f)
...
>>> print(E.f(3))
('E', 3)
>>> print(E().f(3))
('E', 3)
```

This behavior is useful whenever the function only needs to have a class reference and does not care about any underlying data. One use for classmethods is to create alternate class constructors. In Python 2.3, the classmethod `dict.fromkeys()` creates a new dictionary from a list of keys. The pure Python equivalent is:

```
class Dict(object):
    . . .
    def fromkeys(klass, iterable, value=None):
        "Emulate dict_fromkeys() in Objects/dictobject.c"
        d = klass()
        for key in iterable:
            d[key] = value
        return d
    fromkeys = classmethod(fromkeys)
```

Now a new dictionary of unique keys can be constructed like this:

```
>>> Dict.fromkeys('abracadabra')
{'a': None, 'r': None, 'b': None, 'c': None, 'd': None}
```

Using the non-data descriptor protocol, a pure Python version of `classmethod()` would look like this:

```
class ClassMethod(object):
    "Emulate PyClassMethod_Type() in Objects/funcobject.c"

    def __init__(self, f):
        self.f = f

    def __get__(self, obj, klass=None):
        if klass is None:
            klass = type(obj)
        def newfunc(*args):
            return self.f(klass, *args)
        return newfunc
```

Curses Programming with Python

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and the Python development team

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Abstract

This document describes how to use the `curses` extension module to control text-mode displays.

1 What is curses?

The curses library supplies a terminal-independent screen-painting and keyboard-handling facility for text-based terminals; such terminals include VT100s, the Linux console, and the simulated terminal provided by various programs. Display terminals support various control codes to perform common operations such as

moving the cursor, scrolling the screen, and erasing areas. Different terminals use widely differing codes, and often have their own minor quirks.

In a world of graphical displays, one might ask "why bother"? It's true that character-cell display terminals are an obsolete technology, but there are niches in which being able to do fancy things with them are still valuable. One niche is on small-footprint or embedded Unixes that don't run an X server. Another is tools such as OS installers and kernel configurators that may have to run before any graphical support is available.

The curses library provides fairly basic functionality, providing the programmer with an abstraction of a display containing multiple non-overlapping windows of text. The contents of a window can be changed in various ways—adding text, erasing it, changing its appearance—and the curses library will figure out what control codes need to be sent to the terminal to produce the right output. curses doesn't provide many user-interface concepts such as buttons, checkboxes, or dialogs; if you need such features, consider a user interface library such as Urwid.

The curses library was originally written for BSD Unix; the later System V versions of Unix from AT&T added many enhancements and new functions. BSD curses is no longer maintained, having been replaced by ncurses, which is an open-source implementation of the AT&T interface. If you're using an open-source Unix such as Linux or FreeBSD, your system almost certainly uses ncurses. Since most current commercial Unix versions are based on System V code, all the functions described here will probably be available. The older versions of curses carried by some proprietary Unixes may not support everything, though.

The Windows version of Python doesn't include the `curses` module. A ported version called UniCurses is available. You could also try the Console module written by Fredrik Lundh, which doesn't use the same API as curses but provides cursor-addressable text output and full support for mouse and keyboard input.

1.1 The Python curses module

The Python module is a fairly simple wrapper over the C functions provided by curses; if you're already familiar with curses programming in C, it's really easy to transfer that knowledge to Python. The biggest difference is that the Python interface makes things simpler by merging different C functions such as `addstr()`, `mvaddstr()`, and `mvwaddstr()` into a single `addstr()` method. You'll see this covered in more detail later.

This HOWTO is an introduction to writing text-mode programs with curses and Python. It doesn't attempt to be a complete guide to the curses API; for that, see the Python library guide's section on ncurses, and the C manual pages for ncurses. It will, however, give you the basic ideas.

2 Starting and ending a curses application

Before doing anything, curses must be initialized. This is done by calling the `initscr()` function, which will determine the terminal type, send any required setup codes to the terminal, and create various internal data structures. If successful, `initscr()` returns a window object representing the entire screen; this is usually called `stdscr` after the name of the corresponding C variable.

```
import curses
stdscr = curses.initscr()
```

Usually curses applications turn off automatic echoing of keys to the screen, in order to be able to read keys and only display them under certain circumstances. This requires calling the `noecho()` function.

```
curses.noecho()
```

Applications will also commonly need to react to keys instantly, without requiring the Enter key to be pressed; this is called cbreak mode, as opposed to the usual buffered input mode.

```
curses.cbreak()
```

Terminals usually return special keys, such as the cursor keys or navigation keys such as Page Up and Home, as a multibyte escape sequence. While you could write your application to expect such sequences and process them accordingly, curses can do it for you, returning a special value such as `curses.KEY_LEFT`. To get curses to do the job, you'll have to enable keypad mode.

```
stdscr.keypad(True)
```

Terminating a curses application is much easier than starting one. You'll need to call:

```
curses.nocbreak()
stdscr.keypad(False)
curses.echo()
```

to reverse the curses-friendly terminal settings. Then call the `endwin()` function to restore the terminal to its original operating mode.

```
curses.endwin()
```

A common problem when debugging a curses application is to get your terminal messed up when the application dies without restoring the terminal to its previous state. In Python this commonly happens when your code is buggy and raises an uncaught exception. Keys are no longer echoed to the screen when you type them, for example, which makes using the shell difficult.

In Python you can avoid these complications and make debugging much easier by importing the `curses.wrapper()` function and using it like this:

```
from curses import wrapper

def main(stdscr):
    # Clear screen
    stdscr.clear()

    # This raises ZeroDivisionError when i == 10.
    for i in range(0, 11):
        v = i-10
        stdscr.addstr(i, 0, '10 divided by {} is {}'.format(v, 10/v))

    stdscr.refresh()
    stdscr.getkey()

wrapper(main)
```

The `wrapper()` function takes a callable object and does the initializations described above, also initializing colors if color support is present. `wrapper()` then runs your provided callable. Once the callable returns, `wrapper()` will restore the original state of the terminal. The callable is called inside a `try…except` that catches exceptions, restores the state of the terminal, and then re-raises the exception. Therefore your terminal won't be left in a funny state on exception and you'll be able to read the exception's message and traceback.

3 Windows and Pads

Windows are the basic abstraction in curses. A window object represents a rectangular area of the screen, and supports methods to display text, erase it, allow the user to input strings, and so forth.

The `stdscr` object returned by the `initscr()` function is a window object that covers the entire screen. Many programs may need only this single window, but you might wish to divide the screen into smaller windows, in order to redraw or clear them separately. The `newwin()` function creates a new window of a given size, returning the new window object.

```
begin_x = 20; begin_y = 7
height = 5; width = 40
win = curses.newwin(height, width, begin_y, begin_x)
```

Note that the coordinate system used in curses is unusual. Coordinates are always passed in the order *y*,*x*, and the top-left corner of a window is coordinate (0,0). This breaks the normal convention for handling coordinates where the *x* coordinate comes first. This is an unfortunate difference from most other computer applications, but it's been part of curses since it was first written, and it's too late to change things now.

Your application can determine the size of the screen by using the `curses.LINES` and `curses.COLS` variables to obtain the *y* and *x* sizes. Legal coordinates will then extend from `(0,0)` to `(curses.LINES - 1, curses.COLS - 1)`.

When you call a method to display or erase text, the effect doesn't immediately show up on the display. Instead you must call the `refresh()` method of window objects to update the screen.

This is because curses was originally written with slow 300-baud terminal connections in mind; with these terminals, minimizing the time required to redraw the screen was very important. Instead curses accumulates changes to the screen and displays them in the most efficient manner when you call `refresh()`. For example, if your program displays some text in a window and then clears the window, there's no need to send the original text because they're never visible.

In practice, explicitly telling curses to redraw a window doesn't really complicate programming with curses much. Most programs go into a flurry of activity, and then pause waiting for a keypress or some other action on the part of the user. All you have to do is to be sure that the screen has been redrawn before pausing to wait for user input, by first calling `stdscr.refresh()` or the `refresh()` method of some other relevant window.

A pad is a special case of a window; it can be larger than the actual display screen, and only a portion of the pad displayed at a time. Creating a pad requires the pad's height and width, while refreshing a pad requires giving the coordinates of the on-screen area where a subsection of the pad will be displayed.

```
pad = curses.newpad(100, 100)
# These loops fill the pad with letters; addch() is
# explained in the next section
for y in range(0, 99):
    for x in range(0, 99):
        pad.addch(y,x, ord('a') + (x*x+y*y) % 26)

# Displays a section of the pad in the middle of the screen.
# (0,0) : coordinate of upper-left corner of pad area to display.
# (5,5) : coordinate of upper-left corner of window area to be filled
#         with pad content.
# (20, 75) : coordinate of lower-right corner of window area to be
#          : filled with pad content.
pad.refresh( 0,0, 5,5, 20,75)
```

The `refresh()` call displays a section of the pad in the rectangle extending from coordinate (5,5) to coordinate (20,75) on the screen; the upper left corner of the displayed section is coordinate (0,0) on the pad. Beyond that difference, pads are exactly like ordinary windows and support the same methods.

If you have multiple windows and pads on screen there is a more efficient way to update the screen and prevent annoying screen flicker as each part of the screen gets updated. `refresh()` actually does two things:

1. Calls the `noutrefresh()` method of each window to update an underlying data structure representing the desired state of the screen.
2. Calls the function `doupdate()` function to change the physical screen to match the desired state recorded in the data structure.

Instead you can call `noutrefresh()` on a number of windows to update the data structure, and then call `doupdate()` to update the screen.

4 Displaying Text

From a C programmer's point of view, curses may sometimes look like a twisty maze of functions, all subtly different. For example, `addstr()` displays a string at the current cursor location in the `stdscr` window, while `mvaddstr()` moves to a given y,x coordinate first before displaying the string. `waddstr()` is just like `addstr()`, but allows specifying a window to use instead of using `stdscr` by default. `mvwaddstr()` allows specifying both a window and a coordinate.

Fortunately the Python interface hides all these details. `stdscr` is a window object like any other, and methods such as `addstr()` accept multiple argument forms. Usually there are four different forms.

Form	Description
str or *ch*	Display the string *str* or character *ch* at the current position
str or *ch*, *attr*	Display the string *str* or character *ch*, using attribute *attr* at the current position
y, *x*, *str* or *ch*	Move to position *y,x* within the window, and display *str* or *ch*
y, *x*, *str* or *ch*, *attr*	Move to position *y,x* within the window, and display *str* or *ch*, using attribute *attr*

Attributes allow displaying text in highlighted forms such as boldface, underline, reverse code, or in color. They'll be explained in more detail in the next subsection.

The `addstr()` method takes a Python string or bytestring as the value to be displayed. The contents of bytestrings are sent to the terminal as-is. Strings are encoded to bytes using the value of the window's `encoding` attribute; this defaults to the default system encoding as returned by `locale.getpreferredencoding()`.

The `addch()` methods take a character, which can be either a string of length 1, a bytestring of length 1, or an integer.

Constants are provided for extension characters; these constants are integers greater than 255. For example, `ACS_PLMINUS` is a +/- symbol, and `ACS_ULCORNER` is the upper left corner of a box (handy for drawing borders). You can also use the appropriate Unicode character.

Windows remember where the cursor was left after the last operation, so if you leave out the *y,x* coordinates, the string or character will be displayed wherever the last operation left off. You can also move the cursor with the `move(y,x)` method. Because some terminals always display a flashing cursor, you may want to ensure that the cursor is positioned in some location where it won't be distracting; it can be confusing to have the cursor blinking at some apparently random location.

If your application doesn't need a blinking cursor at all, you can call `curs_set(False)` to make it invisible. For compatibility with older curses versions, there's a `leaveok(bool)` function that's a synonym for `curs_set()`. When *bool* is true, the curses library will attempt to suppress the flashing cursor, and you won't need to worry about leaving it in odd locations.

4.1 Attributes and Color

Characters can be displayed in different ways. Status lines in a text-based application are commonly shown in reverse video, or a text viewer may need to highlight certain words. curses supports this by allowing you

to specify an attribute for each cell on the screen.

An attribute is an integer, each bit representing a different attribute. You can try to display text with multiple attribute bits set, but curses doesn't guarantee that all the possible combinations are available, or that they're all visually distinct. That depends on the ability of the terminal being used, so it's safest to stick to the most commonly available attributes, listed here.

Attribute	Description
`A_BLINK`	Blinking text
`A_BOLD`	Extra bright or bold text
`A_DIM`	Half bright text
`A_REVERSE`	Reverse-video text
`A_STANDOUT`	The best highlighting mode available
`A_UNDERLINE`	Underlined text

So, to display a reverse-video status line on the top line of the screen, you could code:

```
stdscr.addstr(0, 0, "Current mode: Typing mode",
              curses.A_REVERSE)
stdscr.refresh()
```

The curses library also supports color on those terminals that provide it. The most common such terminal is probably the Linux console, followed by color xterms.

To use color, you must call the `start_color()` function soon after calling `initscr()`, to initialize the default color set (the `curses.wrapper()` function does this automatically). Once that's done, the `has_colors()` function returns TRUE if the terminal in use can actually display color. (Note: curses uses the American spelling 'color', instead of the Canadian/British spelling 'colour'. If you're used to the British spelling, you'll have to resign yourself to misspelling it for the sake of these functions.)

The curses library maintains a finite number of color pairs, containing a foreground (or text) color and a background color. You can get the attribute value corresponding to a color pair with the `color_pair()` function; this can be bitwise-OR'ed with other attributes such as `A_REVERSE`, but again, such combinations are not guaranteed to work on all terminals.

An example, which displays a line of text using color pair 1:

```
stdscr.addstr("Pretty text", curses.color_pair(1))
stdscr.refresh()
```

As I said before, a color pair consists of a foreground and background color. The `init_pair(n, f, b)` function changes the definition of color pair n, to foreground color f and background color b. Color pair 0 is hard-wired to white on black, and cannot be changed.

Colors are numbered, and `start_color()` initializes 8 basic colors when it activates color mode. They are: 0:black, 1:red, 2:green, 3:yellow, 4:blue, 5:magenta, 6:cyan, and 7:white. The `curses` module defines named constants for each of these colors: `curses.COLOR_BLACK`, `curses.COLOR_RED`, and so forth.

Let's put all this together. To change color 1 to red text on a white background, you would call:

```
curses.init_pair(1, curses.COLOR_RED, curses.COLOR_WHITE)
```

When you change a color pair, any text already displayed using that color pair will change to the new colors. You can also display new text in this color with:

```
stdscr.addstr(0,0, "RED ALERT!", curses.color_pair(1))
```

Very fancy terminals can change the definitions of the actual colors to a given RGB value. This lets you change color 1, which is usually red, to purple or blue or any other color you like. Unfortunately, the Linux

console doesn't support this, so I'm unable to try it out, and can't provide any examples. You can check if your terminal can do this by calling `can_change_color()`, which returns `True` if the capability is there. If you're lucky enough to have such a talented terminal, consult your system's man pages for more information.

5 User Input

The C curses library offers only very simple input mechanisms. Python's `curses` module adds a basic text-input widget. (Other libraries such as Urwid have more extensive collections of widgets.)

There are two methods for getting input from a window:

- `getch()` refreshes the screen and then waits for the user to hit a key, displaying the key if `echo()` has been called earlier. You can optionally specify a coordinate to which the cursor should be moved before pausing.
- `getkey()` does the same thing but converts the integer to a string. Individual characters are returned as 1-character strings, and special keys such as function keys return longer strings containing a key name such as `KEY_UP` or `^G`.

It's possible to not wait for the user using the `nodelay()` window method. After `nodelay(True)`, `getch()` and `getkey()` for the window become non-blocking. To signal that no input is ready, `getch()` returns `curses.ERR` (a value of -1) and `getkey()` raises an exception. There's also a `halfdelay()` function, which can be used to (in effect) set a timer on each `getch()`; if no input becomes available within a specified delay (measured in tenths of a second), curses raises an exception.

The `getch()` method returns an integer; if it's between 0 and 255, it represents the ASCII code of the key pressed. Values greater than 255 are special keys such as Page Up, Home, or the cursor keys. You can compare the value returned to constants such as `curses.KEY_PPAGE`, `curses.KEY_HOME`, or `curses.KEY_LEFT`. The main loop of your program may look something like this:

```
while True:
    c = stdscr.getch()
    if c == ord('p'):
        PrintDocument()
    elif c == ord('q'):
        break  # Exit the while loop
    elif c == curses.KEY_HOME:
        x = y = 0
```

The `curses.ascii` module supplies ASCII class membership functions that take either integer or 1-character string arguments; these may be useful in writing more readable tests for such loops. It also supplies conversion functions that take either integer or 1-character-string arguments and return the same type. For example, `curses.ascii.ctrl()` returns the control character corresponding to its argument.

There's also a method to retrieve an entire string, `getstr()`. It isn't used very often, because its functionality is quite limited; the only editing keys available are the backspace key and the Enter key, which terminates the string. It can optionally be limited to a fixed number of characters.

```
curses.echo()             # Enable echoing of characters

# Get a 15-character string, with the cursor on the top line
s = stdscr.getstr(0,0, 15)
```

The `curses.textpad` module supplies a text box that supports an Emacs-like set of keybindings. Various methods of the `Textbox` class support editing with input validation and gathering the edit results either with or without trailing spaces. Here's an example:

```
import curses
from curses.textpad import Textbox, rectangle

def main(stdscr):
    stdscr.addstr(0, 0, "Enter IM message: (hit Ctrl-G to send)")

    editwin = curses.newwin(5,30, 2,1)
    rectangle(stdscr, 1,0, 1+5+1, 1+30+1)
    stdscr.refresh()

    box = Textbox(editwin)

    # Let the user edit until Ctrl-G is struck.
    box.edit()

    # Get resulting contents
    message = box.gather()
```

See the library documentation on `curses.textpad` for more details.

6 For More Information

This HOWTO doesn't cover some advanced topics, such as reading the contents of the screen or capturing mouse events from an xterm instance, but the Python library page for the `curses` module is now reasonably complete. You should browse it next.

If you're in doubt about the detailed behavior of the curses functions, consult the manual pages for your curses implementation, whether it's ncurses or a proprietary Unix vendor's. The manual pages will document any quirks, and provide complete lists of all the functions, attributes, and `ACS_*` characters available to you.

Because the curses API is so large, some functions aren't supported in the Python interface. Often this isn't because they're difficult to implement, but because no one has needed them yet. Also, Python doesn't yet support the menu library associated with ncurses. Patches adding support for these would be welcome; see the Python Developer's Guide to learn more about submitting patches to Python.

- Writing Programs with NCURSES: a lengthy tutorial for C programmers.
- The ncurses man page
- The ncurses FAQ
- "Use curses… don't swear": video of a PyCon 2013 talk on controlling terminals using curses or Urwid.
- "Console Applications with Urwid": video of a PyCon CA 2012 talk demonstrating some applications written using Urwid.

Porting Extension Modules to Python 3

Release 3.7.0

Guido van Rossum
and the Python development team

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Python Software Foundation
Email: docs@python.org

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Abstract

Although changing the C-API was not one of Python 3's objectives, the many Python-level changes made leaving Python 2's API intact impossible. In fact, some changes such as `int()` and `long()` unification are more obvious on the C level. This document endeavors to document incompatibilities and how they can be worked around.

1 Conditional compilation

The easiest way to compile only some code for Python 3 is to check if `PY_MAJOR_VERSION` is greater than or equal to 3.

```
#if PY_MAJOR_VERSION >= 3
#define IS_PY3K
#endif
```

API functions that are not present can be aliased to their equivalents within conditional blocks.

2 Changes to Object APIs

Python 3 merged together some types with similar functions while cleanly separating others.

2.1 str/unicode Unification

Python 3's `str()` type is equivalent to Python 2's `unicode()`; the C functions are called `PyUnicode_*` for both. The old 8-bit string type has become `bytes()`, with C functions called `PyBytes_*`. Python 2.6 and later provide a compatibility header, `bytesobject.h`, mapping `PyBytes` names to `PyString` ones. For best compatibility with Python 3, `PyUnicode` should be used for textual data and `PyBytes` for binary data. It's also important to remember that `PyBytes` and `PyUnicode` in Python 3 are not interchangeable like `PyString` and `PyUnicode` are in Python 2. The following example shows best practices with regards to `PyUnicode`, `PyString`, and `PyBytes`.

```
#include "stdlib.h"
#include "Python.h"
#include "bytesobject.h"

/* text example */
static PyObject *
say_hello(PyObject *self, PyObject *args) {
    PyObject *name, *result;

    if (!PyArg_ParseTuple(args, "U:say_hello", &name))
        return NULL;

    result = PyUnicode_FromFormat("Hello, %S!", name);
    return result;
}

/* just a forward */
static char * do_encode(PyObject *);

/* bytes example */
static PyObject *
encode_object(PyObject *self, PyObject *args) {
    char *encoded;
    PyObject *result, *myobj;

    if (!PyArg_ParseTuple(args, "O:encode_object", &myobj))
        return NULL;

    encoded = do_encode(myobj);
    if (encoded == NULL)
        return NULL;
    result = PyBytes_FromString(encoded);
    free(encoded);
```

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```
    return result;
}
```

2.2 long/int Unification

Python 3 has only one integer type, `int()`. But it actually corresponds to Python 2's `long()` type—the `int()` type used in Python 2 was removed. In the C-API, `PyInt_*` functions are replaced by their `PyLong_*` equivalents.

3 Module initialization and state

Python 3 has a revamped extension module initialization system. (See **PEP 3121**.) Instead of storing module state in globals, they should be stored in an interpreter specific structure. Creating modules that act correctly in both Python 2 and Python 3 is tricky. The following simple example demonstrates how.

```
#include "Python.h"

struct module_state {
    PyObject *error;
};

#if PY_MAJOR_VERSION >= 3
#define GETSTATE(m) ((struct module_state*)PyModule_GetState(m))
#else
#define GETSTATE(m) (&_state)
static struct module_state _state;
#endif

static PyObject *
error_out(PyObject *m) {
    struct module_state *st = GETSTATE(m);
    PyErr_SetString(st->error, "something bad happened");
    return NULL;
}

static PyMethodDef myextension_methods[] = {
    {"error_out", (PyCFunction)error_out, METH_NOARGS, NULL},
    {NULL, NULL}
};

#if PY_MAJOR_VERSION >= 3

static int myextension_traverse(PyObject *m, visitproc visit, void *arg) {
    Py_VISIT(GETSTATE(m)->error);
    return 0;
}

static int myextension_clear(PyObject *m) {
    Py_CLEAR(GETSTATE(m)->error);
    return 0;
}
```

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```
static struct PyModuleDef moduledef = {
        PyModuleDef_HEAD_INIT,
        "myextension",
        NULL,
        sizeof(struct module_state),
        myextension_methods,
        NULL,
        myextension_traverse,
        myextension_clear,
        NULL
};

#define INITERROR return NULL

PyMODINIT_FUNC
PyInit_myextension(void)

#else
#define INITERROR return

void
initmyextension(void)
#endif
{
#if PY_MAJOR_VERSION >= 3
    PyObject *module = PyModule_Create(&moduledef);
#else
    PyObject *module = Py_InitModule("myextension", myextension_methods);
#endif

    if (module == NULL)
        INITERROR;
    struct module_state *st = GETSTATE(module);

    st->error = PyErr_NewException("myextension.Error", NULL, NULL);
    if (st->error == NULL) {
        Py_DECREF(module);
        INITERROR;
    }

#if PY_MAJOR_VERSION >= 3
    return module;
#endif
}
```

4 CObject replaced with Capsule

The `Capsule` object was introduced in Python 3.1 and 2.7 to replace `CObject`. CObjects were useful, but the `CObject` API was problematic: it didn't permit distinguishing between valid CObjects, which allowed mismatched CObjects to crash the interpreter, and some of its APIs relied on undefined behavior in C. (For further reading on the rationale behind Capsules, please see bpo-5630.)

If you're currently using CObjects, and you want to migrate to 3.1 or newer, you'll need to switch to Capsules. `CObject` was deprecated in 3.1 and 2.7 and completely removed in Python 3.2. If you only support 2.7, or

3.1 and above, you can simply switch to `Capsule`. If you need to support Python 3.0, or versions of Python earlier than 2.7, you'll have to support both CObjects and Capsules. (Note that Python 3.0 is no longer supported, and it is not recommended for production use.)

The following example header file `capsulethunk.h` may solve the problem for you. Simply write your code against the `Capsule` API and include this header file after `Python.h`. Your code will automatically use Capsules in versions of Python with Capsules, and switch to CObjects when Capsules are unavailable.

`capsulethunk.h` simulates Capsules using CObjects. However, `CObject` provides no place to store the capsule's "name". As a result the simulated `Capsule` objects created by `capsulethunk.h` behave slightly differently from real Capsules. Specifically:

- The name parameter passed in to `PyCapsule_New()` is ignored.
- The name parameter passed in to `PyCapsule_IsValid()` and `PyCapsule_GetPointer()` is ignored, and no error checking of the name is performed.
- `PyCapsule_GetName()` always returns NULL.
- `PyCapsule_SetName()` always raises an exception and returns failure. (Since there's no way to store a name in a CObject, noisy failure of `PyCapsule_SetName()` was deemed preferable to silent failure here. If this is inconvenient, feel free to modify your local copy as you see fit.)

You can find `capsulethunk.h` in the Python source distribution as Doc/includes/capsulethunk.h. We also include it here for your convenience:

```
#ifndef __CAPSULETHUNK_H
#define __CAPSULETHUNK_H

#if (    (PY_VERSION_HEX <  0x02070000) \
     || ((PY_VERSION_HEX >= 0x03000000) \
      && (PY_VERSION_HEX <  0x03010000)) )

#define __PyCapsule_GetField(capsule, field, default_value) \
    ( PyCapsule_CheckExact(capsule) \
        ? (((PyCObject *)capsule)->field) \
        : (default_value) \
    ) \

#define __PyCapsule_SetField(capsule, field, value) \
    ( PyCapsule_CheckExact(capsule) \
        ? (((PyCObject *)capsule)->field = value), 1 \
        : 0 \
    ) \


#define PyCapsule_Type PyCObject_Type

#define PyCapsule_CheckExact(capsule) (PyCObject_Check(capsule))
#define PyCapsule_IsValid(capsule, name) (PyCObject_Check(capsule))


#define PyCapsule_New(pointer, name, destructor) \
    (PyCObject_FromVoidPtr(pointer, destructor))


#define PyCapsule_GetPointer(capsule, name) \
    (PyCObject_AsVoidPtr(capsule))

/* Don't call PyCObject_SetPointer here, it fails if there's a destructor */
```

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```
#define PyCapsule_SetPointer(capsule, pointer) \
    __PyCapsule_SetField(capsule, cobject, pointer)


#define PyCapsule_GetDestructor(capsule) \
    __PyCapsule_GetField(capsule, destructor)

#define PyCapsule_SetDestructor(capsule, dtor) \
    __PyCapsule_SetField(capsule, destructor, dtor)


/*
 * Sorry, there's simply no place
 * to store a Capsule "name" in a CObject.
 */
#define PyCapsule_GetName(capsule) NULL

static int
PyCapsule_SetName(PyObject *capsule, const char *unused)
{
    unused = unused;
    PyErr_SetString(PyExc_NotImplementedError,
        "can't use PyCapsule_SetName with CObjects");
    return 1;
}



#define PyCapsule_GetContext(capsule) \
    __PyCapsule_GetField(capsule, descr)

#define PyCapsule_SetContext(capsule, context) \
    __PyCapsule_SetField(capsule, descr, context)


static void *
PyCapsule_Import(const char *name, int no_block)
{
    PyObject *object = NULL;
    void *return_value = NULL;
    char *trace;
    size_t name_length = (strlen(name) + 1) * sizeof(char);
    char *name_dup = (char *)PyMem_MALLOC(name_length);

    if (!name_dup) {
        return NULL;
    }

    memcpy(name_dup, name, name_length);

    trace = name_dup;
    while (trace) {
        char *dot = strchr(trace, '.');
        if (dot) {
            *dot++ = '\0';
        }
```

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```
        if (object == NULL) {
            if (no_block) {
                object = PyImport_ImportModuleNoBlock(trace);
            } else {
                object = PyImport_ImportModule(trace);
                if (!object) {
                    PyErr_Format(PyExc_ImportError,
                        "PyCapsule_Import could not "
                        "import module \"%s\"", trace);
                }
            }
        } else {
            PyObject *object2 = PyObject_GetAttrString(object, trace);
            Py_DECREF(object);
            object = object2;
        }
        if (!object) {
            goto EXIT;
        }

        trace = dot;
    }

    if (PyCObject_Check(object)) {
        PyCObject *cobject = (PyCObject *)object;
        return_value = cobject->cobject;
    } else {
        PyErr_Format(PyExc_AttributeError,
            "PyCapsule_Import \"%s\" is not valid",
            name);
    }

EXIT:
    Py_XDECREF(object);
    if (name_dup) {
        PyMem_FREE(name_dup);
    }
    return return_value;
}

#endif /* #if PY_VERSION_HEX < 0x02070000 */

#endif /* __CAPSULETHUNK_H */
```

5 Other options

If you are writing a new extension module, you might consider Cython. It translates a Python-like language to C. The extension modules it creates are compatible with Python 3 and Python 2.

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Argument Clinic How-To

Release 3.7.0

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and the Python development team

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Python Software Foundation
Email: docs@python.org

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Abstract

Argument Clinic is a preprocessor for CPython C files. Its purpose is to automate all the boilerplate involved with writing argument parsing code for "builtins". This document shows you how to convert your first C function to work with Argument Clinic, and then introduces some advanced topics on Argument Clinic usage.

Currently Argument Clinic is considered internal-only for CPython. Its use is not supported for files outside CPython, and no guarantees are made regarding backwards compatibility for future versions. In other words: if you maintain an external C extension for CPython, you're welcome to experiment with Argument Clinic in your own code. But the version of Argument Clinic that ships with the next version of CPython *could* be totally incompatible and break all your code.

1 The Goals Of Argument Clinic

Argument Clinic's primary goal is to take over responsibility for all argument parsing code inside CPython. This means that, when you convert a function to work with Argument Clinic, that function should no longer do any of its own argument parsing—the code generated by Argument Clinic should be a "black box" to you, where CPython calls in at the top, and your code gets called at the bottom, with `PyObject *args` (and maybe `PyObject *kwargs`) magically converted into the C variables and types you need.

In order for Argument Clinic to accomplish its primary goal, it must be easy to use. Currently, working with CPython's argument parsing library is a chore, requiring maintaining redundant information in a surprising number of places. When you use Argument Clinic, you don't have to repeat yourself.

Obviously, no one would want to use Argument Clinic unless it's solving their problem—and without creating new problems of its own. So it's paramount that Argument Clinic generate correct code. It'd be nice if the code was faster, too, but at the very least it should not introduce a major speed regression. (Eventually Argument Clinic *should* make a major speedup possible—we could rewrite its code generator to produce tailor-made argument parsing code, rather than calling the general-purpose CPython argument parsing library. That would make for the fastest argument parsing possible!)

Additionally, Argument Clinic must be flexible enough to work with any approach to argument parsing. Python has some functions with some very strange parsing behaviors; Argument Clinic's goal is to support all of them.

Finally, the original motivation for Argument Clinic was to provide introspection "signatures" for CPython builtins. It used to be, the introspection query functions would throw an exception if you passed in a builtin. With Argument Clinic, that's a thing of the past!

One idea you should keep in mind, as you work with Argument Clinic: the more information you give it, the better job it'll be able to do. Argument Clinic is admittedly relatively simple right now. But as it evolves it will get more sophisticated, and it should be able to do many interesting and smart things with all the information you give it.

2 Basic Concepts And Usage

Argument Clinic ships with CPython; you'll find it in `Tools/clinic/clinic.py`. If you run that script, specifying a C file as an argument:

```
$ python3 Tools/clinic/clinic.py foo.c
```

Argument Clinic will scan over the file looking for lines that look exactly like this:

```
/*[clinic input]
```

When it finds one, it reads everything up to a line that looks exactly like this:

```
[clinic start generated code]*/
```

Everything in between these two lines is input for Argument Clinic. All of these lines, including the beginning and ending comment lines, are collectively called an Argument Clinic "block".

When Argument Clinic parses one of these blocks, it generates output. This output is rewritten into the C file immediately after the block, followed by a comment containing a checksum. The Argument Clinic block now looks like this:

```
/*[clinic input]
... clinic input goes here ...
[clinic start generated code]*/
... clinic output goes here ...
/*[clinic end generated code: checksum=...]*/
```

If you run Argument Clinic on the same file a second time, Argument Clinic will discard the old output and write out the new output with a fresh checksum line. However, if the input hasn't changed, the output won't change either.

You should never modify the output portion of an Argument Clinic block. Instead, change the input until it produces the output you want. (That's the purpose of the checksum—to detect if someone changed the output, as these edits would be lost the next time Argument Clinic writes out fresh output.)

For the sake of clarity, here's the terminology we'll use with Argument Clinic:

- The first line of the comment (`/*[clinic input]`) is the *start line*.
- The last line of the initial comment (`[clinic start generated code]*/`) is the *end line*.
- The last line (`/*[clinic end generated code: checksum=...]*/`) is the *checksum line*.
- In between the start line and the end line is the *input*.
- In between the end line and the checksum line is the *output*.
- All the text collectively, from the start line to the checksum line inclusively, is the *block*. (A block that hasn't been successfully processed by Argument Clinic yet doesn't have output or a checksum line, but it's still considered a block.)

3 Converting Your First Function

The best way to get a sense of how Argument Clinic works is to convert a function to work with it. Here, then, are the bare minimum steps you'd need to follow to convert a function to work with Argument Clinic. Note that for code you plan to check in to CPython, you really should take the conversion farther, using some of the advanced concepts you'll see later on in the document (like "return converters" and "self converters"). But we'll keep it simple for this walkthrough so you can learn.

Let's dive in!

0. Make sure you're working with a freshly updated checkout of the CPython trunk.
1. Find a Python builtin that calls either `PyArg_ParseTuple()` or `PyArg_ParseTupleAndKeywords()`, and hasn't been converted to work with Argument Clinic yet. For my example I'm using `_pickle.Pickler.dump()`.
2. If the call to the `PyArg_Parse` function uses any of the following format units:

```
O&
O!
es
es#
et
et#
```

or if it has multiple calls to `PyArg_ParseTuple()`, you should choose a different function. Argument Clinic *does* support all of these scenarios. But these are advanced topics—let's do something simpler for your first function.

Also, if the function has multiple calls to `PyArg_ParseTuple()` or `PyArg_ParseTupleAndKeywords()` where it supports different types for the same argument, or if the function uses something besides PyArg_Parse functions to parse its arguments, it probably isn't suitable for conversion to Argument Clinic. Argument Clinic doesn't support generic functions or polymorphic parameters.

3. Add the following boilerplate above the function, creating our block:

```
/*[clinic input]
[clinic start generated code]*/
```

4. Cut the docstring and paste it in between the `[clinic]` lines, removing all the junk that makes it a properly quoted C string. When you're done you should have just the text, based at the left margin, with no line wider than 80 characters. (Argument Clinic will preserve indents inside the docstring.)

   If the old docstring had a first line that looked like a function signature, throw that line away. (The docstring doesn't need it anymore—when you use `help()` on your builtin in the future, the first line will be built automatically based on the function's signature.)

   Sample:

```
/*[clinic input]
Write a pickled representation of obj to the open file.
[clinic start generated code]*/
```

5. If your docstring doesn't have a "summary" line, Argument Clinic will complain. So let's make sure it has one. The "summary" line should be a paragraph consisting of a single 80-column line at the beginning of the docstring.

   (Our example docstring consists solely of a summary line, so the sample code doesn't have to change for this step.)

6. Above the docstring, enter the name of the function, followed by a blank line. This should be the Python name of the function, and should be the full dotted path to the function—it should start with the name of the module, include any sub-modules, and if the function is a method on a class it should include the class name too.

   Sample:

```
/*[clinic input]
_pickle.Pickler.dump

Write a pickled representation of obj to the open file.
[clinic start generated code]*/
```

7. If this is the first time that module or class has been used with Argument Clinic in this C file, you must declare the module and/or class. Proper Argument Clinic hygiene prefers declaring these in a separate block somewhere near the top of the C file, in the same way that include files and statics go at the top. (In our sample code we'll just show the two blocks next to each other.)

The name of the class and module should be the same as the one seen by Python. Check the name defined in the `PyModuleDef` or `PyTypeObject` as appropriate.

When you declare a class, you must also specify two aspects of its type in C: the type declaration you'd use for a pointer to an instance of this class, and a pointer to the `PyTypeObject` for this class.

Sample:

```
/*[clinic input]
module _pickle
class _pickle.Pickler "PicklerObject *" "&Pickler_Type"
[clinic start generated code]*/

/*[clinic input]
_pickle.Pickler.dump

Write a pickled representation of obj to the open file.
[clinic start generated code]*/
```

8. Declare each of the parameters to the function. Each parameter should get its own line. All the parameter lines should be indented from the function name and the docstring.

   The general form of these parameter lines is as follows:

   ```
   name_of_parameter: converter
   ```

   If the parameter has a default value, add that after the converter:

   ```
   name_of_parameter: converter = default_value
   ```

   Argument Clinic's support for "default values" is quite sophisticated; please see *the section below on default values* for more information.

   Add a blank line below the parameters.

   What's a "converter"? It establishes both the type of the variable used in C, and the method to convert the Python value into a C value at runtime. For now you're going to use what's called a "legacy converter"—a convenience syntax intended to make porting old code into Argument Clinic easier.

   For each parameter, copy the "format unit" for that parameter from the `PyArg_Parse()` format argument and specify *that* as its converter, as a quoted string. ("format unit" is the formal name for the one-to-three character substring of the `format` parameter that tells the argument parsing function what the type of the variable is and how to convert it. For more on format units please see arg-parsing.)

   For multicharacter format units like `z#`, use the entire two-or-three character string.

   Sample:

   ```
   /*[clinic input]
   module _pickle
   class _pickle.Pickler "PicklerObject *" "&Pickler_Type"
   [clinic start generated code]*/

   /*[clinic input]
   _pickle.Pickler.dump

       obj: 'O'

   Write a pickled representation of obj to the open file.
   [clinic start generated code]*/
   ```

9. If your function has `|` in the format string, meaning some parameters have default values, you can ignore it. Argument Clinic infers which parameters are optional based on whether or not they have default values.

   If your function has `$` in the format string, meaning it takes keyword-only arguments, specify `*` on a line by itself before the first keyword-only argument, indented the same as the parameter lines.

   (`_pickle.Pickler.dump` has neither, so our sample is unchanged.)

10. If the existing C function calls `PyArg_ParseTuple()` (as opposed to `PyArg_ParseTupleAndKeywords()`), then all its arguments are positional-only.

    To mark all parameters as positional-only in Argument Clinic, add a `/` on a line by itself after the last parameter, indented the same as the parameter lines.

    Currently this is all-or-nothing; either all parameters are positional-only, or none of them are. (In the future Argument Clinic may relax this restriction.)

    Sample:

```
/*[clinic input]
module _pickle
class _pickle.Pickler "PicklerObject *" "&Pickler_Type"
[clinic start generated code]*/

/*[clinic input]
_pickle.Pickler.dump

    obj: 'O'
    /

Write a pickled representation of obj to the open file.
[clinic start generated code]*/
```

11. It's helpful to write a per-parameter docstring for each parameter. But per-parameter docstrings are optional; you can skip this step if you prefer.

    Here's how to add a per-parameter docstring. The first line of the per-parameter docstring must be indented further than the parameter definition. The left margin of this first line establishes the left margin for the whole per-parameter docstring; all the text you write will be outdented by this amount. You can write as much text as you like, across multiple lines if you wish.

    Sample:

```
/*[clinic input]
module _pickle
class _pickle.Pickler "PicklerObject *" "&Pickler_Type"
[clinic start generated code]*/

/*[clinic input]
_pickle.Pickler.dump

    obj: 'O'
        The object to be pickled.
    /

Write a pickled representation of obj to the open file.
[clinic start generated code]*/
```

12. Save and close the file, then run `Tools/clinic/clinic.py` on it. With luck everything worked—your block now has output, and a `.c.h` file has been generated! Reopen the file in your text editor to see:

```
/*[clinic input]
_pickle.Pickler.dump

    obj: 'O'
        The object to be pickled.
    /

Write a pickled representation of obj to the open file.
[clinic start generated code]*/

static PyObject *
_pickle_Pickler_dump(PicklerObject *self, PyObject *obj)
/*[clinic end generated code: output=87ecad1261e02ac7 input=552eb1c0f52260d9]*/
```

Obviously, if Argument Clinic didn't produce any output, it's because it found an error in your input. Keep fixing your errors and retrying until Argument Clinic processes your file without complaint.

For readability, most of the glue code has been generated to a `.c.h` file. You'll need to include that in your original `.c` file, typically right after the clinic module block:

```
#include "clinic/_pickle.c.h"
```

13. Double-check that the argument-parsing code Argument Clinic generated looks basically the same as the existing code.

    First, ensure both places use the same argument-parsing function. The existing code must call either `PyArg_ParseTuple()` or `PyArg_ParseTupleAndKeywords()`; ensure that the code generated by Argument Clinic calls the *exact* same function.

    Second, the format string passed in to `PyArg_ParseTuple()` or `PyArg_ParseTupleAndKeywords()` should be *exactly* the same as the hand-written one in the existing function, up to the colon or semicolon.

    (Argument Clinic always generates its format strings with a `:` followed by the name of the function. If the existing code's format string ends with `;`, to provide usage help, this change is harmless—don't worry about it.)

    Third, for parameters whose format units require two arguments (like a length variable, or an encoding string, or a pointer to a conversion function), ensure that the second argument is *exactly* the same between the two invocations.

    Fourth, inside the output portion of the block you'll find a preprocessor macro defining the appropriate static `PyMethodDef` structure for this builtin:

```
#define __PICKLE_PICKLER_DUMP_METHODDEF    \
{"dump", (PyCFunction)__pickle_Pickler_dump, METH_O, __pickle_Pickler_dump__doc__},
```

    This static structure should be *exactly* the same as the existing static `PyMethodDef` structure for this builtin.

    If any of these items differ in *any way*, adjust your Argument Clinic function specification and rerun `Tools/clinic/clinic.py` until they *are* the same.

14. Notice that the last line of its output is the declaration of your "impl" function. This is where the builtin's implementation goes. Delete the existing prototype of the function you're modifying, but leave the opening curly brace. Now delete its argument parsing code and the declarations of all the variables it dumps the arguments into. Notice how the Python arguments are now arguments to this impl function; if the implementation used different names for these variables, fix it.

    Let's reiterate, just because it's kind of weird. Your code should now look like this:

```
static return_type
your_function_impl(...)
/*[clinic end generated code: checksum=...]*/
{
...
```

Argument Clinic generated the checksum line and the function prototype just above it. You should write the opening (and closing) curly braces for the function, and the implementation inside.

Sample:

```
/*[clinic input]
module _pickle
class _pickle.Pickler "PicklerObject *" "&Pickler_Type"
[clinic start generated code]*/
/*[clinic end generated code: checksum=da39a3ee5e6b4b0d3255bfef95601890afd80709]*/

/*[clinic input]
_pickle.Pickler.dump

    obj: 'O'
        The object to be pickled.
    /

Write a pickled representation of obj to the open file.
[clinic start generated code]*/

PyDoc_STRVAR(__pickle_Pickler_dump__doc__,
"Write a pickled representation of obj to the open file.\n"
"\n"
...
static PyObject *
_pickle_Pickler_dump_impl(PicklerObject *self, PyObject *obj)
/*[clinic end generated code: checksum=3bd30745bf206a48f8b576a1da3d90f55a0a4187]*/
{
    /* Check whether the Pickler was initialized correctly (issue3664).
       Developers often forget to call __init__() in their subclasses, which
       would trigger a segfault without this check. */
    if (self->write == NULL) {
        PyErr_Format(PicklingError,
                     "Pickler.__init__() was not called by %s.__init__()",
                     Py_TYPE(self)->tp_name);
        return NULL;
    }

    if (_Pickler_ClearBuffer(self) < 0)
        return NULL;

    ...
```

15. Remember the macro with the `PyMethodDef` structure for this function? Find the existing `PyMethodDef` structure for this function and replace it with a reference to the macro. (If the builtin is at module scope, this will probably be very near the end of the file; if the builtin is a class method, this will probably be below but relatively near to the implementation.)

    Note that the body of the macro contains a trailing comma. So when you replace the existing static `PyMethodDef` structure with the macro, *don't* add a comma to the end.

    Sample:

```
static struct PyMethodDef Pickler_methods[] = {
    __PICKLE_PICKLER_DUMP_METHODDEF
    __PICKLE_PICKLER_CLEAR_MEMO_METHODDEF
    {NULL, NULL}                /* sentinel */
};
```

16. Compile, then run the relevant portions of the regression-test suite. This change should not introduce any new compile-time warnings or errors, and there should be no externally-visible change to Python's behavior.

    Well, except for one difference: `inspect.signature()` run on your function should now provide a valid signature!

    Congratulations, you've ported your first function to work with Argument Clinic!

4 Advanced Topics

Now that you've had some experience working with Argument Clinic, it's time for some advanced topics.

4.1 Symbolic default values

The default value you provide for a parameter can't be any arbitrary expression. Currently the following are explicitly supported:

- Numeric constants (integer and float)
- String constants
- `True`, `False`, and `None`
- Simple symbolic constants like `sys.maxsize`, which must start with the name of the module

In case you're curious, this is implemented in `from_builtin()` in `Lib/inspect.py`.

(In the future, this may need to get even more elaborate, to allow full expressions like `CONSTANT - 1`.)

4.2 Renaming the C functions and variables generated by Argument Clinic

Argument Clinic automatically names the functions it generates for you. Occasionally this may cause a problem, if the generated name collides with the name of an existing C function. There's an easy solution: override the names used for the C functions. Just add the keyword `"as"` to your function declaration line, followed by the function name you wish to use. Argument Clinic will use that function name for the base (generated) function, then add `"_impl"` to the end and use that for the name of the impl function.

For example, if we wanted to rename the C function names generated for `pickle.Pickler.dump`, it'd look like this:

```
/*[clinic input]
pickle.Pickler.dump as pickler_dumper

...
```

The base function would now be named `pickler_dumper()`, and the impl function would now be named `pickler_dumper_impl()`.

Similarly, you may have a problem where you want to give a parameter a specific Python name, but that name may be inconvenient in C. Argument Clinic allows you to give a parameter different names in Python and in C, using the same `"as"` syntax:

```
/*[clinic input]
pickle.Pickler.dump

    obj: object
    file as file_obj: object
    protocol: object = NULL
    *
    fix_imports: bool = True
```

Here, the name used in Python (in the signature and the `keywords` array) would be `file`, but the C variable would be named `file_obj`.

You can use this to rename the `self` parameter too!

4.3 Converting functions using PyArg_UnpackTuple

To convert a function parsing its arguments with `PyArg_UnpackTuple()`, simply write out all the arguments, specifying each as an `object`. You may specify the `type` argument to cast the type as appropriate. All arguments should be marked positional-only (add a `/` on a line by itself after the last argument).

Currently the generated code will use `PyArg_ParseTuple()`, but this will change soon.

4.4 Optional Groups

Some legacy functions have a tricky approach to parsing their arguments: they count the number of positional arguments, then use a `switch` statement to call one of several different `PyArg_ParseTuple()` calls depending on how many positional arguments there are. (These functions cannot accept keyword-only arguments.) This approach was used to simulate optional arguments back before `PyArg_ParseTupleAndKeywords()` was created.

While functions using this approach can often be converted to use `PyArg_ParseTupleAndKeywords()`, optional arguments, and default values, it's not always possible. Some of these legacy functions have behaviors `PyArg_ParseTupleAndKeywords()` doesn't directly support. The most obvious example is the builtin function `range()`, which has an optional argument on the *left* side of its required argument! Another example is `curses.window.addch()`, which has a group of two arguments that must always be specified together. (The arguments are called `x` and `y`; if you call the function passing in `x`, you must also pass in `y`—and if you don't pass in `x` you may not pass in `y` either.)

In any case, the goal of Argument Clinic is to support argument parsing for all existing CPython builtins without changing their semantics. Therefore Argument Clinic supports this alternate approach to parsing, using what are called *optional groups*. Optional groups are groups of arguments that must all be passed in together. They can be to the left or the right of the required arguments. They can *only* be used with positional-only parameters.

Note: Optional groups are *only* intended for use when converting functions that make multiple calls to `PyArg_ParseTuple()`! Functions that use *any* other approach for parsing arguments should *almost never* be converted to Argument Clinic using optional groups. Functions using optional groups currently cannot have accurate signatures in Python, because Python just doesn't understand the concept. Please avoid using optional groups wherever possible.

To specify an optional group, add a `[` on a line by itself before the parameters you wish to group together, and a `]` on a line by itself after these parameters. As an example, here's how `curses.window.addch` uses optional groups to make the first two parameters and the last parameter optional:

```
/*[clinic input]

curses.window.addch

    [
    x: int
      X-coordinate.
    y: int
      Y-coordinate.
    ]

    ch: object
      Character to add.

    [
    attr: long
      Attributes for the character.
    ]
    /

...
```

Notes:

- For every optional group, one additional parameter will be passed into the impl function representing the group. The parameter will be an int named `group_{direction}_{number}`, where `{direction}` is either `right` or `left` depending on whether the group is before or after the required parameters, and `{number}` is a monotonically increasing number (starting at 1) indicating how far away the group is from the required parameters. When the impl is called, this parameter will be set to zero if this group was unused, and set to non-zero if this group was used. (By used or unused, I mean whether or not the parameters received arguments in this invocation.)
- If there are no required arguments, the optional groups will behave as if they're to the right of the required arguments.
- In the case of ambiguity, the argument parsing code favors parameters on the left (before the required parameters).
- Optional groups can only contain positional-only parameters.
- Optional groups are *only* intended for legacy code. Please do not use optional groups for new code.

4.5 Using real Argument Clinic converters, instead of "legacy converters"

To save time, and to minimize how much you need to learn to achieve your first port to Argument Clinic, the walkthrough above tells you to use "legacy converters". "Legacy converters" are a convenience, designed explicitly to make porting existing code to Argument Clinic easier. And to be clear, their use is acceptable when porting code for Python 3.4.

However, in the long term we probably want all our blocks to use Argument Clinic's real syntax for converters. Why? A couple reasons:

- The proper converters are far easier to read and clearer in their intent.
- There are some format units that are unsupported as "legacy converters", because they require arguments, and the legacy converter syntax doesn't support specifying arguments.
- In the future we may have a new argument parsing library that isn't restricted to what `PyArg_ParseTuple()` supports; this flexibility won't be available to parameters using legacy converters.

Therefore, if you don't mind a little extra effort, please use the normal converters instead of legacy converters.

In a nutshell, the syntax for Argument Clinic (non-legacy) converters looks like a Python function call. However, if there are no explicit arguments to the function (all functions take their default values), you may omit the parentheses. Thus `bool` and `bool()` are exactly the same converters.

All arguments to Argument Clinic converters are keyword-only. All Argument Clinic converters accept the following arguments:

`c_default` The default value for this parameter when defined in C. Specifically, this will be the initializer for the variable declared in the "parse function". See *the section on default values* for how to use this. Specified as a string.

`annotation` The annotation value for this parameter. Not currently supported, because PEP 8 mandates that the Python library may not use annotations.

In addition, some converters accept additional arguments. Here is a list of these arguments, along with their meanings:

`accept` A set of Python types (and possibly pseudo-types); this restricts the allowable Python argument to values of these types. (This is not a general-purpose facility; as a rule it only supports specific lists of types as shown in the legacy converter table.)

To accept `None`, add `NoneType` to this set.

`bitwise` Only supported for unsigned integers. The native integer value of this Python argument will be written to the parameter without any range checking, even for negative values.

`converter` Only supported by the `object` converter. Specifies the name of a C "converter function" to use to convert this object to a native type.

`encoding` Only supported for strings. Specifies the encoding to use when converting this string from a Python str (Unicode) value into a C `char *` value.

`subclass_of` Only supported for the `object` converter. Requires that the Python value be a subclass of a Python type, as expressed in C.

`type` Only supported for the `object` and `self` converters. Specifies the C type that will be used to declare the variable. Default value is `"PyObject *"`.

`zeroes` Only supported for strings. If true, embedded NUL bytes (`'\\0'`) are permitted inside the value. The length of the string will be passed in to the impl function, just after the string parameter, as a parameter named `<parameter_name>_length`.

Please note, not every possible combination of arguments will work. Usually these arguments are implemented by specific `PyArg_ParseTuple` *format units*, with specific behavior. For example, currently you cannot call `unsigned_short` without also specifying `bitwise=True`. Although it's perfectly reasonable to think this would work, these semantics don't map to any existing format unit. So Argument Clinic doesn't support it. (Or, at least, not yet.)

Below is a table showing the mapping of legacy converters into real Argument Clinic converters. On the left is the legacy converter, on the right is the text you'd replace it with.

`'B'`	`unsigned_char(bitwise=True)`
`'b'`	`unsigned_char`
`'c'`	`char`
`'C'`	`int(accept={str})`
`'d'`	`double`
`'D'`	`Py_complex`
`'es'`	`str(encoding='name_of_encoding')`
`'es#'`	`str(encoding='name_of_encoding', zeroes=True)`

Continued on next page

Table 1 – continued from previous page

'et'	str(encoding='name_of_encoding', accept={bytes, bytearray, str})
'et#'	str(encoding='name_of_encoding', accept={bytes, bytearray, str}, zeroes=True)
'f'	float
'h'	short
'H'	unsigned_short(bitwise=True)
'i'	int
'I'	unsigned_int(bitwise=True)
'k'	unsigned_long(bitwise=True)
'K'	unsigned_long_long(bitwise=True)
'l'	long
'L'	long long
'n'	Py_ssize_t
'O'	object
'O!'	object(subclass_of='&PySomething_Type')
'O&'	object(converter='name_of_c_function')
'p'	bool
'S'	PyBytesObject
's'	str
's#'	str(zeroes=True)
's*'	Py_buffer(accept={buffer, str})
'U'	unicode
'u'	Py_UNICODE
'u#'	Py_UNICODE(zeroes=True)
'w*'	Py_buffer(accept={rwbuffer})
'Y'	PyByteArrayObject
'y'	str(accept={bytes})
'y#'	str(accept={robuffer}, zeroes=True)
'y*'	Py_buffer
'Z'	Py_UNICODE(accept={str, NoneType})
'Z#'	Py_UNICODE(accept={str, NoneType}, zeroes=True)
'z'	str(accept={str, NoneType})
'z#'	str(accept={str, NoneType}, zeroes=True)
'z*'	Py_buffer(accept={buffer, str, NoneType})

As an example, here's our sample `pickle.Pickler.dump` using the proper converter:

```
/*[clinic input]
pickle.Pickler.dump

    obj: object
        The object to be pickled.
    /

Write a pickled representation of obj to the open file.
[clinic start generated code]*/
```

Argument Clinic will show you all the converters it has available. For each converter it'll show you all the parameters it accepts, along with the default value for each parameter. Just run `Tools/clinic/clinic.py --converters` to see the full list.

4.6 Py_buffer

When using the `Py_buffer` converter (or the `'s*'`, `'w*'`, `'*y'`, or `'z*'` legacy converters), you *must* not call `PyBuffer_Release()` on the provided buffer. Argument Clinic generates code that does it for you (in the parsing function).

4.7 Advanced converters

Remember those format units you skipped for your first time because they were advanced? Here's how to handle those too.

The trick is, all those format units take arguments—either conversion functions, or types, or strings specifying an encoding. (But "legacy converters" don't support arguments. That's why we skipped them for your first function.) The argument you specified to the format unit is now an argument to the converter; this argument is either `converter` (for `O&`), `subclass_of` (for `O!`), or `encoding` (for all the format units that start with `e`).

When using `subclass_of`, you may also want to use the other custom argument for `object()`: `type`, which lets you set the type actually used for the parameter. For example, if you want to ensure that the object is a subclass of `PyUnicode_Type`, you probably want to use the converter `object(type='PyUnicodeObject *', subclass_of='&PyUnicode_Type')`.

One possible problem with using Argument Clinic: it takes away some possible flexibility for the format units starting with `e`. When writing a `PyArg_Parse` call by hand, you could theoretically decide at runtime what encoding string to pass in to `PyArg_ParseTuple()`. But now this string must be hard-coded at Argument-Clinic-preprocessing-time. This limitation is deliberate; it made supporting this format unit much easier, and may allow for future optimizations. This restriction doesn't seem unreasonable; CPython itself always passes in static hard-coded encoding strings for parameters whose format units start with `e`.

4.8 Parameter default values

Default values for parameters can be any of a number of values. At their simplest, they can be string, int, or float literals:

```
foo: str = "abc"
bar: int = 123
bat: float = 45.6
```

They can also use any of Python's built-in constants:

```
yep:  bool = True
nope: bool = False
nada: object = None
```

There's also special support for a default value of `NULL`, and for simple expressions, documented in the following sections.

4.9 The `NULL` default value

For string and object parameters, you can set them to `None` to indicate that there's no default. However, that means the C variable will be initialized to `Py_None`. For convenience's sakes, there's a special value called `NULL` for just this reason: from Python's perspective it behaves like a default value of `None`, but the C variable is initialized with `NULL`.

4.10 Expressions specified as default values

The default value for a parameter can be more than just a literal value. It can be an entire expression, using math operators and looking up attributes on objects. However, this support isn't exactly simple, because of some non-obvious semantics.

Consider the following example:

```
foo: Py_ssize_t = sys.maxsize - 1
```

`sys.maxsize` can have different values on different platforms. Therefore Argument Clinic can't simply evaluate that expression locally and hard-code it in C. So it stores the default in such a way that it will get evaluated at runtime, when the user asks for the function's signature.

What namespace is available when the expression is evaluated? It's evaluated in the context of the module the builtin came from. So, if your module has an attribute called "`max_widgets`", you may simply use it:

```
foo: Py_ssize_t = max_widgets
```

If the symbol isn't found in the current module, it fails over to looking in `sys.modules`. That's how it can find `sys.maxsize` for example. (Since you don't know in advance what modules the user will load into their interpreter, it's best to restrict yourself to modules that are preloaded by Python itself.)

Evaluating default values only at runtime means Argument Clinic can't compute the correct equivalent C default value. So you need to tell it explicitly. When you use an expression, you must also specify the equivalent expression in C, using the `c_default` parameter to the converter:

```
foo: Py_ssize_t(c_default="PY_SSIZE_T_MAX - 1") = sys.maxsize - 1
```

Another complication: Argument Clinic can't know in advance whether or not the expression you supply is valid. It parses it to make sure it looks legal, but it can't *actually* know. You must be very careful when using expressions to specify values that are guaranteed to be valid at runtime!

Finally, because expressions must be representable as static C values, there are many restrictions on legal expressions. Here's a list of Python features you're not permitted to use:

- Function calls.
- Inline if statements (`3 if foo else 5`).
- Automatic sequence unpacking (`*[1, 2, 3]`).
- List/set/dict comprehensions and generator expressions.
- Tuple/list/set/dict literals.

4.11 Using a return converter

By default the impl function Argument Clinic generates for you returns `PyObject *`. But your C function often computes some C type, then converts it into the `PyObject *` at the last moment. Argument Clinic handles converting your inputs from Python types into native C types—why not have it convert your return value from a native C type into a Python type too?

That's what a "return converter" does. It changes your impl function to return some C type, then adds code to the generated (non-impl) function to handle converting that value into the appropriate `PyObject *`.

The syntax for return converters is similar to that of parameter converters. You specify the return converter like it was a return annotation on the function itself. Return converters behave much the same as parameter converters; they take arguments, the arguments are all keyword-only, and if you're not changing any of the default arguments you can omit the parentheses.

(If you use both `"as"` *and* a return converter for your function, the `"as"` should come before the return converter.)

There's one additional complication when using return converters: how do you indicate an error has occurred? Normally, a function returns a valid (non-`NULL`) pointer for success, and `NULL` for failure. But if you use an integer return converter, all integers are valid. How can Argument Clinic detect an error? Its solution: each return converter implicitly looks for a special value that indicates an error. If you return that value, and an error has been set (`PyErr_Occurred()` returns a true value), then the generated code will propagate the error. Otherwise it will encode the value you return like normal.

Currently Argument Clinic supports only a few return converters:

```
bool
int
unsigned int
long
unsigned int
size_t
Py_ssize_t
float
double
DecodeFSDefault
```

None of these take parameters. For the first three, return -1 to indicate error. For `DecodeFSDefault`, the return type is `const char *`; return a NULL pointer to indicate an error.

(There's also an experimental `NoneType` converter, which lets you return `Py_None` on success or `NULL` on failure, without having to increment the reference count on `Py_None`. I'm not sure it adds enough clarity to be worth using.)

To see all the return converters Argument Clinic supports, along with their parameters (if any), just run `Tools/clinic/clinic.py --converters` for the full list.

4.12 Cloning existing functions

If you have a number of functions that look similar, you may be able to use Clinic's "clone" feature. When you clone an existing function, you reuse:

- its parameters, including
  - their names,
  - their converters, with all parameters,
  - their default values,
  - their per-parameter docstrings,
  - their *kind* (whether they're positional only, positional or keyword, or keyword only), and
- its return converter.

The only thing not copied from the original function is its docstring; the syntax allows you to specify a new docstring.

Here's the syntax for cloning a function:

```
/*[clinic input]
module.class.new_function [as c_basename] = module.class.existing_function

Docstring for new_function goes here.
[clinic start generated code]*/
```

(The functions can be in different modules or classes. I wrote `module.class` in the sample just to illustrate that you must use the full path to *both* functions.)

Sorry, there's no syntax for partially-cloning a function, or cloning a function then modifying it. Cloning is an all-or nothing proposition.

Also, the function you are cloning from must have been previously defined in the current file.

4.13 Calling Python code

The rest of the advanced topics require you to write Python code which lives inside your C file and modifies Argument Clinic's runtime state. This is simple: you simply define a Python block.

A Python block uses different delimiter lines than an Argument Clinic function block. It looks like this:

```
/*[python input]
# python code goes here
[python start generated code]*/
```

All the code inside the Python block is executed at the time it's parsed. All text written to stdout inside the block is redirected into the "output" after the block.

As an example, here's a Python block that adds a static integer variable to the C code:

```
/*[python input]
print('static int __ignored_unused_variable__ = 0;')
[python start generated code]*/
static int __ignored_unused_variable__ = 0;
/*[python checksum:...]*/
```

4.14 Using a "self converter"

Argument Clinic automatically adds a "self" parameter for you using a default converter. It automatically sets the `type` of this parameter to the "pointer to an instance" you specified when you declared the type. However, you can override Argument Clinic's converter and specify one yourself. Just add your own `self` parameter as the first parameter in a block, and ensure that its converter is an instance of `self_converter` or a subclass thereof.

What's the point? This lets you override the type of `self`, or give it a different default name.

How do you specify the custom type you want to cast `self` to? If you only have one or two functions with the same type for `self`, you can directly use Argument Clinic's existing `self` converter, passing in the type you want to use as the `type` parameter:

```
/*[clinic input]

_pickle.Pickler.dump

  self: self(type="PicklerObject *")
  obj: object
  /

Write a pickled representation of the given object to the open file.
[clinic start generated code]*/
```

On the other hand, if you have a lot of functions that will use the same type for `self`, it's best to create your own converter, subclassing `self_converter` but overwriting the `type` member:

```
/*[python input]
class PicklerObject_converter(self_converter):
    type = "PicklerObject *"
[python start generated code]*/

/*[clinic input]

_pickle.Pickler.dump

  self: PicklerObject
  obj: object
  /

Write a pickled representation of the given object to the open file.
[clinic start generated code]*/
```

4.15 Writing a custom converter

As we hinted at in the previous section... you can write your own converters! A converter is simply a Python class that inherits from `CConverter`. The main purpose of a custom converter is if you have a parameter using the `O&` format unit—parsing this parameter means calling a `PyArg_ParseTuple()` "converter function".

Your converter class should be named `*something*_converter`. If the name follows this convention, then your converter class will be automatically registered with Argument Clinic; its name will be the name of your class with the `_converter` suffix stripped off. (This is accomplished with a metaclass.)

You shouldn't subclass `CConverter.__init__`. Instead, you should write a `converter_init()` function. `converter_init()` always accepts a `self` parameter; after that, all additional parameters *must* be keyword-only. Any arguments passed in to the converter in Argument Clinic will be passed along to your `converter_init()`.

There are some additional members of `CConverter` you may wish to specify in your subclass. Here's the current list:

`type` The C type to use for this variable. `type` should be a Python string specifying the type, e.g. `int`. If this is a pointer type, the type string should end with `' *'`.

`default` The Python default value for this parameter, as a Python value. Or the magic value `unspecified` if there is no default.

`py_default` `default` as it should appear in Python code, as a string. Or `None` if there is no default.

`c_default` `default` as it should appear in C code, as a string. Or `None` if there is no default.

`c_ignored_default` The default value used to initialize the C variable when there is no default, but not specifying a default may result in an "uninitialized variable" warning. This can easily happen when using option groups—although properly-written code will never actually use this value, the variable does get passed in to the impl, and the C compiler will complain about the "use" of the uninitialized value. This value should always be a non-empty string.

`converter` The name of the C converter function, as a string.

`impl_by_reference` A boolean value. If true, Argument Clinic will add a `&` in front of the name of the variable when passing it into the impl function.

`parse_by_reference` A boolean value. If true, Argument Clinic will add a `&` in front of the name of the variable when passing it into `PyArg_ParseTuple()`.

Here's the simplest example of a custom converter, from `Modules/zlibmodule.c`:

```
/*[python input]

class ssize_t_converter(CConverter):
    type = 'Py_ssize_t'
    converter = 'ssize_t_converter'

[python start generated code]*/
/*[python end generated code: output=da39a3ee5e6b4b0d input=35521e4e733823c7]*/
```

This block adds a converter to Argument Clinic named `ssize_t`. Parameters declared as `ssize_t` will be declared as type `Py_ssize_t`, and will be parsed by the `'O&'` format unit, which will call the `ssize_t_converter` converter function. `ssize_t` variables automatically support default values.

More sophisticated custom converters can insert custom C code to handle initialization and cleanup. You can see more examples of custom converters in the CPython source tree; grep the C files for the string `CConverter`.

4.16 Writing a custom return converter

Writing a custom return converter is much like writing a custom converter. Except it's somewhat simpler, because return converters are themselves much simpler.

Return converters must subclass `CReturnConverter`. There are no examples yet of custom return converters, because they are not widely used yet. If you wish to write your own return converter, please read `Tools/clinic/clinic.py`, specifically the implementation of `CReturnConverter` and all its subclasses.

4.17 METH_O and METH_NOARGS

To convert a function using `METH_O`, make sure the function's single argument is using the `object` converter, and mark the arguments as positional-only:

```
/*[clinic input]
meth_o_sample

     argument: object
     /
[clinic start generated code]*/
```

To convert a function using `METH_NOARGS`, just don't specify any arguments.

You can still use a self converter, a return converter, and specify a `type` argument to the object converter for `METH_O`.

4.18 tp_new and tp_init functions

You can convert `tp_new` and `tp_init` functions. Just name them `__new__` or `__init__` as appropriate. Notes:

- The function name generated for `__new__` doesn't end in `__new__` like it would by default. It's just the name of the class, converted into a valid C identifier.
- No `PyMethodDef #define` is generated for these functions.
- `__init__` functions return `int`, not `PyObject *`.
- Use the docstring as the class docstring.

- Although `__new__` and `__init__` functions must always accept both the `args` and `kwargs` objects, when converting you may specify any signature for these functions that you like. (If your function doesn't support keywords, the parsing function generated will throw an exception if it receives any.)

4.19 Changing and redirecting Clinic's output

It can be inconvenient to have Clinic's output interspersed with your conventional hand-edited C code. Luckily, Clinic is configurable: you can buffer up its output for printing later (or earlier!), or write its output to a separate file. You can also add a prefix or suffix to every line of Clinic's generated output.

While changing Clinic's output in this manner can be a boon to readability, it may result in Clinic code using types before they are defined, or your code attempting to use Clinic-generated code before it is defined. These problems can be easily solved by rearranging the declarations in your file, or moving where Clinic's generated code goes. (This is why the default behavior of Clinic is to output everything into the current block; while many people consider this hampers readability, it will never require rearranging your code to fix definition-before-use problems.)

Let's start with defining some terminology:

field A field, in this context, is a subsection of Clinic's output. For example, the `#define` for the `PyMethodDef` structure is a field, called `methoddef_define`. Clinic has seven different fields it can output per function definition:

```
docstring_prototype
docstring_definition
methoddef_define
impl_prototype
parser_prototype
parser_definition
impl_definition
```

All the names are of the form `"<a>_<b>"`, where `"<a>"` is the semantic object represented (the parsing function, the impl function, the docstring, or the methoddef structure) and `"<b>"` represents what kind of statement the field is. Field names that end in `"_prototype"` represent forward declarations of that thing, without the actual body/data of the thing; field names that end in `"_definition"` represent the actual definition of the thing, with the body/data of the thing. (`"methoddef"` is special, it's the only one that ends with `"_define"`, representing that it's a preprocessor #define.)

destination A destination is a place Clinic can write output to. There are five built-in destinations:

`block` The default destination: printed in the output section of the current Clinic block.

`buffer` A text buffer where you can save text for later. Text sent here is appended to the end of any existing text. It's an error to have any text left in the buffer when Clinic finishes processing a file.

`file` A separate "clinic file" that will be created automatically by Clinic. The filename chosen for the file is `{basename}.clinic{extension}`, where `basename` and `extension` were assigned the output from `os.path.splitext()` run on the current file. (Example: the `file` destination for `_pickle.c` would be written to `_pickle.clinic.c`.)

Important: When using a `file` destination, you *must check in* the generated file!

`two-pass` A buffer like `buffer`. However, a two-pass buffer can only be dumped once, and it prints out all text sent to it during all processing, even from Clinic blocks *after* the dumping point.

`suppress` The text is suppressed—thrown away.

Clinic defines five new directives that let you reconfigure its output.

The first new directive is `dump`:

```
dump <destination>
```

This dumps the current contents of the named destination into the output of the current block, and empties it. This only works with `buffer` and `two-pass` destinations.

The second new directive is `output`. The most basic form of `output` is like this:

```
output <field> <destination>
```

This tells Clinic to output *field* to *destination*. `output` also supports a special meta-destination, called `everything`, which tells Clinic to output *all* fields to that *destination*.

`output` has a number of other functions:

```
output push
output pop
output preset <preset>
```

`output push` and `output pop` allow you to push and pop configurations on an internal configuration stack, so that you can temporarily modify the output configuration, then easily restore the previous configuration. Simply push before your change to save the current configuration, then pop when you wish to restore the previous configuration.

`output preset` sets Clinic's output to one of several built-in preset configurations, as follows:

`block` Clinic's original starting configuration. Writes everything immediately after the input block.

Suppress the `parser_prototype` and `docstring_prototype`, write everything else to `block`.

`file` Designed to write everything to the "clinic file" that it can. You then `#include` this file near the top of your file. You may need to rearrange your file to make this work, though usually this just means creating forward declarations for various `typedef` and `PyTypeObject` definitions.

Suppress the `parser_prototype` and `docstring_prototype`, write the `impl_definition` to `block`, and write everything else to `file`.

The default filename is `"{dirname}/clinic/{basename}.h"`.

`buffer` Save up most of the output from Clinic, to be written into your file near the end. For Python files implementing modules or builtin types, it's recommended that you dump the buffer just above the static structures for your module or builtin type; these are normally very near the end. Using `buffer` may require even more editing than `file`, if your file has static `PyMethodDef` arrays defined in the middle of the file.

Suppress the `parser_prototype`, `impl_prototype`, and `docstring_prototype`, write the `impl_definition` to `block`, and write everything else to `file`.

`two-pass` Similar to the `buffer` preset, but writes forward declarations to the `two-pass` buffer, and definitions to the `buffer`. This is similar to the `buffer` preset, but may require less editing than `buffer`. Dump the `two-pass` buffer near the top of your file, and dump the `buffer` near the end just like you would when using the `buffer` preset.

Suppresses the `impl_prototype`, write the `impl_definition` to `block`, write `docstring_prototype`, `methoddef_define`, and `parser_prototype` to `two-pass`, write everything else to `buffer`.

`partial-buffer` Similar to the `buffer` preset, but writes more things to `block`, only writing the really big chunks of generated code to `buffer`. This avoids the definition-before-use problem of `buffer` completely, at the small cost of having slightly more stuff in the block's output. Dump the `buffer` near the end, just like you would when using the `buffer` preset.

Suppresses the `impl_prototype`, write the `docstring_definition` and `parser_definition` to `buffer`, write everything else to `block`.

The third new directive is `destination`:

```
destination <name> <command> [...]
```

This performs an operation on the destination named `name`.

There are two defined subcommands: `new` and `clear`.

The `new` subcommand works like this:

```
destination <name> new <type>
```

This creates a new destination with name `<name>` and type `<type>`.

There are five destination types:

`suppress` Throws the text away.

`block` Writes the text to the current block. This is what Clinic originally did.

`buffer` A simple text buffer, like the "buffer" builtin destination above.

`file` A text file. The file destination takes an extra argument, a template to use for building the filename, like so:

destination <name> new <type> <file_template>

The template can use three strings internally that will be replaced by bits of the filename:

{path} The full path to the file, including directory and full filename.

{dirname} The name of the directory the file is in.

{basename} Just the name of the file, not including the directory.

{basename_root} Basename with the extension clipped off (everything up to but not including the last '.').

{basename_extension} The last '.' and everything after it. If the basename does not contain a period, this will be the empty string.

If there are no periods in the filename, {basename} and {filename} are the same, and {extension} is empty. "{basename}{extension}" is always exactly the same as "{filename}"."

`two-pass` A two-pass buffer, like the "two-pass" builtin destination above.

The `clear` subcommand works like this:

```
destination <name> clear
```

It removes all the accumulated text up to this point in the destination. (I don't know what you'd need this for, but I thought maybe it'd be useful while someone's experimenting.)

The fourth new directive is `set`:

```
set line_prefix "string"
set line_suffix "string"
```

`set` lets you set two internal variables in Clinic. `line_prefix` is a string that will be prepended to every line of Clinic's output; `line_suffix` is a string that will be appended to every line of Clinic's output.

Both of these support two format strings:

`{block comment start}` Turns into the string `/*`, the start-comment text sequence for C files.

`{block comment end}` Turns into the string `*/`, the end-comment text sequence for C files.

The final new directive is one you shouldn't need to use directly, called `preserve`:

```
preserve
```

This tells Clinic that the current contents of the output should be kept, unmodified. This is used internally by Clinic when dumping output into `file` files; wrapping it in a Clinic block lets Clinic use its existing checksum functionality to ensure the file was not modified by hand before it gets overwritten.

4.20 The #ifdef trick

If you're converting a function that isn't available on all platforms, there's a trick you can use to make life a little easier. The existing code probably looks like this:

```
#ifdef HAVE_FUNCTIONNAME
static module_functionname(...)
{
...
}
#endif /* HAVE_FUNCTIONNAME */
```

And then in the `PyMethodDef` structure at the bottom the existing code will have:

```
#ifdef HAVE_FUNCTIONNAME
{'functionname', ... },
#endif /* HAVE_FUNCTIONNAME */
```

In this scenario, you should enclose the body of your impl function inside the `#ifdef`, like so:

```
#ifdef HAVE_FUNCTIONNAME
/*[clinic input]
module.functionname
...
[clinic start generated code]*/
static module_functionname(...)
{
...
}
#endif /* HAVE_FUNCTIONNAME */
```

Then, remove those three lines from the `PyMethodDef` structure, replacing them with the macro Argument Clinic generated:

```
MODULE_FUNCTIONNAME_METHODDEF
```

(You can find the real name for this macro inside the generated code. Or you can calculate it yourself: it's the name of your function as defined on the first line of your block, but with periods changed to underscores, uppercased, and `"_METHODDEF"` added to the end.)

Perhaps you're wondering: what if `HAVE_FUNCTIONNAME` isn't defined? The `MODULE_FUNCTIONNAME_METHODDEF` macro won't be defined either!

Here's where Argument Clinic gets very clever. It actually detects that the Argument Clinic block might be deactivated by the `#ifdef`. When that happens, it generates a little extra code that looks like this:

```
#ifndef MODULE_FUNCTIONNAME_METHODDEF
    #define MODULE_FUNCTIONNAME_METHODDEF
#endif /* !defined(MODULE_FUNCTIONNAME_METHODDEF) */
```

That means the macro always works. If the function is defined, this turns into the correct structure, including the trailing comma. If the function is undefined, this turns into nothing.

However, this causes one ticklish problem: where should Argument Clinic put this extra code when using the "block" output preset? It can't go in the output block, because that could be deactivated by the `#ifdef`. (That's the whole point!)

In this situation, Argument Clinic writes the extra code to the "buffer" destination. This may mean that you get a complaint from Argument Clinic:

```
Warning in file "Modules/posixmodule.c" on line 12357:
Destination buffer 'buffer' not empty at end of file, emptying.
```

When this happens, just open your file, find the `dump buffer` block that Argument Clinic added to your file (it'll be at the very bottom), then move it above the `PyMethodDef` structure where that macro is used.

4.21 Using Argument Clinic in Python files

It's actually possible to use Argument Clinic to preprocess Python files. There's no point to using Argument Clinic blocks, of course, as the output wouldn't make any sense to the Python interpreter. But using Argument Clinic to run Python blocks lets you use Python as a Python preprocessor!

Since Python comments are different from C comments, Argument Clinic blocks embedded in Python files look slightly different. They look like this:

```
#/*[python input]
#print("def foo(): pass")
#[python start generated code]*/
def foo(): pass
#/*[python checksum:...]*/
```

Argparse Tutorial

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This tutorial is intended to be a gentle introduction to `argparse`, the recommended command-line parsing module in the Python standard library.

Note: There are two other modules that fulfill the same task, namely `getopt` (an equivalent for `getopt()` from the C language) and the deprecated `optparse`. Note also that `argparse` is based on `optparse`, and therefore very similar in terms of usage.

1 Concepts

Let's show the sort of functionality that we are going to explore in this introductory tutorial by making use of the `ls` command:

```
$ ls
cpython  devguide  prog.py  pypy  rm-unused-function.patch
$ ls pypy
ctypes_configure  demo  dotviewer  include  lib_pypy  lib-python ...
$ ls -l
total 20
drwxr-xr-x 19 wena wena 4096 Feb 18 18:51 cpython
drwxr-xr-x  4 wena wena 4096 Feb  8 12:04 devguide
-rwxr-xr-x  1 wena wena  535 Feb 19 00:05 prog.py
drwxr-xr-x 14 wena wena 4096 Feb  7 00:59 pypy
-rw-r--r--  1 wena wena  741 Feb 18 01:01 rm-unused-function.patch
$ ls --help
Usage: ls [OPTION]... [FILE]...
List information about the FILEs (the current directory by default).
Sort entries alphabetically if none of -cftuvSUX nor --sort is specified.
...
```

A few concepts we can learn from the four commands:

- The `ls` command is useful when run without any options at all. It defaults to displaying the contents of the current directory.
- If we want beyond what it provides by default, we tell it a bit more. In this case, we want it to display a different directory, `pypy`. What we did is specify what is known as a positional argument. It's named so because the program should know what to do with the value, solely based on where it appears on the command line. This concept is more relevant to a command like `cp`, whose most basic usage is `cp SRC DEST`. The first position is *what you want copied,* and the second position is *where you want it copied to.*
- Now, say we want to change behaviour of the program. In our example, we display more info for each file instead of just showing the file names. The `-l` in that case is known as an optional argument.
- That's a snippet of the help text. It's very useful in that you can come across a program you have never used before, and can figure out how it works simply by reading its help text.

2 The basics

Let us start with a very simple example which does (almost) nothing:

```
import argparse
parser = argparse.ArgumentParser()
parser.parse_args()
```

Following is a result of running the code:

```
$ python3 prog.py
$ python3 prog.py --help
usage: prog.py [-h]

optional arguments:
  -h, --help  show this help message and exit
```

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```
$ python3 prog.py --verbose
usage: prog.py [-h]
prog.py: error: unrecognized arguments: --verbose
$ python3 prog.py foo
usage: prog.py [-h]
prog.py: error: unrecognized arguments: foo
```

Here is what is happening:

- Running the script without any options results in nothing displayed to stdout. Not so useful.
- The second one starts to display the usefulness of the `argparse` module. We have done almost nothing, but already we get a nice help message.
- The `--help` option, which can also be shortened to `-h`, is the only option we get for free (i.e. no need to specify it). Specifying anything else results in an error. But even then, we do get a useful usage message, also for free.

3 Introducing Positional arguments

An example:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("echo")
args = parser.parse_args()
print(args.echo)
```

And running the code:

```
$ python3 prog.py
usage: prog.py [-h] echo
prog.py: error: the following arguments are required: echo
$ python3 prog.py --help
usage: prog.py [-h] echo

positional arguments:
  echo

optional arguments:
  -h, --help  show this help message and exit
$ python3 prog.py foo
foo
```

Here is what's happening:

- We've added the `add_argument()` method, which is what we use to specify which command-line options the program is willing to accept. In this case, I've named it `echo` so that it's in line with its function.
- Calling our program now requires us to specify an option.
- The `parse_args()` method actually returns some data from the options specified, in this case, `echo`.
- The variable is some form of 'magic' that `argparse` performs for free (i.e. no need to specify which variable that value is stored in). You will also notice that its name matches the string argument given to the method, `echo`.

Note however that, although the help display looks nice and all, it currently is not as helpful as it can be. For example we see that we got `echo` as a positional argument, but we don't know what it does, other than by guessing or by reading the source code. So, let's make it a bit more useful:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("echo", help="echo the string you use here")
args = parser.parse_args()
print(args.echo)
```

And we get:

```
$ python3 prog.py -h
usage: prog.py [-h] echo

positional arguments:
  echo        echo the string you use here

optional arguments:
  -h, --help  show this help message and exit
```

Now, how about doing something even more useful:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", help="display a square of a given number")
args = parser.parse_args()
print(args.square**2)
```

Following is a result of running the code:

```
$ python3 prog.py 4
Traceback (most recent call last):
  File "prog.py", line 5, in <module>
    print(args.square**2)
TypeError: unsupported operand type(s) for ** or pow(): 'str' and 'int'
```

That didn't go so well. That's because `argparse` treats the options we give it as strings, unless we tell it otherwise. So, let's tell `argparse` to treat that input as an integer:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", help="display a square of a given number",
                    type=int)
args = parser.parse_args()
print(args.square**2)
```

Following is a result of running the code:

```
$ python3 prog.py 4
16
$ python3 prog.py four
usage: prog.py [-h] square
prog.py: error: argument square: invalid int value: 'four'
```

That went well. The program now even helpfully quits on bad illegal input before proceeding.

4 Introducing Optional arguments

So far we have been playing with positional arguments. Let us have a look on how to add optional ones:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("--verbosity", help="increase output verbosity")
args = parser.parse_args()
if args.verbosity:
    print("verbosity turned on")
```

And the output:

```
$ python3 prog.py --verbosity 1
verbosity turned on
$ python3 prog.py
$ python3 prog.py --help
usage: prog.py [-h] [--verbosity VERBOSITY]

optional arguments:
  -h, --help            show this help message and exit
  --verbosity VERBOSITY
                        increase output verbosity
$ python3 prog.py --verbosity
usage: prog.py [-h] [--verbosity VERBOSITY]
prog.py: error: argument --verbosity: expected one argument
```

Here is what is happening:

- The program is written so as to display something when `--verbosity` is specified and display nothing when not.
- To show that the option is actually optional, there is no error when running the program without it. Note that by default, if an optional argument isn't used, the relevant variable, in this case `args.verbosity`, is given `None` as a value, which is the reason it fails the truth test of the `if` statement.
- The help message is a bit different.
- When using the `--verbosity` option, one must also specify some value, any value.

The above example accepts arbitrary integer values for `--verbosity`, but for our simple program, only two values are actually useful, `True` or `False`. Let's modify the code accordingly:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("--verbose", help="increase output verbosity",
                    action="store_true")
args = parser.parse_args()
if args.verbose:
    print("verbosity turned on")
```

And the output:

```
$ python3 prog.py --verbose
verbosity turned on
$ python3 prog.py --verbose 1
usage: prog.py [-h] [--verbose]
prog.py: error: unrecognized arguments: 1
$ python3 prog.py --help
```

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```
usage: prog.py [-h] [--verbose]

optional arguments:
  -h, --help  show this help message and exit
  --verbose   increase output verbosity
```

Here is what is happening:

- The option is now more of a flag than something that requires a value. We even changed the name of the option to match that idea. Note that we now specify a new keyword, `action`, and give it the value `"store_true"`. This means that, if the option is specified, assign the value `True` to `args.verbose`. Not specifying it implies `False`.
- It complains when you specify a value, in true spirit of what flags actually are.
- Notice the different help text.

4.1 Short options

If you are familiar with command line usage, you will notice that I haven't yet touched on the topic of short versions of the options. It's quite simple:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("-v", "--verbose", help="increase output verbosity",
                    action="store_true")
args = parser.parse_args()
if args.verbose:
    print("verbosity turned on")
```

And here goes:

```
$ python3 prog.py -v
verbosity turned on
$ python3 prog.py --help
usage: prog.py [-h] [-v]

optional arguments:
  -h, --help     show this help message and exit
  -v, --verbose  increase output verbosity
```

Note that the new ability is also reflected in the help text.

5 Combining Positional and Optional arguments

Our program keeps growing in complexity:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbose", action="store_true",
                    help="increase output verbosity")
args = parser.parse_args()
```

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```
answer = args.square**2
if args.verbose:
    print("the square of {} equals {}".format(args.square, answer))
else:
    print(answer)
```

And now the output:

```
$ python3 prog.py
usage: prog.py [-h] [-v] square
prog.py: error: the following arguments are required: square
$ python3 prog.py 4
16
$ python3 prog.py 4 --verbose
the square of 4 equals 16
$ python3 prog.py --verbose 4
the square of 4 equals 16
```

- We've brought back a positional argument, hence the complaint.
- Note that the order does not matter.

How about we give this program of ours back the ability to have multiple verbosity values, and actually get to use them:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", type=int,
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbosity == 2:
    print("the square of {} equals {}".format(args.square, answer))
elif args.verbosity == 1:
    print("{}^2 == {}".format(args.square, answer))
else:
    print(answer)
```

And the output:

```
$ python3 prog.py 4
16
$ python3 prog.py 4 -v
usage: prog.py [-h] [-v VERBOSITY] square
prog.py: error: argument -v/--verbosity: expected one argument
$ python3 prog.py 4 -v 1
4^2 == 16
$ python3 prog.py 4 -v 2
the square of 4 equals 16
$ python3 prog.py 4 -v 3
16
```

These all look good except the last one, which exposes a bug in our program. Let's fix it by restricting the values the `--verbosity` option can accept:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", type=int, choices=[0, 1, 2],
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbosity == 2:
    print("the square of {} equals {}".format(args.square, answer))
elif args.verbosity == 1:
    print("{}^2 == {}".format(args.square, answer))
else:
    print(answer)
```

And the output:

```
$ python3 prog.py 4 -v 3
usage: prog.py [-h] [-v {0,1,2}] square
prog.py: error: argument -v/--verbosity: invalid choice: 3 (choose from 0, 1, 2)
$ python3 prog.py 4 -h
usage: prog.py [-h] [-v {0,1,2}] square

positional arguments:
  square                display a square of a given number

optional arguments:
  -h, --help            show this help message and exit
  -v {0,1,2}, --verbosity {0,1,2}
                        increase output verbosity
```

Note that the change also reflects both in the error message as well as the help string.

Now, let's use a different approach of playing with verbosity, which is pretty common. It also matches the way the CPython executable handles its own verbosity argument (check the output of `python --help`):

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display the square of a given number")
parser.add_argument("-v", "--verbosity", action="count",
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbosity == 2:
    print("the square of {} equals {}".format(args.square, answer))
elif args.verbosity == 1:
    print("{}^2 == {}".format(args.square, answer))
else:
    print(answer)
```

We have introduced another action, "count", to count the number of occurrences of a specific optional arguments:

```
$ python3 prog.py 4
16
$ python3 prog.py 4 -v
4^2 == 16
```

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```
$ python3 prog.py 4 -vv
the square of 4 equals 16
$ python3 prog.py 4 --verbosity --verbosity
the square of 4 equals 16
$ python3 prog.py 4 -v 1
usage: prog.py [-h] [-v] square
prog.py: error: unrecognized arguments: 1
$ python3 prog.py 4 -h
usage: prog.py [-h] [-v] square

positional arguments:
  square           display a square of a given number

optional arguments:
  -h, --help       show this help message and exit
  -v, --verbosity  increase output verbosity
$ python3 prog.py 4 -vvv
16
```

- Yes, it's now more of a flag (similar to `action="store_true"`) in the previous version of our script. That should explain the complaint.
- It also behaves similar to "store_true" action.
- Now here's a demonstration of what the "count" action gives. You've probably seen this sort of usage before.
- And if you don't specify the `-v` flag, that flag is considered to have `None` value.
- As should be expected, specifying the long form of the flag, we should get the same output.
- Sadly, our help output isn't very informative on the new ability our script has acquired, but that can always be fixed by improving the documentation for our script (e.g. via the `help` keyword argument).
- That last output exposes a bug in our program.

Let's fix:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", action="count",
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2

# bugfix: replace == with >=
if args.verbosity >= 2:
    print("the square of {} equals {}".format(args.square, answer))
elif args.verbosity >= 1:
    print("{}^2 == {}".format(args.square, answer))
else:
    print(answer)
```

And this is what it gives:

```
$ python3 prog.py 4 -vvv
the square of 4 equals 16
```

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```
$ python3 prog.py 4 -vvvv
the square of 4 equals 16
$ python3 prog.py 4
Traceback (most recent call last):
  File "prog.py", line 11, in <module>
    if args.verbosity >= 2:
TypeError: '>=' not supported between instances of 'NoneType' and 'int'
```

- First output went well, and fixes the bug we had before. That is, we want any value >= 2 to be as verbose as possible.
- Third output not so good.

Let's fix that bug:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("square", type=int,
                    help="display a square of a given number")
parser.add_argument("-v", "--verbosity", action="count", default=0,
                    help="increase output verbosity")
args = parser.parse_args()
answer = args.square**2
if args.verbosity >= 2:
    print("the square of {} equals {}".format(args.square, answer))
elif args.verbosity >= 1:
    print("{}^2 == {}".format(args.square, answer))
else:
    print(answer)
```

We've just introduced yet another keyword, `default`. We've set it to `0` in order to make it comparable to the other int values. Remember that by default, if an optional argument isn't specified, it gets the `None` value, and that cannot be compared to an int value (hence the `TypeError` exception).

And:

```
$ python3 prog.py 4
16
```

You can go quite far just with what we've learned so far, and we have only scratched the surface. The `argparse` module is very powerful, and we'll explore a bit more of it before we end this tutorial.

6 Getting a little more advanced

What if we wanted to expand our tiny program to perform other powers, not just squares:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
parser.add_argument("-v", "--verbosity", action="count", default=0)
args = parser.parse_args()
answer = args.x**args.y
if args.verbosity >= 2:
    print("{} to the power {} equals {}".format(args.x, args.y, answer))
elif args.verbosity >= 1:
```

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```
    print("{}^{} == {}".format(args.x, args.y, answer))
else:
    print(answer)
```

Output:

```
$ python3 prog.py
usage: prog.py [-h] [-v] x y
prog.py: error: the following arguments are required: x, y
$ python3 prog.py -h
usage: prog.py [-h] [-v] x y

positional arguments:
  x                the base
  y                the exponent

optional arguments:
  -h, --help       show this help message and exit
  -v, --verbosity
$ python3 prog.py 4 2 -v
4^2 == 16
```

Notice that so far we've been using verbosity level to *change* the text that gets displayed. The following example instead uses verbosity level to display *more* text instead:

```
import argparse
parser = argparse.ArgumentParser()
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
parser.add_argument("-v", "--verbosity", action="count", default=0)
args = parser.parse_args()
answer = args.x**args.y
if args.verbosity >= 2:
    print("Running '{}'".format(__file__))
if args.verbosity >= 1:
    print("{}^{} == ".format(args.x, args.y), end="")
print(answer)
```

Output:

```
$ python3 prog.py 4 2
16
$ python3 prog.py 4 2 -v
4^2 == 16
$ python3 prog.py 4 2 -vv
Running 'prog.py'
4^2 == 16
```

6.1 Conflicting options

So far, we have been working with two methods of an `argparse.ArgumentParser` instance. Let's introduce a third one, `add_mutually_exclusive_group()`. It allows for us to specify options that conflict with each other. Let's also change the rest of the program so that the new functionality makes more sense: we'll introduce the `--quiet` option, which will be the opposite of the `--verbose` one:

```
import argparse

parser = argparse.ArgumentParser()
group = parser.add_mutually_exclusive_group()
group.add_argument("-v", "--verbose", action="store_true")
group.add_argument("-q", "--quiet", action="store_true")
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
args = parser.parse_args()
answer = args.x**args.y

if args.quiet:
    print(answer)
elif args.verbose:
    print("{} to the power {} equals {}".format(args.x, args.y, answer))
else:
    print("{}^{} == {}".format(args.x, args.y, answer))
```

Our program is now simpler, and we've lost some functionality for the sake of demonstration. Anyways, here's the output:

```
$ python3 prog.py 4 2
4^2 == 16
$ python3 prog.py 4 2 -q
16
$ python3 prog.py 4 2 -v
4 to the power 2 equals 16
$ python3 prog.py 4 2 -vq
usage: prog.py [-h] [-v | -q] x y
prog.py: error: argument -q/--quiet: not allowed with argument -v/--verbose
$ python3 prog.py 4 2 -v --quiet
usage: prog.py [-h] [-v | -q] x y
prog.py: error: argument -q/--quiet: not allowed with argument -v/--verbose
```

That should be easy to follow. I've added that last output so you can see the sort of flexibility you get, i.e. mixing long form options with short form ones.

Before we conclude, you probably want to tell your users the main purpose of your program, just in case they don't know:

```
import argparse

parser = argparse.ArgumentParser(description="calculate X to the power of Y")
group = parser.add_mutually_exclusive_group()
group.add_argument("-v", "--verbose", action="store_true")
group.add_argument("-q", "--quiet", action="store_true")
parser.add_argument("x", type=int, help="the base")
parser.add_argument("y", type=int, help="the exponent")
args = parser.parse_args()
answer = args.x**args.y

if args.quiet:
    print(answer)
elif args.verbose:
    print("{} to the power {} equals {}".format(args.x, args.y, answer))
else:
    print("{}^{} == {}".format(args.x, args.y, answer))
```

Note that slight difference in the usage text. Note the `[-v | -q]`, which tells us that we can either use `-v` or `-q`, but not both at the same time:

```
$ python3 prog.py --help
usage: prog.py [-h] [-v | -q] x y

calculate X to the power of Y

positional arguments:
  x              the base
  y              the exponent

optional arguments:
  -h, --help     show this help message and exit
  -v, --verbose
  -q, --quiet
```

7 Conclusion

The `argparse` module offers a lot more than shown here. Its docs are quite detailed and thorough, and full of examples. Having gone through this tutorial, you should easily digest them without feeling overwhelmed.

Python Frequently Asked Questions

Release 3.7.0

Guido van Rossum
and the Python development team

July 07, 2018

Python Software Foundation
Email: docs@python.org

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CHAPTER

ONE

GENERAL PYTHON FAQ

1.1 General Information

1.1.1 What is Python?

Python is an interpreted, interactive, object-oriented programming language. It incorporates modules, exceptions, dynamic typing, very high level dynamic data types, and classes. Python combines remarkable power with very clear syntax. It has interfaces to many system calls and libraries, as well as to various window systems, and is extensible in C or C++. It is also usable as an extension language for applications that need a programmable interface. Finally, Python is portable: it runs on many Unix variants, on the Mac, and on Windows 2000 and later.

To find out more, start with tutorial-index. The Beginner's Guide to Python links to other introductory tutorials and resources for learning Python.

1.1.2 What is the Python Software Foundation?

The Python Software Foundation is an independent non-profit organization that holds the copyright on Python versions 2.1 and newer. The PSF's mission is to advance open source technology related to the Python programming language and to publicize the use of Python. The PSF's home page is at https://www.python.org/psf/.

Donations to the PSF are tax-exempt in the US. If you use Python and find it helpful, please contribute via the PSF donation page.

1.1.3 Are there copyright restrictions on the use of Python?

You can do anything you want with the source, as long as you leave the copyrights in and display those copyrights in any documentation about Python that you produce. If you honor the copyright rules, it's OK to use Python for commercial use, to sell copies of Python in source or binary form (modified or unmodified), or to sell products that incorporate Python in some form. We would still like to know about all commercial use of Python, of course.

See the PSF license page to find further explanations and a link to the full text of the license.

The Python logo is trademarked, and in certain cases permission is required to use it. Consult the Trademark Usage Policy for more information.

1.1.4 Why was Python created in the first place?

Here's a *very* brief summary of what started it all, written by Guido van Rossum:

I had extensive experience with implementing an interpreted language in the ABC group at CWI, and from working with this group I had learned a lot about language design. This is the origin of many Python features, including the use of indentation for statement grouping and the inclusion of very-high-level data types (although the details are all different in Python).

I had a number of gripes about the ABC language, but also liked many of its features. It was impossible to extend the ABC language (or its implementation) to remedy my complaints – in fact its lack of extensibility was one of its biggest problems. I had some experience with using Modula-2+ and talked with the designers of Modula-3 and read the Modula-3 report. Modula-3 is the origin of the syntax and semantics used for exceptions, and some other Python features.

I was working in the Amoeba distributed operating system group at CWI. We needed a better way to do system administration than by writing either C programs or Bourne shell scripts, since Amoeba had its own system call interface which wasn't easily accessible from the Bourne shell. My experience with error handling in Amoeba made me acutely aware of the importance of exceptions as a programming language feature.

It occurred to me that a scripting language with a syntax like ABC but with access to the Amoeba system calls would fill the need. I realized that it would be foolish to write an Amoeba-specific language, so I decided that I needed a language that was generally extensible.

During the 1989 Christmas holidays, I had a lot of time on my hand, so I decided to give it a try. During the next year, while still mostly working on it in my own time, Python was used in the Amoeba project with increasing success, and the feedback from colleagues made me add many early improvements.

In February 1991, after just over a year of development, I decided to post to USENET. The rest is in the `Misc/HISTORY` file.

1.1.5 What is Python good for?

Python is a high-level general-purpose programming language that can be applied to many different classes of problems.

The language comes with a large standard library that covers areas such as string processing (regular expressions, Unicode, calculating differences between files), Internet protocols (HTTP, FTP, SMTP, XML-RPC, POP, IMAP, CGI programming), software engineering (unit testing, logging, profiling, parsing Python code), and operating system interfaces (system calls, filesystems, TCP/IP sockets). Look at the table of contents for library-index to get an idea of what's available. A wide variety of third-party extensions are also available. Consult the Python Package Index to find packages of interest to you.

1.1.6 How does the Python version numbering scheme work?

Python versions are numbered A.B.C or A.B. A is the major version number – it is only incremented for really major changes in the language. B is the minor version number, incremented for less earth-shattering changes. C is the micro-level – it is incremented for each bugfix release. See **PEP 6** for more information about bugfix releases.

Not all releases are bugfix releases. In the run-up to a new major release, a series of development releases are made, denoted as alpha, beta, or release candidate. Alphas are early releases in which interfaces aren't yet finalized; it's not unexpected to see an interface change between two alpha releases. Betas are more stable, preserving existing interfaces but possibly adding new modules, and release candidates are frozen, making no changes except as needed to fix critical bugs.

Alpha, beta and release candidate versions have an additional suffix. The suffix for an alpha version is "aN" for some small number N, the suffix for a beta version is "bN" for some small number N, and the suffix

for a release candidate version is "cN" for some small number N. In other words, all versions labeled 2.0aN precede the versions labeled 2.0bN, which precede versions labeled 2.0cN, and *those* precede 2.0.

You may also find version numbers with a "+" suffix, e.g. "2.2+". These are unreleased versions, built directly from the CPython development repository. In practice, after a final minor release is made, the version is incremented to the next minor version, which becomes the "a0" version, e.g. "2.4a0".

See also the documentation for `sys.version`, `sys.hexversion`, and `sys.version_info`.

1.1.7 How do I obtain a copy of the Python source?

The latest Python source distribution is always available from python.org, at https://www.python.org/downloads/. The latest development sources can be obtained at https://github.com/python/cpython/.

The source distribution is a gzipped tar file containing the complete C source, Sphinx-formatted documentation, Python library modules, example programs, and several useful pieces of freely distributable software. The source will compile and run out of the box on most UNIX platforms.

Consult the Getting Started section of the Python Developer's Guide for more information on getting the source code and compiling it.

1.1.8 How do I get documentation on Python?

The standard documentation for the current stable version of Python is available at https://docs.python.org/3/. PDF, plain text, and downloadable HTML versions are also available at https://docs.python.org/3/download.html.

The documentation is written in reStructuredText and processed by the Sphinx documentation tool. The reStructuredText source for the documentation is part of the Python source distribution.

1.1.9 I've never programmed before. Is there a Python tutorial?

There are numerous tutorials and books available. The standard documentation includes tutorial-index.

Consult the Beginner's Guide to find information for beginning Python programmers, including lists of tutorials.

1.1.10 Is there a newsgroup or mailing list devoted to Python?

There is a newsgroup, *comp.lang.python*, and a mailing list, python-list. The newsgroup and mailing list are gatewayed into each other – if you can read news it's unnecessary to subscribe to the mailing list. *comp.lang.python* is high-traffic, receiving hundreds of postings every day, and Usenet readers are often more able to cope with this volume.

Announcements of new software releases and events can be found in comp.lang.python.announce, a low-traffic moderated list that receives about five postings per day. It's available as the python-announce mailing list.

More info about other mailing lists and newsgroups can be found at https://www.python.org/community/lists/.

1.1.11 How do I get a beta test version of Python?

Alpha and beta releases are available from https://www.python.org/downloads/. All releases are announced on the comp.lang.python and comp.lang.python.announce newsgroups and on the Python home page at https://www.python.org/; an RSS feed of news is available.

You can also access the development version of Python through Git. See The Python Developer's Guide for details.

1.1.12 How do I submit bug reports and patches for Python?

To report a bug or submit a patch, please use the Roundup installation at https://bugs.python.org/.

You must have a Roundup account to report bugs; this makes it possible for us to contact you if we have follow-up questions. It will also enable Roundup to send you updates as we act on your bug. If you had previously used SourceForge to report bugs to Python, you can obtain your Roundup password through Roundup's password reset procedure.

For more information on how Python is developed, consult the Python Developer's Guide.

1.1.13 Are there any published articles about Python that I can reference?

It's probably best to cite your favorite book about Python.

The very first article about Python was written in 1991 and is now quite outdated.

> Guido van Rossum and Jelke de Boer, "Interactively Testing Remote Servers Using the Python Programming Language", CWI Quarterly, Volume 4, Issue 4 (December 1991), Amsterdam, pp 283–303.

1.1.14 Are there any books on Python?

Yes, there are many, and more are being published. See the python.org wiki at https://wiki.python.org/moin/PythonBooks for a list.

You can also search online bookstores for "Python" and filter out the Monty Python references; or perhaps search for "Python" and "language".

1.1.15 Where in the world is www.python.org located?

The Python project's infrastructure is located all over the world. www.python.org is graciously hosted by Rackspace, with CDN caching provided by Fastly. Upfront Systems hosts bugs.python.org. Many other Python services like the Wiki are hosted by Oregon State University Open Source Lab.

1.1.16 Why is it called Python?

When he began implementing Python, Guido van Rossum was also reading the published scripts from "Monty Python's Flying Circus", a BBC comedy series from the 1970s. Van Rossum thought he needed a name that was short, unique, and slightly mysterious, so he decided to call the language Python.

1.1.17 Do I have to like "Monty Python's Flying Circus"?

No, but it helps. :)

1.2 Python in the real world

1.2.1 How stable is Python?

Very stable. New, stable releases have been coming out roughly every 6 to 18 months since 1991, and this seems likely to continue. Currently there are usually around 18 months between major releases.

The developers issue "bugfix" releases of older versions, so the stability of existing releases gradually improves. Bugfix releases, indicated by a third component of the version number (e.g. 2.5.3, 2.6.2), are managed for stability; only fixes for known problems are included in a bugfix release, and it's guaranteed that interfaces will remain the same throughout a series of bugfix releases.

The latest stable releases can always be found on the Python download page. There are two recommended production-ready versions at this point in time, because at the moment there are two branches of stable releases: 2.x and 3.x. Python 3.x may be less useful than 2.x, since currently there is more third party software available for Python 2 than for Python 3. Python 2 code will generally not run unchanged in Python 3.

1.2.2 How many people are using Python?

There are probably tens of thousands of users, though it's difficult to obtain an exact count.

Python is available for free download, so there are no sales figures, and it's available from many different sites and packaged with many Linux distributions, so download statistics don't tell the whole story either.

The comp.lang.python newsgroup is very active, but not all Python users post to the group or even read it.

1.2.3 Have any significant projects been done in Python?

See https://www.python.org/about/success for a list of projects that use Python. Consulting the proceedings for past Python conferences will reveal contributions from many different companies and organizations.

High-profile Python projects include the Mailman mailing list manager and the Zope application server. Several Linux distributions, most notably Red Hat, have written part or all of their installer and system administration software in Python. Companies that use Python internally include Google, Yahoo, and Lucasfilm Ltd.

1.2.4 What new developments are expected for Python in the future?

See https://www.python.org/dev/peps/ for the Python Enhancement Proposals (PEPs). PEPs are design documents describing a suggested new feature for Python, providing a concise technical specification and a rationale. Look for a PEP titled "Python X.Y Release Schedule", where X.Y is a version that hasn't been publicly released yet.

New development is discussed on the python-dev mailing list.

1.2.5 Is it reasonable to propose incompatible changes to Python?

In general, no. There are already millions of lines of Python code around the world, so any change in the language that invalidates more than a very small fraction of existing programs has to be frowned upon. Even if you can provide a conversion program, there's still the problem of updating all documentation; many books have been written about Python, and we don't want to invalidate them all at a single stroke.

Providing a gradual upgrade path is necessary if a feature has to be changed. **PEP 5** describes the procedure followed for introducing backward-incompatible changes while minimizing disruption for users.

1.2.6 Is Python a good language for beginning programmers?

Yes.

It is still common to start students with a procedural and statically typed language such as Pascal, C, or a subset of C++ or Java. Students may be better served by learning Python as their first language. Python has a very simple and consistent syntax and a large standard library and, most importantly, using Python in a beginning programming course lets students concentrate on important programming skills such as problem decomposition and data type design. With Python, students can be quickly introduced to basic concepts such as loops and procedures. They can probably even work with user-defined objects in their very first course.

For a student who has never programmed before, using a statically typed language seems unnatural. It presents additional complexity that the student must master and slows the pace of the course. The students are trying to learn to think like a computer, decompose problems, design consistent interfaces, and encapsulate data. While learning to use a statically typed language is important in the long term, it is not necessarily the best topic to address in the students' first programming course.

Many other aspects of Python make it a good first language. Like Java, Python has a large standard library so that students can be assigned programming projects very early in the course that *do* something. Assignments aren't restricted to the standard four-function calculator and check balancing programs. By using the standard library, students can gain the satisfaction of working on realistic applications as they learn the fundamentals of programming. Using the standard library also teaches students about code reuse. Third-party modules such as PyGame are also helpful in extending the students' reach.

Python's interactive interpreter enables students to test language features while they're programming. They can keep a window with the interpreter running while they enter their program's source in another window. If they can't remember the methods for a list, they can do something like this:

```
>>> L = []
>>> dir(L)
['__add__', '__class__', '__contains__', '__delattr__', '__delitem__',
'__dir__', '__doc__', '__eq__', '__format__', '__ge__',
'__getattribute__', '__getitem__', '__gt__', '__hash__', '__iadd__',
'__imul__', '__init__', '__iter__', '__le__', '__len__', '__lt__',
'__mul__', '__ne__', '__new__', '__reduce__', '__reduce_ex__',
'__repr__', '__reversed__', '__rmul__', '__setattr__', '__setitem__',
'__sizeof__', '__str__', '__subclasshook__', 'append', 'clear',
'copy', 'count', 'extend', 'index', 'insert', 'pop', 'remove',
'reverse', 'sort']
>>> [d for d in dir(L) if '__' not in d]
['append', 'clear', 'copy', 'count', 'extend', 'index', 'insert', 'pop', 'remove', 'reverse', 'sort
↪']

>>> help(L.append)
Help on built-in function append:

append(...)
    L.append(object) -> None -- append object to end

>>> L.append(1)
>>> L
[1]
```

With the interpreter, documentation is never far from the student as they are programming.

There are also good IDEs for Python. IDLE is a cross-platform IDE for Python that is written in Python using Tkinter. PythonWin is a Windows-specific IDE. Emacs users will be happy to know that there is a very good Python mode for Emacs. All of these programming environments provide syntax highlighting,

auto-indenting, and access to the interactive interpreter while coding. Consult the Python wiki for a full list of Python editing environments.

If you want to discuss Python's use in education, you may be interested in joining the edu-sig mailing list.

CHAPTER

TWO

PROGRAMMING FAQ

2.1 General Questions

2.1.1 Is there a source code level debugger with breakpoints, single-stepping, etc.?

Yes.

The pdb module is a simple but adequate console-mode debugger for Python. It is part of the standard Python library, and is `documented in the Library Reference Manual`. You can also write your own debugger by using the code for pdb as an example.

The IDLE interactive development environment, which is part of the standard Python distribution (normally available as Tools/scripts/idle), includes a graphical debugger.

PythonWin is a Python IDE that includes a GUI debugger based on pdb. The Pythonwin debugger colors breakpoints and has quite a few cool features such as debugging non-Pythonwin programs. Pythonwin is available as part of the Python for Windows Extensions project and as a part of the ActivePython distribution (see https://www.activestate.com/activepython).

Boa Constructor is an IDE and GUI builder that uses wxWidgets. It offers visual frame creation and manipulation, an object inspector, many views on the source like object browsers, inheritance hierarchies, doc string generated html documentation, an advanced debugger, integrated help, and Zope support.

Eric is an IDE built on PyQt and the Scintilla editing component.

Pydb is a version of the standard Python debugger pdb, modified for use with DDD (Data Display Debugger), a popular graphical debugger front end. Pydb can be found at http://bashdb.sourceforge.net/pydb/ and DDD can be found at https://www.gnu.org/software/ddd.

There are a number of commercial Python IDEs that include graphical debuggers. They include:

- Wing IDE (https://wingware.com/)
- Komodo IDE (https://komodoide.com/)
- PyCharm (https://www.jetbrains.com/pycharm/)

2.1.2 Is there a tool to help find bugs or perform static analysis?

Yes.

PyChecker is a static analysis tool that finds bugs in Python source code and warns about code complexity and style. You can get PyChecker from http://pychecker.sourceforge.net/.

Pylint is another tool that checks if a module satisfies a coding standard, and also makes it possible to write plug-ins to add a custom feature. In addition to the bug checking that PyChecker performs, Pylint offers some additional features such as checking line length, whether variable names are well-formed according to

your coding standard, whether declared interfaces are fully implemented, and more. https://docs.pylint.org/ provides a full list of Pylint's features.

2.1.3 How can I create a stand-alone binary from a Python script?

You don't need the ability to compile Python to C code if all you want is a stand-alone program that users can download and run without having to install the Python distribution first. There are a number of tools that determine the set of modules required by a program and bind these modules together with a Python binary to produce a single executable.

One is to use the freeze tool, which is included in the Python source tree as `Tools/freeze`. It converts Python byte code to C arrays; a C compiler you can embed all your modules into a new program, which is then linked with the standard Python modules.

It works by scanning your source recursively for import statements (in both forms) and looking for the modules in the standard Python path as well as in the source directory (for built-in modules). It then turns the bytecode for modules written in Python into C code (array initializers that can be turned into code objects using the marshal module) and creates a custom-made config file that only contains those built-in modules which are actually used in the program. It then compiles the generated C code and links it with the rest of the Python interpreter to form a self-contained binary which acts exactly like your script.

Obviously, freeze requires a C compiler. There are several other utilities which don't. One is Thomas Heller's py2exe (Windows only) at

http://www.py2exe.org/

Another tool is Anthony Tuininga's cx_Freeze.

2.1.4 Are there coding standards or a style guide for Python programs?

Yes. The coding style required for standard library modules is documented as **PEP 8**.

2.2 Core Language

2.2.1 Why am I getting an UnboundLocalError when the variable has a value?

It can be a surprise to get the UnboundLocalError in previously working code when it is modified by adding an assignment statement somewhere in the body of a function.

This code:

```
>>> x = 10
>>> def bar():
...     print(x)
>>> bar()
10
```

works, but this code:

```
>>> x = 10
>>> def foo():
...     print(x)
...     x += 1
```

results in an UnboundLocalError:

```
>>> foo()
Traceback (most recent call last):
  ...
UnboundLocalError: local variable 'x' referenced before assignment
```

This is because when you make an assignment to a variable in a scope, that variable becomes local to that scope and shadows any similarly named variable in the outer scope. Since the last statement in foo assigns a new value to `x`, the compiler recognizes it as a local variable. Consequently when the earlier `print(x)` attempts to print the uninitialized local variable and an error results.

In the example above you can access the outer scope variable by declaring it global:

```
>>> x = 10
>>> def foobar():
...     global x
...     print(x)
...     x += 1
>>> foobar()
10
```

This explicit declaration is required in order to remind you that (unlike the superficially analogous situation with class and instance variables) you are actually modifying the value of the variable in the outer scope:

```
>>> print(x)
11
```

You can do a similar thing in a nested scope using the `nonlocal` keyword:

```
>>> def foo():
...     x = 10
...     def bar():
...         nonlocal x
...         print(x)
...         x += 1
...     bar()
...     print(x)
>>> foo()
10
11
```

2.2.2 What are the rules for local and global variables in Python?

In Python, variables that are only referenced inside a function are implicitly global. If a variable is assigned a value anywhere within the function's body, it's assumed to be a local unless explicitly declared as global.

Though a bit surprising at first, a moment's consideration explains this. On one hand, requiring `global` for assigned variables provides a bar against unintended side-effects. On the other hand, if `global` was required for all global references, you'd be using `global` all the time. You'd have to declare as global every reference to a built-in function or to a component of an imported module. This clutter would defeat the usefulness of the `global` declaration for identifying side-effects.

2.2.3 Why do lambdas defined in a loop with different values all return the same result?

Assume you use a for loop to define a few different lambdas (or even plain functions), e.g.:

```
>>> squares = []
>>> for x in range(5):
...     squares.append(lambda: x**2)
```

This gives you a list that contains 5 lambdas that calculate `x**2`. You might expect that, when called, they would return, respectively, `0`, `1`, `4`, `9`, and `16`. However, when you actually try you will see that they all return `16`:

```
>>> squares[2]()
16
>>> squares[4]()
16
```

This happens because `x` is not local to the lambdas, but is defined in the outer scope, and it is accessed when the lambda is called — not when it is defined. At the end of the loop, the value of `x` is `4`, so all the functions now return `4**2`, i.e. `16`. You can also verify this by changing the value of `x` and see how the results of the lambdas change:

```
>>> x = 8
>>> squares[2]()
64
```

In order to avoid this, you need to save the values in variables local to the lambdas, so that they don't rely on the value of the global `x`:

```
>>> squares = []
>>> for x in range(5):
...     squares.append(lambda n=x: n**2)
```

Here, `n=x` creates a new variable `n` local to the lambda and computed when the lambda is defined so that it has the same value that `x` had at that point in the loop. This means that the value of `n` will be `0` in the first lambda, `1` in the second, `2` in the third, and so on. Therefore each lambda will now return the correct result:

```
>>> squares[2]()
4
>>> squares[4]()
16
```

Note that this behaviour is not peculiar to lambdas, but applies to regular functions too.

2.2.4 How do I share global variables across modules?

The canonical way to share information across modules within a single program is to create a special module (often called config or cfg). Just import the config module in all modules of your application; the module then becomes available as a global name. Because there is only one instance of each module, any changes made to the module object get reflected everywhere. For example:

config.py:

```
x = 0   # Default value of the 'x' configuration setting
```

mod.py:

```
import config
config.x = 1
```

main.py:

```
import config
import mod
print(config.x)
```

Note that using a module is also the basis for implementing the Singleton design pattern, for the same reason.

2.2.5 What are the "best practices" for using import in a module?

In general, don't use `from modulename import *`. Doing so clutters the importer's namespace, and makes it much harder for linters to detect undefined names.

Import modules at the top of a file. Doing so makes it clear what other modules your code requires and avoids questions of whether the module name is in scope. Using one import per line makes it easy to add and delete module imports, but using multiple imports per line uses less screen space.

It's good practice if you import modules in the following order:

1. standard library modules – e.g. `sys`, `os`, `getopt`, `re`
2. third-party library modules (anything installed in Python's site-packages directory) – e.g. mx.DateTime, ZODB, PIL.Image, etc.
3. locally-developed modules

It is sometimes necessary to move imports to a function or class to avoid problems with circular imports. Gordon McMillan says:

> Circular imports are fine where both modules use the "import <module>" form of import. They fail when the 2nd module wants to grab a name out of the first ("from module import name") and the import is at the top level. That's because names in the 1st are not yet available, because the first module is busy importing the 2nd.

In this case, if the second module is only used in one function, then the import can easily be moved into that function. By the time the import is called, the first module will have finished initializing, and the second module can do its import.

It may also be necessary to move imports out of the top level of code if some of the modules are platform-specific. In that case, it may not even be possible to import all of the modules at the top of the file. In this case, importing the correct modules in the corresponding platform-specific code is a good option.

Only move imports into a local scope, such as inside a function definition, if it's necessary to solve a problem such as avoiding a circular import or are trying to reduce the initialization time of a module. This technique is especially helpful if many of the imports are unnecessary depending on how the program executes. You may also want to move imports into a function if the modules are only ever used in that function. Note that loading a module the first time may be expensive because of the one time initialization of the module, but loading a module multiple times is virtually free, costing only a couple of dictionary lookups. Even if the module name has gone out of scope, the module is probably available in `sys.modules`.

2.2.6 Why are default values shared between objects?

This type of bug commonly bites neophyte programmers. Consider this function:

```
def foo(mydict={}):  # Danger: shared reference to one dict for all calls
    ... compute something ...
    mydict[key] = value
    return mydict
```

The first time you call this function, `mydict` contains a single item. The second time, `mydict` contains two items because when `foo()` begins executing, `mydict` starts out with an item already in it.

It is often expected that a function call creates new objects for default values. This is not what happens. Default values are created exactly once, when the function is defined. If that object is changed, like the dictionary in this example, subsequent calls to the function will refer to this changed object.

By definition, immutable objects such as numbers, strings, tuples, and `None`, are safe from change. Changes to mutable objects such as dictionaries, lists, and class instances can lead to confusion.

Because of this feature, it is good programming practice to not use mutable objects as default values. Instead, use `None` as the default value and inside the function, check if the parameter is `None` and create a new list/dictionary/whatever if it is. For example, don't write:

```
def foo(mydict={}):
    ...
```

but:

```
def foo(mydict=None):
    if mydict is None:
        mydict = {}  # create a new dict for local namespace
```

This feature can be useful. When you have a function that's time-consuming to compute, a common technique is to cache the parameters and the resulting value of each call to the function, and return the cached value if the same value is requested again. This is called "memoizing", and can be implemented like this:

```
# Callers can only provide two parameters and optionally pass _cache by keyword
def expensive(arg1, arg2, *, _cache={}):
    if (arg1, arg2) in _cache:
        return _cache[(arg1, arg2)]

    # Calculate the value
    result = ... expensive computation ...
    _cache[(arg1, arg2)] = result           # Store result in the cache
    return result
```

You could use a global variable containing a dictionary instead of the default value; it's a matter of taste.

2.2.7 How can I pass optional or keyword parameters from one function to another?

Collect the arguments using the `*` and `**` specifiers in the function's parameter list; this gives you the positional arguments as a tuple and the keyword arguments as a dictionary. You can then pass these arguments when calling another function by using `*` and `**`:

```
def f(x, *args, **kwargs):
    ...
    kwargs['width'] = '14.3c'
    ...
    g(x, *args, **kwargs)
```

2.2.8 What is the difference between arguments and parameters?

Parameters are defined by the names that appear in a function definition, whereas *arguments* are the values actually passed to a function when calling it. Parameters define what types of arguments a function can accept. For example, given the function definition:

```
def func(foo, bar=None, **kwargs):
    pass
```

foo, *bar* and *kwargs* are parameters of `func`. However, when calling `func`, for example:

```
func(42, bar=314, extra=somevar)
```

the values `42`, `314`, and `somevar` are arguments.

2.2.9 Why did changing list 'y' also change list 'x'?

If you wrote code like:

```
>>> x = []
>>> y = x
>>> y.append(10)
>>> y
[10]
>>> x
[10]
```

you might be wondering why appending an element to `y` changed `x` too.

There are two factors that produce this result:

1. Variables are simply names that refer to objects. Doing `y = x` doesn't create a copy of the list – it creates a new variable `y` that refers to the same object `x` refers to. This means that there is only one object (the list), and both `x` and `y` refer to it.
2. Lists are *mutable*, which means that you can change their content.

After the call to `append()`, the content of the mutable object has changed from `[]` to `[10]`. Since both the variables refer to the same object, using either name accesses the modified value `[10]`.

If we instead assign an immutable object to `x`:

```
>>> x = 5  # ints are immutable
>>> y = x
>>> x = x + 1  # 5 can't be mutated, we are creating a new object here
>>> x
6
>>> y
5
```

we can see that in this case `x` and `y` are not equal anymore. This is because integers are *immutable*, and when we do `x = x + 1` we are not mutating the int `5` by incrementing its value; instead, we are creating a new object (the int `6`) and assigning it to `x` (that is, changing which object `x` refers to). After this assignment we have two objects (the ints `6` and `5`) and two variables that refer to them (`x` now refers to `6` but `y` still refers to `5`).

Some operations (for example `y.append(10)` and `y.sort()`) mutate the object, whereas superficially similar operations (for example `y = y + [10]` and `sorted(y)`) create a new object. In general in Python (and in all cases in the standard library) a method that mutates an object will return `None` to help avoid getting the two types of operations confused. So if you mistakenly write `y.sort()` thinking it will give you a sorted copy of `y`, you'll instead end up with `None`, which will likely cause your program to generate an easily diagnosed error.

However, there is one class of operations where the same operation sometimes has different behaviors with different types: the augmented assignment operators. For example, `+=` mutates lists but not tuples or

ints (`a_list += [1, 2, 3]` is equivalent to `a_list.extend([1, 2, 3])` and mutates `a_list`, whereas `some_tuple += (1, 2, 3)` and `some_int += 1` create new objects).

In other words:

- If we have a mutable object (`list`, `dict`, `set`, etc.), we can use some specific operations to mutate it and all the variables that refer to it will see the change.
- If we have an immutable object (`str`, `int`, `tuple`, etc.), all the variables that refer to it will always see the same value, but operations that transform that value into a new value always return a new object.

If you want to know if two variables refer to the same object or not, you can use the `is` operator, or the built-in function `id()`.

2.2.10 How do I write a function with output parameters (call by reference)?

Remember that arguments are passed by assignment in Python. Since assignment just creates references to objects, there's no alias between an argument name in the caller and callee, and so no call-by-reference per se. You can achieve the desired effect in a number of ways.

1. By returning a tuple of the results:

```
def func2(a, b):
    a = 'new-value'        # a and b are local names
    b = b + 1              # assigned to new objects
    return a, b            # return new values

x, y = 'old-value', 99
x, y = func2(x, y)
print(x, y)                # output: new-value 100
```

   This is almost always the clearest solution.

2. By using global variables. This isn't thread-safe, and is not recommended.

3. By passing a mutable (changeable in-place) object:

```
def func1(a):
    a[0] = 'new-value'     # 'a' references a mutable list
    a[1] = a[1] + 1        # changes a shared object

args = ['old-value', 99]
func1(args)
print(args[0], args[1])    # output: new-value 100
```

4. By passing in a dictionary that gets mutated:

```
def func3(args):
    args['a'] = 'new-value'     # args is a mutable dictionary
    args['b'] = args['b'] + 1   # change it in-place

args = {'a': 'old-value', 'b': 99}
func3(args)
print(args['a'], args['b'])
```

5. Or bundle up values in a class instance:

```
class callByRef:
    def __init__(self, **args):
        for (key, value) in args.items():
```

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```
            setattr(self, key, value)

def func4(args):
    args.a = 'new-value'        # args is a mutable callByRef
    args.b = args.b + 1         # change object in-place

args = callByRef(a='old-value', b=99)
func4(args)
print(args.a, args.b)
```

There's almost never a good reason to get this complicated.

Your best choice is to return a tuple containing the multiple results.

2.2.11 How do you make a higher order function in Python?

You have two choices: you can use nested scopes or you can use callable objects. For example, suppose you wanted to define `linear(a,b)` which returns a function `f(x)` that computes the value `a*x+b`. Using nested scopes:

```
def linear(a, b):
    def result(x):
        return a * x + b
    return result
```

Or using a callable object:

```
class linear:

    def __init__(self, a, b):
        self.a, self.b = a, b

    def __call__(self, x):
        return self.a * x + self.b
```

In both cases,

```
taxes = linear(0.3, 2)
```

gives a callable object where `taxes(10e6) == 0.3 * 10e6 + 2`.

The callable object approach has the disadvantage that it is a bit slower and results in slightly longer code. However, note that a collection of callables can share their signature via inheritance:

```
class exponential(linear):
    # __init__ inherited
    def __call__(self, x):
        return self.a * (x ** self.b)
```

Object can encapsulate state for several methods:

```
class counter:

    value = 0

    def set(self, x):
```

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```
        self.value = x

    def up(self):
        self.value = self.value + 1

    def down(self):
        self.value = self.value - 1

count = counter()
inc, dec, reset = count.up, count.down, count.set
```

Here `inc()`, `dec()` and `reset()` act like functions which share the same counting variable.

2.2.12 How do I copy an object in Python?

In general, try `copy.copy()` or `copy.deepcopy()` for the general case. Not all objects can be copied, but most can.

Some objects can be copied more easily. Dictionaries have a `copy()` method:

```
newdict = olddict.copy()
```

Sequences can be copied by slicing:

```
new_l = l[:]
```

2.2.13 How can I find the methods or attributes of an object?

For an instance x of a user-defined class, `dir(x)` returns an alphabetized list of the names containing the instance attributes and methods and attributes defined by its class.

2.2.14 How can my code discover the name of an object?

Generally speaking, it can't, because objects don't really have names. Essentially, assignment always binds a name to a value; The same is true of `def` and `class` statements, but in that case the value is a callable. Consider the following code:

```
>>> class A:
...     pass
...
>>> B = A
>>> a = B()
>>> b = a
>>> print(b)
<__main__.A object at 0x16D07CC>
>>> print(a)
<__main__.A object at 0x16D07CC>
```

Arguably the class has a name: even though it is bound to two names and invoked through the name B the created instance is still reported as an instance of class A. However, it is impossible to say whether the instance's name is a or b, since both names are bound to the same value.

Generally speaking it should not be necessary for your code to "know the names" of particular values. Unless you are deliberately writing introspective programs, this is usually an indication that a change of approach might be beneficial.

In comp.lang.python, Fredrik Lundh once gave an excellent analogy in answer to this question:

> The same way as you get the name of that cat you found on your porch: the cat (object) itself cannot tell you its name, and it doesn't really care – so the only way to find out what it's called is to ask all your neighbours (namespaces) if it's their cat (object)…
>
> ….and don't be surprised if you'll find that it's known by many names, or no name at all!

2.2.15 What's up with the comma operator's precedence?

Comma is not an operator in Python. Consider this session:

```
>>> "a" in "b", "a"
(False, 'a')
```

Since the comma is not an operator, but a separator between expressions the above is evaluated as if you had entered:

```
("a" in "b"), "a"
```

not:

```
"a" in ("b", "a")
```

The same is true of the various assignment operators (=, += etc). They are not truly operators but syntactic delimiters in assignment statements.

2.2.16 Is there an equivalent of C's "?:" ternary operator?

Yes, there is. The syntax is as follows:

```
[on_true] if [expression] else [on_false]

x, y = 50, 25
small = x if x < y else y
```

Before this syntax was introduced in Python 2.5, a common idiom was to use logical operators:

```
[expression] and [on_true] or [on_false]
```

However, this idiom is unsafe, as it can give wrong results when *on_true* has a false boolean value. Therefore, it is always better to use the `... if ... else ...` form.

2.2.17 Is it possible to write obfuscated one-liners in Python?

Yes. Usually this is done by nesting `lambda` within `lambda`. See the following three examples, due to Ulf Bartelt:

```
from functools import reduce

# Primes < 1000
```

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```
print(list(filter(None,map(lambda y:y*reduce(lambda x,y:x*y!=0,
map(lambda x,y=y:y%x,range(2,int(pow(y,0.5)+1))),1),range(2,1000)))))

# First 10 Fibonacci numbers
print(list(map(lambda x,f=lambda x,f:(f(x-1,f)+f(x-2,f)) if x>1 else 1:
f(x,f), range(10))))

# Mandelbrot set
print((lambda Ru,Ro,Iu,Io,IM,Sx,Sy:reduce(lambda x,y:x+y,map(lambda y,
Iu=Iu,Io=Io,Ru=Ru,Ro=Ro,Sy=Sy,L=lambda yc,Iu=Iu,Io=Io,Ru=Ru,Ro=Ro,i=IM,
Sx=Sx,Sy=Sy:reduce(lambda x,y:x+y,map(lambda x,xc=Ru,yc=yc,Ru=Ru,Ro=Ro,
i=i,Sx=Sx,F=lambda xc,yc,x,y,k,f=lambda xc,yc,x,y,k,f:(k<=0)or (x*x+y*y
>=4.0) or 1+f(xc,yc,x*x-y*y+xc,2.0*x*y+yc,k-1,f):f(xc,yc,x,y,k,f):chr(
64+F(Ru+x*(Ro-Ru)/Sx,yc,0,0,i)),range(Sx))):L(Iu+y*(Io-Iu)/Sy),range(Sy
))))(-2.1, 0.7, -1.2, 1.2, 30, 80, 24))
#     \___ ___/  \___ ___/  |   |   |__ lines on screen
#         V          V      |   |______ columns on screen
#         |          |      |_________ maximum of "iterations"
#         |          |________________ range on y axis
#         |___________________________ range on x axis
```

Don't try this at home, kids!

2.3 Numbers and strings

2.3.1 How do I specify hexadecimal and octal integers?

To specify an octal digit, precede the octal value with a zero, and then a lower or uppercase "o". For example, to set the variable "a" to the octal value "10" (8 in decimal), type:

```
>>> a = 0o10
>>> a
8
```

Hexadecimal is just as easy. Simply precede the hexadecimal number with a zero, and then a lower or uppercase "x". Hexadecimal digits can be specified in lower or uppercase. For example, in the Python interpreter:

```
>>> a = 0xa5
>>> a
165
>>> b = 0XB2
>>> b
178
```

2.3.2 Why does -22 // 10 return -3?

It's primarily driven by the desire that `i % j` have the same sign as `j`. If you want that, and also want:

```
i == (i // j) * j + (i % j)
```

then integer division has to return the floor. C also requires that identity to hold, and then compilers that truncate `i // j` need to make `i % j` have the same sign as `i`.

There are few real use cases for `i % j` when `j` is negative. When `j` is positive, there are many, and in virtually all of them it's more useful for `i % j` to be `>= 0`. If the clock says 10 now, what did it say 200 hours ago? `-190 % 12 == 2` is useful; `-190 % 12 == -10` is a bug waiting to bite.

2.3.3 How do I convert a string to a number?

For integers, use the built-in `int()` type constructor, e.g. `int('144') == 144`. Similarly, `float()` converts to floating-point, e.g. `float('144') == 144.0`.

By default, these interpret the number as decimal, so that `int('0144') == 144` and `int('0x144')` raises `ValueError`. `int(string, base)` takes the base to convert from as a second optional argument, so `int('0x144', 16) == 324`. If the base is specified as 0, the number is interpreted using Python's rules: a leading '0o' indicates octal, and '0x' indicates a hex number.

Do not use the built-in function `eval()` if all you need is to convert strings to numbers. `eval()` will be significantly slower and it presents a security risk: someone could pass you a Python expression that might have unwanted side effects. For example, someone could pass `__import__('os').system("rm -rf $HOME")` which would erase your home directory.

`eval()` also has the effect of interpreting numbers as Python expressions, so that e.g. `eval('09')` gives a syntax error because Python does not allow leading '0' in a decimal number (except '0').

2.3.4 How do I convert a number to a string?

To convert, e.g., the number 144 to the string '144', use the built-in type constructor `str()`. If you want a hexadecimal or octal representation, use the built-in functions `hex()` or `oct()`. For fancy formatting, see the f-strings and formatstrings sections, e.g. `"{:04d}".format(144)` yields `'0144'` and `"{:.3f}".format(1.0/3.0)` yields `'0.333'`.

2.3.5 How do I modify a string in place?

You can't, because strings are immutable. In most situations, you should simply construct a new string from the various parts you want to assemble it from. However, if you need an object with the ability to modify in-place unicode data, try using an `io.StringIO` object or the `array` module:

```
>>> import io
>>> s = "Hello, world"
>>> sio = io.StringIO(s)
>>> sio.getvalue()
'Hello, world'
>>> sio.seek(7)
7
>>> sio.write("there!")
6
>>> sio.getvalue()
'Hello, there!'

>>> import array
>>> a = array.array('u', s)
>>> print(a)
array('u', 'Hello, world')
>>> a[0] = 'y'
>>> print(a)
array('u', 'yello, world')
```

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```
>>> a.tounicode()
'yello, world'
```

2.3.6 How do I use strings to call functions/methods?

There are various techniques.

- The best is to use a dictionary that maps strings to functions. The primary advantage of this technique is that the strings do not need to match the names of the functions. This is also the primary technique used to emulate a case construct:

```
def a():
    pass

def b():
    pass

dispatch = {'go': a, 'stop': b}  # Note lack of parens for funcs

dispatch[get_input()]()  # Note trailing parens to call function
```

- Use the built-in function `getattr()`:

```
import foo
getattr(foo, 'bar')()
```

  Note that `getattr()` works on any object, including classes, class instances, modules, and so on.

  This is used in several places in the standard library, like this:

```
class Foo:
    def do_foo(self):
        ...

    def do_bar(self):
        ...

f = getattr(foo_instance, 'do_' + opname)
f()
```

- Use `locals()` or `eval()` to resolve the function name:

```
def myFunc():
    print("hello")

fname = "myFunc"

f = locals()[fname]
f()

f = eval(fname)
f()
```

  Note: Using `eval()` is slow and dangerous. If you don't have absolute control over the contents of the string, someone could pass a string that resulted in an arbitrary function being executed.

2.3.7 Is there an equivalent to Perl's chomp() for removing trailing newlines from strings?

You can use `S.rstrip("\r\n")` to remove all occurrences of any line terminator from the end of the string `S` without removing other trailing whitespace. If the string `S` represents more than one line, with several empty lines at the end, the line terminators for all the blank lines will be removed:

```
>>> lines = ("line 1 \r\n"
...          "\r\n"
...          "\r\n")
>>> lines.rstrip("\n\r")
'line 1 '
```

Since this is typically only desired when reading text one line at a time, using `S.rstrip()` this way works well.

2.3.8 Is there a scanf() or sscanf() equivalent?

Not as such.

For simple input parsing, the easiest approach is usually to split the line into whitespace-delimited words using the `split()` method of string objects and then convert decimal strings to numeric values using `int()` or `float()`. `split()` supports an optional "sep" parameter which is useful if the line uses something other than whitespace as a separator.

For more complicated input parsing, regular expressions are more powerful than C's `sscanf()` and better suited for the task.

2.3.9 What does 'UnicodeDecodeError' or 'UnicodeEncodeError' error mean?

See the unicode-howto.

2.4 Performance

2.4.1 My program is too slow. How do I speed it up?

That's a tough one, in general. First, here are a list of things to remember before diving further:

- Performance characteristics vary across Python implementations. This FAQ focusses on *CPython*.
- Behaviour can vary across operating systems, especially when talking about I/O or multi-threading.
- You should always find the hot spots in your program *before* attempting to optimize any code (see the `profile` module).
- Writing benchmark scripts will allow you to iterate quickly when searching for improvements (see the `timeit` module).
- It is highly recommended to have good code coverage (through unit testing or any other technique) before potentially introducing regressions hidden in sophisticated optimizations.

That being said, there are many tricks to speed up Python code. Here are some general principles which go a long way towards reaching acceptable performance levels:

- Making your algorithms faster (or changing to faster ones) can yield much larger benefits than trying to sprinkle micro-optimization tricks all over your code.

- Use the right data structures. Study documentation for the bltin-types and the `collections` module.
- When the standard library provides a primitive for doing something, it is likely (although not guaranteed) to be faster than any alternative you may come up with. This is doubly true for primitives written in C, such as builtins and some extension types. For example, be sure to use either the `list.sort()` built-in method or the related `sorted()` function to do sorting (and see the sortinghowto for examples of moderately advanced usage).
- Abstractions tend to create indirections and force the interpreter to work more. If the levels of indirection outweigh the amount of useful work done, your program will be slower. You should avoid excessive abstraction, especially under the form of tiny functions or methods (which are also often detrimental to readability).

If you have reached the limit of what pure Python can allow, there are tools to take you further away. For example, Cython can compile a slightly modified version of Python code into a C extension, and can be used on many different platforms. Cython can take advantage of compilation (and optional type annotations) to make your code significantly faster than when interpreted. If you are confident in your C programming skills, you can also write a C extension module yourself.

See also:

The wiki page devoted to performance tips.

2.4.2 What is the most efficient way to concatenate many strings together?

`str` and `bytes` objects are immutable, therefore concatenating many strings together is inefficient as each concatenation creates a new object. In the general case, the total runtime cost is quadratic in the total string length.

To accumulate many `str` objects, the recommended idiom is to place them into a list and call `str.join()` at the end:

```
chunks = []
for s in my_strings:
    chunks.append(s)
result = ''.join(chunks)
```

(another reasonably efficient idiom is to use `io.StringIO`)

To accumulate many `bytes` objects, the recommended idiom is to extend a `bytearray` object using in-place concatenation (the `+=` operator):

```
result = bytearray()
for b in my_bytes_objects:
    result += b
```

2.5 Sequences (Tuples/Lists)

2.5.1 How do I convert between tuples and lists?

The type constructor `tuple(seq)` converts any sequence (actually, any iterable) into a tuple with the same items in the same order.

For example, `tuple([1, 2, 3])` yields `(1, 2, 3)` and `tuple('abc')` yields `('a', 'b', 'c')`. If the argument is a tuple, it does not make a copy but returns the same object, so it is cheap to call `tuple()` when you aren't sure that an object is already a tuple.

The type constructor `list(seq)` converts any sequence or iterable into a list with the same items in the same order. For example, `list((1, 2, 3))` yields `[1, 2, 3]` and `list('abc')` yields `['a', 'b', 'c']`. If the argument is a list, it makes a copy just like `seq[:]` would.

2.5.2 What's a negative index?

Python sequences are indexed with positive numbers and negative numbers. For positive numbers 0 is the first index 1 is the second index and so forth. For negative indices -1 is the last index and -2 is the penultimate (next to last) index and so forth. Think of `seq[-n]` as the same as `seq[len(seq)-n]`.

Using negative indices can be very convenient. For example `S[:-1]` is all of the string except for its last character, which is useful for removing the trailing newline from a string.

2.5.3 How do I iterate over a sequence in reverse order?

Use the `reversed()` built-in function, which is new in Python 2.4:

```
for x in reversed(sequence):
    ...  # do something with x ...
```

This won't touch your original sequence, but build a new copy with reversed order to iterate over.

With Python 2.3, you can use an extended slice syntax:

```
for x in sequence[::-1]:
    ...  # do something with x ...
```

2.5.4 How do you remove duplicates from a list?

See the Python Cookbook for a long discussion of many ways to do this:

https://code.activestate.com/recipes/52560/

If you don't mind reordering the list, sort it and then scan from the end of the list, deleting duplicates as you go:

```
if mylist:
    mylist.sort()
    last = mylist[-1]
    for i in range(len(mylist)-2, -1, -1):
        if last == mylist[i]:
            del mylist[i]
        else:
            last = mylist[i]
```

If all elements of the list may be used as set keys (i.e. they are all *hashable*) this is often faster

```
mylist = list(set(mylist))
```

This converts the list into a set, thereby removing duplicates, and then back into a list.

2.5.5 How do you make an array in Python?

Use a list:

```
["this", 1, "is", "an", "array"]
```

Lists are equivalent to C or Pascal arrays in their time complexity; the primary difference is that a Python list can contain objects of many different types.

The `array` module also provides methods for creating arrays of fixed types with compact representations, but they are slower to index than lists. Also note that the Numeric extensions and others define array-like structures with various characteristics as well.

To get Lisp-style linked lists, you can emulate cons cells using tuples:

```
lisp_list = ("like",  ("this",  ("example", None) ) )
```

If mutability is desired, you could use lists instead of tuples. Here the analogue of lisp car is `lisp_list[0]` and the analogue of cdr is `lisp_list[1]`. Only do this if you're sure you really need to, because it's usually a lot slower than using Python lists.

2.5.6 How do I create a multidimensional list?

You probably tried to make a multidimensional array like this:

```
>>> A = [[None] * 2] * 3
```

This looks correct if you print it:

```
>>> A
[[None, None], [None, None], [None, None]]
```

But when you assign a value, it shows up in multiple places:

```
>>> A[0][0] = 5
>>> A
[[5, None], [5, None], [5, None]]
```

The reason is that replicating a list with `*` doesn't create copies, it only creates references to the existing objects. The `*3` creates a list containing 3 references to the same list of length two. Changes to one row will show in all rows, which is almost certainly not what you want.

The suggested approach is to create a list of the desired length first and then fill in each element with a newly created list:

```
A = [None] * 3
for i in range(3):
    A[i] = [None] * 2
```

This generates a list containing 3 different lists of length two. You can also use a list comprehension:

```
w, h = 2, 3
A = [[None] * w for i in range(h)]
```

Or, you can use an extension that provides a matrix datatype; NumPy is the best known.

2.5.7 How do I apply a method to a sequence of objects?

Use a list comprehension:

```
result = [obj.method() for obj in mylist]
```

2.5.8 Why does a_tuple[i] += ['item'] raise an exception when the addition works?

This is because of a combination of the fact that augmented assignment operators are *assignment* operators, and the difference between mutable and immutable objects in Python.

This discussion applies in general when augmented assignment operators are applied to elements of a tuple that point to mutable objects, but we'll use a `list` and `+=` as our exemplar.

If you wrote:

```
>>> a_tuple = (1, 2)
>>> a_tuple[0] += 1
Traceback (most recent call last):
  ...
TypeError: 'tuple' object does not support item assignment
```

The reason for the exception should be immediately clear: `1` is added to the object `a_tuple[0]` points to (`1`), producing the result object, `2`, but when we attempt to assign the result of the computation, `2`, to element `0` of the tuple, we get an error because we can't change what an element of a tuple points to.

Under the covers, what this augmented assignment statement is doing is approximately this:

```
>>> result = a_tuple[0] + 1
>>> a_tuple[0] = result
Traceback (most recent call last):
  ...
TypeError: 'tuple' object does not support item assignment
```

It is the assignment part of the operation that produces the error, since a tuple is immutable.

When you write something like:

```
>>> a_tuple = (['foo'], 'bar')
>>> a_tuple[0] += ['item']
Traceback (most recent call last):
  ...
TypeError: 'tuple' object does not support item assignment
```

The exception is a bit more surprising, and even more surprising is the fact that even though there was an error, the append worked:

```
>>> a_tuple[0]
['foo', 'item']
```

To see why this happens, you need to know that (a) if an object implements an `__iadd__` magic method, it gets called when the `+=` augmented assignment is executed, and its return value is what gets used in the assignment statement; and (b) for lists, `__iadd__` is equivalent to calling `extend` on the list and returning the list. That's why we say that for lists, `+=` is a "shorthand" for `list.extend`:

```
>>> a_list = []
>>> a_list += [1]
>>> a_list
[1]
```

This is equivalent to:

```
>>> result = a_list.__iadd__([1])
>>> a_list = result
```

The object pointed to by a_list has been mutated, and the pointer to the mutated object is assigned back to `a_list`. The end result of the assignment is a no-op, since it is a pointer to the same object that `a_list` was previously pointing to, but the assignment still happens.

Thus, in our tuple example what is happening is equivalent to:

```
>>> result = a_tuple[0].__iadd__(['item'])
>>> a_tuple[0] = result
Traceback (most recent call last):
  ...
TypeError: 'tuple' object does not support item assignment
```

The `__iadd__` succeeds, and thus the list is extended, but even though `result` points to the same object that `a_tuple[0]` already points to, that final assignment still results in an error, because tuples are immutable.

2.6 Dictionaries

2.6.1 I want to do a complicated sort: can you do a Schwartzian Transform in Python?

The technique, attributed to Randal Schwartz of the Perl community, sorts the elements of a list by a metric which maps each element to its "sort value". In Python, use the `key` argument for the `list.sort()` method:

```
Isorted = L[:]
Isorted.sort(key=lambda s: int(s[10:15]))
```

2.6.2 How can I sort one list by values from another list?

Merge them into an iterator of tuples, sort the resulting list, and then pick out the element you want.

```
>>> list1 = ["what", "I'm", "sorting", "by"]
>>> list2 = ["something", "else", "to", "sort"]
>>> pairs = zip(list1, list2)
>>> pairs = sorted(pairs)
>>> pairs
[("I'm", 'else'), ('by', 'sort'), ('sorting', 'to'), ('what', 'something')]
>>> result = [x[1] for x in pairs]
>>> result
['else', 'sort', 'to', 'something']
```

An alternative for the last step is:

```
>>> result = []
>>> for p in pairs: result.append(p[1])
```

If you find this more legible, you might prefer to use this instead of the final list comprehension. However, it is almost twice as slow for long lists. Why? First, the `append()` operation has to reallocate memory, and while it uses some tricks to avoid doing that each time, it still has to do it occasionally, and that costs quite a bit. Second, the expression "result.append" requires an extra attribute lookup, and third, there's a speed reduction from having to make all those function calls.

2.7 Objects

2.7.1 What is a class?

A class is the particular object type created by executing a class statement. Class objects are used as templates to create instance objects, which embody both the data (attributes) and code (methods) specific to a datatype.

A class can be based on one or more other classes, called its base class(es). It then inherits the attributes and methods of its base classes. This allows an object model to be successively refined by inheritance. You might have a generic `Mailbox` class that provides basic accessor methods for a mailbox, and subclasses such as `MboxMailbox`, `MaildirMailbox`, `OutlookMailbox` that handle various specific mailbox formats.

2.7.2 What is a method?

A method is a function on some object `x` that you normally call as `x.name(arguments...)`. Methods are defined as functions inside the class definition:

```
class C:
    def meth(self, arg):
        return arg * 2 + self.attribute
```

2.7.3 What is self?

Self is merely a conventional name for the first argument of a method. A method defined as `meth(self, a, b, c)` should be called as `x.meth(a, b, c)` for some instance `x` of the class in which the definition occurs; the called method will think it is called as `meth(x, a, b, c)`.

See also *Why must 'self' be used explicitly in method definitions and calls?*.

2.7.4 How do I check if an object is an instance of a given class or of a subclass of it?

Use the built-in function `isinstance(obj, cls)`. You can check if an object is an instance of any of a number of classes by providing a tuple instead of a single class, e.g. `isinstance(obj, (class1, class2, ...))`, and can also check whether an object is one of Python's built-in types, e.g. `isinstance(obj, str)` or `isinstance(obj, (int, float, complex))`.

Note that most programs do not use `isinstance()` on user-defined classes very often. If you are developing the classes yourself, a more proper object-oriented style is to define methods on the classes that encapsulate a particular behaviour, instead of checking the object's class and doing a different thing based on what class it is. For example, if you have a function that does something:

```
def search(obj):
    if isinstance(obj, Mailbox):
        ...  # code to search a mailbox
    elif isinstance(obj, Document):
        ...  # code to search a document
    elif ...
```

A better approach is to define a `search()` method on all the classes and just call it:

```
class Mailbox:
    def search(self):
        ...  # code to search a mailbox

class Document:
    def search(self):
        ...  # code to search a document

obj.search()
```

2.7.5 What is delegation?

Delegation is an object oriented technique (also called a design pattern). Let's say you have an object `x` and want to change the behaviour of just one of its methods. You can create a new class that provides a new implementation of the method you're interested in changing and delegates all other methods to the corresponding method of `x`.

Python programmers can easily implement delegation. For example, the following class implements a class that behaves like a file but converts all written data to uppercase:

```
class UpperOut:

    def __init__(self, outfile):
        self._outfile = outfile

    def write(self, s):
        self._outfile.write(s.upper())

    def __getattr__(self, name):
        return getattr(self._outfile, name)
```

Here the `UpperOut` class redefines the `write()` method to convert the argument string to uppercase before calling the underlying `self.__outfile.write()` method. All other methods are delegated to the underlying `self.__outfile` object. The delegation is accomplished via the `__getattr__` method; consult the language reference for more information about controlling attribute access.

Note that for more general cases delegation can get trickier. When attributes must be set as well as retrieved, the class must define a `__setattr__()` method too, and it must do so carefully. The basic implementation of `__setattr__()` is roughly equivalent to the following:

```
class X:
    ...
    def __setattr__(self, name, value):
        self.__dict__[name] = value
    ...
```

Most `__setattr__()` implementations must modify `self.__dict__` to store local state for self without causing an infinite recursion.

2.7.6 How do I call a method defined in a base class from a derived class that overrides it?

Use the built-in `super()` function:

```
class Derived(Base):
    def meth(self):
        super(Derived, self).meth()
```

For version prior to 3.0, you may be using classic classes: For a class definition such as `class Derived(Base): ...` you can call method `meth()` defined in `Base` (or one of `Base`'s base classes) as `Base.meth(self, arguments...)`. Here, `Base.meth` is an unbound method, so you need to provide the `self` argument.

2.7.7 How can I organize my code to make it easier to change the base class?

You could define an alias for the base class, assign the real base class to it before your class definition, and use the alias throughout your class. Then all you have to change is the value assigned to the alias. Incidentally, this trick is also handy if you want to decide dynamically (e.g. depending on availability of resources) which base class to use. Example:

```
BaseAlias = <real base class>

class Derived(BaseAlias):
    def meth(self):
        BaseAlias.meth(self)
        ...
```

2.7.8 How do I create static class data and static class methods?

Both static data and static methods (in the sense of C++ or Java) are supported in Python.

For static data, simply define a class attribute. To assign a new value to the attribute, you have to explicitly use the class name in the assignment:

```
class C:
    count = 0   # number of times C.__init__ called

    def __init__(self):
        C.count = C.count + 1

    def getcount(self):
        return C.count  # or return self.count
```

`c.count` also refers to `C.count` for any `c` such that `isinstance(c, C)` holds, unless overridden by `c` itself or by some class on the base-class search path from `c.__class__` back to `C`.

Caution: within a method of C, an assignment like `self.count = 42` creates a new and unrelated instance named "count" in `self`'s own dict. Rebinding of a class-static data name must always specify the class whether inside a method or not:

```
C.count = 314
```

Static methods are possible:

```
class C:
    @staticmethod
    def static(arg1, arg2, arg3):
        # No 'self' parameter!
        ...
```

However, a far more straightforward way to get the effect of a static method is via a simple module-level function:

```
def getcount():
    return C.count
```

If your code is structured so as to define one class (or tightly related class hierarchy) per module, this supplies the desired encapsulation.

2.7.9 How can I overload constructors (or methods) in Python?

This answer actually applies to all methods, but the question usually comes up first in the context of constructors.

In C++ you'd write

```
class C {
    C() { cout << "No arguments\n"; }
    C(int i) { cout << "Argument is " << i << "\n"; }
}
```

In Python you have to write a single constructor that catches all cases using default arguments. For example:

```
class C:
    def __init__(self, i=None):
        if i is None:
            print("No arguments")
        else:
            print("Argument is", i)
```

This is not entirely equivalent, but close enough in practice.

You could also try a variable-length argument list, e.g.

```
def __init__(self, *args):
    ...
```

The same approach works for all method definitions.

2.7.10 I try to use __spam and I get an error about _SomeClassName__spam.

Variable names with double leading underscores are "mangled" to provide a simple but effective way to define class private variables. Any identifier of the form `__spam` (at least two leading underscores, at most one trailing underscore) is textually replaced with `_classname__spam`, where `classname` is the current class name with any leading underscores stripped.

This doesn't guarantee privacy: an outside user can still deliberately access the "_classname__spam" attribute, and private values are visible in the object's `__dict__`. Many Python programmers never bother to use private variable names at all.

2.7.11 My class defines __del__ but it is not called when I delete the object.

There are several possible reasons for this.

The del statement does not necessarily call `__del__()` – it simply decrements the object's reference count, and if this reaches zero `__del__()` is called.

If your data structures contain circular links (e.g. a tree where each child has a parent reference and each parent has a list of children) the reference counts will never go back to zero. Once in a while Python runs an algorithm to detect such cycles, but the garbage collector might run some time after the last reference to your data structure vanishes, so your `__del__()` method may be called at an inconvenient and random time. This is inconvenient if you're trying to reproduce a problem. Worse, the order in which object's `__del__()` methods are executed is arbitrary. You can run `gc.collect()` to force a collection, but there *are* pathological cases where objects will never be collected.

Despite the cycle collector, it's still a good idea to define an explicit `close()` method on objects to be called whenever you're done with them. The `close()` method can then remove attributes that refer to subobjects. Don't call `__del__()` directly – `__del__()` should call `close()` and `close()` should make sure that it can be called more than once for the same object.

Another way to avoid cyclical references is to use the `weakref` module, which allows you to point to objects without incrementing their reference count. Tree data structures, for instance, should use weak references for their parent and sibling references (if they need them!).

Finally, if your `__del__()` method raises an exception, a warning message is printed to `sys.stderr`.

2.7.12 How do I get a list of all instances of a given class?

Python does not keep track of all instances of a class (or of a built-in type). You can program the class's constructor to keep track of all instances by keeping a list of weak references to each instance.

2.7.13 Why does the result of `id()` appear to be not unique?

The `id()` builtin returns an integer that is guaranteed to be unique during the lifetime of the object. Since in CPython, this is the object's memory address, it happens frequently that after an object is deleted from memory, the next freshly created object is allocated at the same position in memory. This is illustrated by this example:

```
>>> id(1000)
13901272
>>> id(2000)
13901272
```

The two ids belong to different integer objects that are created before, and deleted immediately after execution of the `id()` call. To be sure that objects whose id you want to examine are still alive, create another reference to the object:

```
>>> a = 1000; b = 2000
>>> id(a)
13901272
>>> id(b)
13891296
```

2.8 Modules

2.8.1 How do I create a .pyc file?

When a module is imported for the first time (or when the source file has changed since the current compiled file was created) a `.pyc` file containing the compiled code should be created in a `__pycache__` subdirectory of the directory containing the `.py` file. The `.pyc` file will have a filename that starts with the same name

as the .py file, and ends with .pyc, with a middle component that depends on the particular python binary that created it. (See PEP 3147 for details.)

One reason that a .pyc file may not be created is a permissions problem with the directory containing the source file, meaning that the __pycache__ subdirectory cannot be created. This can happen, for example, if you develop as one user but run as another, such as if you are testing with a web server.

Unless the PYTHONDONTWRITEBYTECODE environment variable is set, creation of a .pyc file is automatic if you're importing a module and Python has the ability (permissions, free space, etc...) to create a __pycache__ subdirectory and write the compiled module to that subdirectory.

Running Python on a top level script is not considered an import and no .pyc will be created. For example, if you have a top-level module foo.py that imports another module xyz.py, when you run foo (by typing python foo.py as a shell command), a .pyc will be created for xyz because xyz is imported, but no .pyc file will be created for foo since foo.py isn't being imported.

If you need to create a .pyc file for foo – that is, to create a .pyc file for a module that is not imported – you can, using the py_compile and compileall modules.

The py_compile module can manually compile any module. One way is to use the compile() function in that module interactively:

```
>>> import py_compile
>>> py_compile.compile('foo.py')
```

This will write the .pyc to a __pycache__ subdirectory in the same location as foo.py (or you can override that with the optional parameter cfile).

You can also automatically compile all files in a directory or directories using the compileall module. You can do it from the shell prompt by running compileall.py and providing the path of a directory containing Python files to compile:

```
python -m compileall .
```

2.8.2 How do I find the current module name?

A module can find out its own module name by looking at the predefined global variable __name__. If this has the value '__main__', the program is running as a script. Many modules that are usually used by importing them also provide a command-line interface or a self-test, and only execute this code after checking __name__:

```
def main():
    print('Running test...')
    ...

if __name__ == '__main__':
    main()
```

2.8.3 How can I have modules that mutually import each other?

Suppose you have the following modules:

foo.py:

```
from bar import bar_var
foo_var = 1
```

bar.py:

```
from foo import foo_var
bar_var = 2
```

The problem is that the interpreter will perform the following steps:

- main imports foo
- Empty globals for foo are created
- foo is compiled and starts executing
- foo imports bar
- Empty globals for bar are created
- bar is compiled and starts executing
- bar imports foo (which is a no-op since there already is a module named foo)
- bar.foo_var = foo.foo_var

The last step fails, because Python isn't done with interpreting `foo` yet and the global symbol dictionary for `foo` is still empty.

The same thing happens when you use `import foo`, and then try to access `foo.foo_var` in global code.

There are (at least) three possible workarounds for this problem.

Guido van Rossum recommends avoiding all uses of `from <module> import ...`, and placing all code inside functions. Initializations of global variables and class variables should use constants or built-in functions only. This means everything from an imported module is referenced as `<module>.<name>`.

Jim Roskind suggests performing steps in the following order in each module:

- exports (globals, functions, and classes that don't need imported base classes)
- `import` statements
- active code (including globals that are initialized from imported values).

van Rossum doesn't like this approach much because the imports appear in a strange place, but it does work.

Matthias Urlichs recommends restructuring your code so that the recursive import is not necessary in the first place.

These solutions are not mutually exclusive.

2.8.4 __import__('x.y.z') returns <module 'x'>; how do I get z?

Consider using the convenience function `import_module()` from `importlib` instead:

```
z = importlib.import_module('x.y.z')
```

2.8.5 When I edit an imported module and reimport it, the changes don't show up. Why does this happen?

For reasons of efficiency as well as consistency, Python only reads the module file on the first time a module is imported. If it didn't, in a program consisting of many modules where each one imports the same basic module, the basic module would be parsed and re-parsed many times. To force re-reading of a changed module, do this:

```
import importlib
import modname
importlib.reload(modname)
```

Warning: this technique is not 100% fool-proof. In particular, modules containing statements like

```
from modname import some_objects
```

will continue to work with the old version of the imported objects. If the module contains class definitions, existing class instances will *not* be updated to use the new class definition. This can result in the following paradoxical behaviour:

```
>>> import importlib
>>> import cls
>>> c = cls.C()                # Create an instance of C
>>> importlib.reload(cls)
<module 'cls' from 'cls.py'>
>>> isinstance(c, cls.C)       # isinstance is false?!?
False
```

The nature of the problem is made clear if you print out the "identity" of the class objects:

```
>>> hex(id(c.__class__))
'0x7352a0'
>>> hex(id(cls.C))
'0x4198d0'
```

CHAPTER

THREE

DESIGN AND HISTORY FAQ

3.1 Why does Python use indentation for grouping of statements?

Guido van Rossum believes that using indentation for grouping is extremely elegant and contributes a lot to the clarity of the average Python program. Most people learn to love this feature after a while.

Since there are no begin/end brackets there cannot be a disagreement between grouping perceived by the parser and the human reader. Occasionally C programmers will encounter a fragment of code like this:

```
if (x <= y)
        x++;
        y--;
z++;
```

Only the `x++` statement is executed if the condition is true, but the indentation leads you to believe otherwise. Even experienced C programmers will sometimes stare at it a long time wondering why `y` is being decremented even for `x > y`.

Because there are no begin/end brackets, Python is much less prone to coding-style conflicts. In C there are many different ways to place the braces. If you're used to reading and writing code that uses one style, you will feel at least slightly uneasy when reading (or being required to write) another style.

Many coding styles place begin/end brackets on a line by themselves. This makes programs considerably longer and wastes valuable screen space, making it harder to get a good overview of a program. Ideally, a function should fit on one screen (say, 20–30 lines). 20 lines of Python can do a lot more work than 20 lines of C. This is not solely due to the lack of begin/end brackets – the lack of declarations and the high-level data types are also responsible – but the indentation-based syntax certainly helps.

3.2 Why am I getting strange results with simple arithmetic operations?

See the next question.

3.3 Why are floating-point calculations so inaccurate?

Users are often surprised by results like this:

```
>>> 1.2 - 1.0
0.19999999999999996
```

and think it is a bug in Python. It's not. This has little to do with Python, and much more to do with how the underlying platform handles floating-point numbers.

The `float` type in CPython uses a C `double` for storage. A `float` object's value is stored in binary floating-point with a fixed precision (typically 53 bits) and Python uses C operations, which in turn rely on the hardware implementation in the processor, to perform floating-point operations. This means that as far as floating-point operations are concerned, Python behaves like many popular languages including C and Java.

Many numbers that can be written easily in decimal notation cannot be expressed exactly in binary floating-point. For example, after:

```
>>> x = 1.2
```

the value stored for `x` is a (very good) approximation to the decimal value `1.2`, but is not exactly equal to it. On a typical machine, the actual stored value is:

```
1.0011001100110011001100110011001100110011001100110011 (binary)
```

which is exactly:

```
1.199999999999999955591079014993738383054733276367187 5 (decimal)
```

The typical precision of 53 bits provides Python floats with 15–16 decimal digits of accuracy.

For a fuller explanation, please see the floating point arithmetic chapter in the Python tutorial.

3.4 Why are Python strings immutable?

There are several advantages.

One is performance: knowing that a string is immutable means we can allocate space for it at creation time, and the storage requirements are fixed and unchanging. This is also one of the reasons for the distinction between tuples and lists.

Another advantage is that strings in Python are considered as "elemental" as numbers. No amount of activity will change the value 8 to anything else, and in Python, no amount of activity will change the string "eight" to anything else.

3.5 Why must 'self' be used explicitly in method definitions and calls?

The idea was borrowed from Modula-3. It turns out to be very useful, for a variety of reasons.

First, it's more obvious that you are using a method or instance attribute instead of a local variable. Reading `self.x` or `self.meth()` makes it absolutely clear that an instance variable or method is used even if you don't know the class definition by heart. In C++, you can sort of tell by the lack of a local variable declaration (assuming globals are rare or easily recognizable) – but in Python, there are no local variable declarations, so you'd have to look up the class definition to be sure. Some C++ and Java coding standards call for instance attributes to have an `m_` prefix, so this explicitness is still useful in those languages, too.

Second, it means that no special syntax is necessary if you want to explicitly reference or call the method from a particular class. In C++, if you want to use a method from a base class which is overridden in a derived class, you have to use the `::` operator – in Python you can write `baseclass.methodname(self, <argument list>)`. This is particularly useful for `__init__()` methods, and in general in cases where a derived class method wants to extend the base class method of the same name and thus has to call the base class method somehow.

Finally, for instance variables it solves a syntactic problem with assignment: since local variables in Python are (by definition!) those variables to which a value is assigned in a function body (and that aren't explicitly declared global), there has to be some way to tell the interpreter that an assignment was meant to assign

to an instance variable instead of to a local variable, and it should preferably be syntactic (for efficiency reasons). C++ does this through declarations, but Python doesn't have declarations and it would be a pity having to introduce them just for this purpose. Using the explicit `self.var` solves this nicely. Similarly, for using instance variables, having to write `self.var` means that references to unqualified names inside a method don't have to search the instance's directories. To put it another way, local variables and instance variables live in two different namespaces, and you need to tell Python which namespace to use.

3.6 Why can't I use an assignment in an expression?

Many people used to C or Perl complain that they want to use this C idiom:

```
while (line = readline(f)) {
    // do something with line
}
```

where in Python you're forced to write this:

```
while True:
    line = f.readline()
    if not line:
        break
    ...  # do something with line
```

The reason for not allowing assignment in Python expressions is a common, hard-to-find bug in those other languages, caused by this construct:

```
if (x = 0) {
    // error handling
}
else {
    // code that only works for nonzero x
}
```

The error is a simple typo: `x = 0`, which assigns 0 to the variable `x`, was written while the comparison `x == 0` is certainly what was intended.

Many alternatives have been proposed. Most are hacks that save some typing but use arbitrary or cryptic syntax or keywords, and fail the simple criterion for language change proposals: it should intuitively suggest the proper meaning to a human reader who has not yet been introduced to the construct.

An interesting phenomenon is that most experienced Python programmers recognize the `while True` idiom and don't seem to be missing the assignment in expression construct much; it's only newcomers who express a strong desire to add this to the language.

There's an alternative way of spelling this that seems attractive but is generally less robust than the "while True" solution:

```
line = f.readline()
while line:
    ...  # do something with line...
    line = f.readline()
```

The problem with this is that if you change your mind about exactly how you get the next line (e.g. you want to change it into `sys.stdin.readline()`) you have to remember to change two places in your program – the second occurrence is hidden at the bottom of the loop.

The best approach is to use iterators, making it possible to loop through objects using the `for` statement. For example, *file objects* support the iterator protocol, so you can write simply:

```
for line in f:
    ...  # do something with line...
```

3.7 Why does Python use methods for some functionality (e.g. list.index()) but functions for other (e.g. len(list))?

The major reason is history. Functions were used for those operations that were generic for a group of types and which were intended to work even for objects that didn't have methods at all (e.g. tuples). It is also convenient to have a function that can readily be applied to an amorphous collection of objects when you use the functional features of Python (`map()`, `zip()` et al).

In fact, implementing `len()`, `max()`, `min()` as a built-in function is actually less code than implementing them as methods for each type. One can quibble about individual cases but it's a part of Python, and it's too late to make such fundamental changes now. The functions have to remain to avoid massive code breakage.

Note: For string operations, Python has moved from external functions (the `string` module) to methods. However, `len()` is still a function.

3.8 Why is join() a string method instead of a list or tuple method?

Strings became much more like other standard types starting in Python 1.6, when methods were added which give the same functionality that has always been available using the functions of the string module. Most of these new methods have been widely accepted, but the one which appears to make some programmers feel uncomfortable is:

```
", ".join(['1', '2', '4', '8', '16'])
```

which gives the result:

```
"1, 2, 4, 8, 16"
```

There are two common arguments against this usage.

The first runs along the lines of: "It looks really ugly using a method of a string literal (string constant)", to which the answer is that it might, but a string literal is just a fixed value. If the methods are to be allowed on names bound to strings there is no logical reason to make them unavailable on literals.

The second objection is typically cast as: "I am really telling a sequence to join its members together with a string constant". Sadly, you aren't. For some reason there seems to be much less difficulty with having `split()` as a string method, since in that case it is easy to see that

```
"1, 2, 4, 8, 16".split(", ")
```

is an instruction to a string literal to return the substrings delimited by the given separator (or, by default, arbitrary runs of white space).

`join()` is a string method because in using it you are telling the separator string to iterate over a sequence of strings and insert itself between adjacent elements. This method can be used with any argument which obeys the rules for sequence objects, including any new classes you might define yourself. Similar methods exist for bytes and bytearray objects.

3.9 How fast are exceptions?

A try/except block is extremely efficient if no exceptions are raised. Actually catching an exception is expensive. In versions of Python prior to 2.0 it was common to use this idiom:

```
try:
    value = mydict[key]
except KeyError:
    mydict[key] = getvalue(key)
    value = mydict[key]
```

This only made sense when you expected the dict to have the key almost all the time. If that wasn't the case, you coded it like this:

```
if key in mydict:
    value = mydict[key]
else:
    value = mydict[key] = getvalue(key)
```

For this specific case, you could also use `value = dict.setdefault(key, getvalue(key))`, but only if the `getvalue()` call is cheap enough because it is evaluated in all cases.

3.10 Why isn't there a switch or case statement in Python?

You can do this easily enough with a sequence of `if... elif... elif... else`. There have been some proposals for switch statement syntax, but there is no consensus (yet) on whether and how to do range tests. See **PEP 275** for complete details and the current status.

For cases where you need to choose from a very large number of possibilities, you can create a dictionary mapping case values to functions to call. For example:

```
def function_1(...):
    ...

functions = {'a': function_1,
             'b': function_2,
             'c': self.method_1, ...}

func = functions[value]
func()
```

For calling methods on objects, you can simplify yet further by using the `getattr()` built-in to retrieve methods with a particular name:

```
def visit_a(self, ...):
    ...
...

def dispatch(self, value):
    method_name = 'visit_' + str(value)
    method = getattr(self, method_name)
    method()
```

It's suggested that you use a prefix for the method names, such as `visit_` in this example. Without such a prefix, if values are coming from an untrusted source, an attacker would be able to call any method on your object.

3.11 Can't you emulate threads in the interpreter instead of relying on an OS-specific thread implementation?

Answer 1: Unfortunately, the interpreter pushes at least one C stack frame for each Python stack frame. Also, extensions can call back into Python at almost random moments. Therefore, a complete threads implementation requires thread support for C.

Answer 2: Fortunately, there is Stackless Python, which has a completely redesigned interpreter loop that avoids the C stack.

3.12 Why can't lambda expressions contain statements?

Python lambda expressions cannot contain statements because Python's syntactic framework can't handle statements nested inside expressions. However, in Python, this is not a serious problem. Unlike lambda forms in other languages, where they add functionality, Python lambdas are only a shorthand notation if you're too lazy to define a function.

Functions are already first class objects in Python, and can be declared in a local scope. Therefore the only advantage of using a lambda instead of a locally-defined function is that you don't need to invent a name for the function – but that's just a local variable to which the function object (which is exactly the same type of object that a lambda expression yields) is assigned!

3.13 Can Python be compiled to machine code, C or some other language?

Cython compiles a modified version of Python with optional annotations into C extensions. Nuitka is an up-and-coming compiler of Python into C++ code, aiming to support the full Python language. For compiling to Java you can consider VOC.

3.14 How does Python manage memory?

The details of Python memory management depend on the implementation. The standard implementation of Python, *CPython*, uses reference counting to detect inaccessible objects, and another mechanism to collect reference cycles, periodically executing a cycle detection algorithm which looks for inaccessible cycles and deletes the objects involved. The `gc` module provides functions to perform a garbage collection, obtain debugging statistics, and tune the collector's parameters.

Other implementations (such as Jython or PyPy), however, can rely on a different mechanism such as a full-blown garbage collector. This difference can cause some subtle porting problems if your Python code depends on the behavior of the reference counting implementation.

In some Python implementations, the following code (which is fine in CPython) will probably run out of file descriptors:

```
for file in very_long_list_of_files:
    f = open(file)
    c = f.read(1)
```

Indeed, using CPython's reference counting and destructor scheme, each new assignment to *f* closes the previous file. With a traditional GC, however, those file objects will only get collected (and closed) at varying and possibly long intervals.

If you want to write code that will work with any Python implementation, you should explicitly close the file or use the `with` statement; this will work regardless of memory management scheme:

```
for file in very_long_list_of_files:
    with open(file) as f:
        c = f.read(1)
```

3.15 Why doesn't CPython use a more traditional garbage collection scheme?

For one thing, this is not a C standard feature and hence it's not portable. (Yes, we know about the Boehm GC library. It has bits of assembler code for *most* common platforms, not for all of them, and although it is mostly transparent, it isn't completely transparent; patches are required to get Python to work with it.)

Traditional GC also becomes a problem when Python is embedded into other applications. While in a standalone Python it's fine to replace the standard malloc() and free() with versions provided by the GC library, an application embedding Python may want to have its *own* substitute for malloc() and free(), and may not want Python's. Right now, CPython works with anything that implements malloc() and free() properly.

3.16 Why isn't all memory freed when CPython exits?

Objects referenced from the global namespaces of Python modules are not always deallocated when Python exits. This may happen if there are circular references. There are also certain bits of memory that are allocated by the C library that are impossible to free (e.g. a tool like Purify will complain about these). Python is, however, aggressive about cleaning up memory on exit and does try to destroy every single object.

If you want to force Python to delete certain things on deallocation use the `atexit` module to run a function that will force those deletions.

3.17 Why are there separate tuple and list data types?

Lists and tuples, while similar in many respects, are generally used in fundamentally different ways. Tuples can be thought of as being similar to Pascal records or C structs; they're small collections of related data which may be of different types which are operated on as a group. For example, a Cartesian coordinate is appropriately represented as a tuple of two or three numbers.

Lists, on the other hand, are more like arrays in other languages. They tend to hold a varying number of objects all of which have the same type and which are operated on one-by-one. For example, `os.listdir('.')` returns a list of strings representing the files in the current directory. Functions which operate on this output would generally not break if you added another file or two to the directory.

Tuples are immutable, meaning that once a tuple has been created, you can't replace any of its elements with a new value. Lists are mutable, meaning that you can always change a list's elements. Only immutable elements can be used as dictionary keys, and hence only tuples and not lists can be used as keys.

3.18 How are lists implemented?

Python's lists are really variable-length arrays, not Lisp-style linked lists. The implementation uses a contiguous array of references to other objects, and keeps a pointer to this array and the array's length in a list

head structure.

This makes indexing a list `a[i]` an operation whose cost is independent of the size of the list or the value of the index.

When items are appended or inserted, the array of references is resized. Some cleverness is applied to improve the performance of appending items repeatedly; when the array must be grown, some extra space is allocated so the next few times don't require an actual resize.

3.19 How are dictionaries implemented?

Python's dictionaries are implemented as resizable hash tables. Compared to B-trees, this gives better performance for lookup (the most common operation by far) under most circumstances, and the implementation is simpler.

Dictionaries work by computing a hash code for each key stored in the dictionary using the `hash()` built-in function. The hash code varies widely depending on the key and a per-process seed; for example, "Python" could hash to -539294296 while "python", a string that differs by a single bit, could hash to 1142331976. The hash code is then used to calculate a location in an internal array where the value will be stored. Assuming that you're storing keys that all have different hash values, this means that dictionaries take constant time – O(1), in Big-O notation – to retrieve a key.

3.20 Why must dictionary keys be immutable?

The hash table implementation of dictionaries uses a hash value calculated from the key value to find the key. If the key were a mutable object, its value could change, and thus its hash could also change. But since whoever changes the key object can't tell that it was being used as a dictionary key, it can't move the entry around in the dictionary. Then, when you try to look up the same object in the dictionary it won't be found because its hash value is different. If you tried to look up the old value it wouldn't be found either, because the value of the object found in that hash bin would be different.

If you want a dictionary indexed with a list, simply convert the list to a tuple first; the function `tuple(L)` creates a tuple with the same entries as the list `L`. Tuples are immutable and can therefore be used as dictionary keys.

Some unacceptable solutions that have been proposed:

- Hash lists by their address (object ID). This doesn't work because if you construct a new list with the same value it won't be found; e.g.:

  ```
  mydict = {[1, 2]: '12'}
  print(mydict[[1, 2]])
  ```

  would raise a KeyError exception because the id of the `[1, 2]` used in the second line differs from that in the first line. In other words, dictionary keys should be compared using `==`, not using `is`.

- Make a copy when using a list as a key. This doesn't work because the list, being a mutable object, could contain a reference to itself, and then the copying code would run into an infinite loop.

- Allow lists as keys but tell the user not to modify them. This would allow a class of hard-to-track bugs in programs when you forgot or modified a list by accident. It also invalidates an important invariant of dictionaries: every value in `d.keys()` is usable as a key of the dictionary.

- Mark lists as read-only once they are used as a dictionary key. The problem is that it's not just the top-level object that could change its value; you could use a tuple containing a list as a key. Entering anything as a key into a dictionary would require marking all objects reachable from there as read-only – and again, self-referential objects could cause an infinite loop.

There is a trick to get around this if you need to, but use it at your own risk: You can wrap a mutable structure inside a class instance which has both a `__eq__()` and a `__hash__()` method. You must then make sure that the hash value for all such wrapper objects that reside in a dictionary (or other hash based structure), remain fixed while the object is in the dictionary (or other structure).

```
class ListWrapper:
    def __init__(self, the_list):
        self.the_list = the_list

    def __eq__(self, other):
        return self.the_list == other.the_list

    def __hash__(self):
        l = self.the_list
        result = 98767 - len(l)*555
        for i, el in enumerate(l):
            try:
                result = result + (hash(el) % 9999999) * 1001 + i
            except Exception:
                result = (result % 7777777) + i * 333
        return result
```

Note that the hash computation is complicated by the possibility that some members of the list may be unhashable and also by the possibility of arithmetic overflow.

Furthermore it must always be the case that if `o1 == o2` (ie `o1.__eq__(o2) is True`) then `hash(o1) == hash(o2)` (ie, `o1.__hash__() == o2.__hash__()`), regardless of whether the object is in a dictionary or not. If you fail to meet these restrictions dictionaries and other hash based structures will misbehave.

In the case of ListWrapper, whenever the wrapper object is in a dictionary the wrapped list must not change to avoid anomalies. Don't do this unless you are prepared to think hard about the requirements and the consequences of not meeting them correctly. Consider yourself warned.

3.21 Why doesn't list.sort() return the sorted list?

In situations where performance matters, making a copy of the list just to sort it would be wasteful. Therefore, `list.sort()` sorts the list in place. In order to remind you of that fact, it does not return the sorted list. This way, you won't be fooled into accidentally overwriting a list when you need a sorted copy but also need to keep the unsorted version around.

If you want to return a new list, use the built-in `sorted()` function instead. This function creates a new list from a provided iterable, sorts it and returns it. For example, here's how to iterate over the keys of a dictionary in sorted order:

```
for key in sorted(mydict):
    ...  # do whatever with mydict[key]...
```

3.22 How do you specify and enforce an interface spec in Python?

An interface specification for a module as provided by languages such as C++ and Java describes the prototypes for the methods and functions of the module. Many feel that compile-time enforcement of interface specifications helps in the construction of large programs.

Python 2.6 adds an `abc` module that lets you define Abstract Base Classes (ABCs). You can then use `isinstance()` and `issubclass()` to check whether an instance or a class implements a particular ABC. The `collections.abc` module defines a set of useful ABCs such as `Iterable`, `Container`, and `MutableMapping`.

For Python, many of the advantages of interface specifications can be obtained by an appropriate test discipline for components. There is also a tool, PyChecker, which can be used to find problems due to subclassing.

A good test suite for a module can both provide a regression test and serve as a module interface specification and a set of examples. Many Python modules can be run as a script to provide a simple "self test." Even modules which use complex external interfaces can often be tested in isolation using trivial "stub" emulations of the external interface. The `doctest` and `unittest` modules or third-party test frameworks can be used to construct exhaustive test suites that exercise every line of code in a module.

An appropriate testing discipline can help build large complex applications in Python as well as having interface specifications would. In fact, it can be better because an interface specification cannot test certain properties of a program. For example, the `append()` method is expected to add new elements to the end of some internal list; an interface specification cannot test that your `append()` implementation will actually do this correctly, but it's trivial to check this property in a test suite.

Writing test suites is very helpful, and you might want to design your code with an eye to making it easily tested. One increasingly popular technique, test-directed development, calls for writing parts of the test suite first, before you write any of the actual code. Of course Python allows you to be sloppy and not write test cases at all.

3.23 Why is there no goto?

You can use exceptions to provide a "structured goto" that even works across function calls. Many feel that exceptions can conveniently emulate all reasonable uses of the "go" or "goto" constructs of C, Fortran, and other languages. For example:

```
class label(Exception): pass  # declare a label

try:
    ...
    if condition: raise label()  # goto label
    ...
except label:  # where to goto
    pass
...
```

This doesn't allow you to jump into the middle of a loop, but that's usually considered an abuse of goto anyway. Use sparingly.

3.24 Why can't raw strings (r-strings) end with a backslash?

More precisely, they can't end with an odd number of backslashes: the unpaired backslash at the end escapes the closing quote character, leaving an unterminated string.

Raw strings were designed to ease creating input for processors (chiefly regular expression engines) that want to do their own backslash escape processing. Such processors consider an unmatched trailing backslash to be an error anyway, so raw strings disallow that. In return, they allow you to pass on the string quote character by escaping it with a backslash. These rules work well when r-strings are used for their intended purpose.

If you're trying to build Windows pathnames, note that all Windows system calls accept forward slashes too:

```
f = open("/mydir/file.txt")  # works fine!
```

If you're trying to build a pathname for a DOS command, try e.g. one of

```
dir = r"\this\is\my\dos\dir" "\\"
dir = r"\this\is\my\dos\dir\ "[:-1]
dir = "\\this\\is\\my\\dos\\dir\\"
```

3.25 Why doesn't Python have a "with" statement for attribute assignments?

Python has a 'with' statement that wraps the execution of a block, calling code on the entrance and exit from the block. Some language have a construct that looks like this:

```
with obj:
    a = 1               # equivalent to obj.a = 1
    total = total + 1   # obj.total = obj.total + 1
```

In Python, such a construct would be ambiguous.

Other languages, such as Object Pascal, Delphi, and C++, use static types, so it's possible to know, in an unambiguous way, what member is being assigned to. This is the main point of static typing – the compiler *always* knows the scope of every variable at compile time.

Python uses dynamic types. It is impossible to know in advance which attribute will be referenced at runtime. Member attributes may be added or removed from objects on the fly. This makes it impossible to know, from a simple reading, what attribute is being referenced: a local one, a global one, or a member attribute?

For instance, take the following incomplete snippet:

```
def foo(a):
    with a:
        print(x)
```

The snippet assumes that "a" must have a member attribute called "x". However, there is nothing in Python that tells the interpreter this. What should happen if "a" is, let us say, an integer? If there is a global variable named "x", will it be used inside the with block? As you see, the dynamic nature of Python makes such choices much harder.

The primary benefit of "with" and similar language features (reduction of code volume) can, however, easily be achieved in Python by assignment. Instead of:

```
function(args).mydict[index][index].a = 21
function(args).mydict[index][index].b = 42
function(args).mydict[index][index].c = 63
```

write this:

```
ref = function(args).mydict[index][index]
ref.a = 21
ref.b = 42
ref.c = 63
```

This also has the side-effect of increasing execution speed because name bindings are resolved at run-time in Python, and the second version only needs to perform the resolution once.

3.26 Why are colons required for the if/while/def/class statements?

The colon is required primarily to enhance readability (one of the results of the experimental ABC language). Consider this:

```
if a == b
    print(a)
```

versus

```
if a == b:
    print(a)
```

Notice how the second one is slightly easier to read. Notice further how a colon sets off the example in this FAQ answer; it's a standard usage in English.

Another minor reason is that the colon makes it easier for editors with syntax highlighting; they can look for colons to decide when indentation needs to be increased instead of having to do a more elaborate parsing of the program text.

3.27 Why does Python allow commas at the end of lists and tuples?

Python lets you add a trailing comma at the end of lists, tuples, and dictionaries:

```
[1, 2, 3,]
('a', 'b', 'c',)
d = {
    "A": [1, 5],
    "B": [6, 7],  # last trailing comma is optional but good style
}
```

There are several reasons to allow this.

When you have a literal value for a list, tuple, or dictionary spread across multiple lines, it's easier to add more elements because you don't have to remember to add a comma to the previous line. The lines can also be reordered without creating a syntax error.

Accidentally omitting the comma can lead to errors that are hard to diagnose. For example:

```
x = [
  "fee",
  "fie"
  "foo",
  "fum"
]
```

This list looks like it has four elements, but it actually contains three: "fee", "fiefoo" and "fum". Always adding the comma avoids this source of error.

Allowing the trailing comma may also make programmatic code generation easier.

CHAPTER

FOUR

LIBRARY AND EXTENSION FAQ

4.1 General Library Questions

4.1.1 How do I find a module or application to perform task X?

Check the Library Reference to see if there's a relevant standard library module. (Eventually you'll learn what's in the standard library and will be able to skip this step.)

For third-party packages, search the Python Package Index or try Google or another Web search engine. Searching for "Python" plus a keyword or two for your topic of interest will usually find something helpful.

4.1.2 Where is the math.py (socket.py, regex.py, etc.) source file?

If you can't find a source file for a module it may be a built-in or dynamically loaded module implemented in C, C++ or other compiled language. In this case you may not have the source file or it may be something like `mathmodule.c`, somewhere in a C source directory (not on the Python Path).

There are (at least) three kinds of modules in Python:

1. modules written in Python (.py);
2. modules written in C and dynamically loaded (.dll, .pyd, .so, .sl, etc);
3. modules written in C and linked with the interpreter; to get a list of these, type:

```
import sys
print(sys.builtin_module_names)
```

4.1.3 How do I make a Python script executable on Unix?

You need to do two things: the script file's mode must be executable and the first line must begin with `#!` followed by the path of the Python interpreter.

The first is done by executing `chmod +x scriptfile` or perhaps `chmod 755 scriptfile`.

The second can be done in a number of ways. The most straightforward way is to write

```
#!/usr/local/bin/python
```

as the very first line of your file, using the pathname for where the Python interpreter is installed on your platform.

If you would like the script to be independent of where the Python interpreter lives, you can use the `env` program. Almost all Unix variants support the following, assuming the Python interpreter is in a directory on the user's `PATH`:

```
#!/usr/bin/env python
```

Don't do this for CGI scripts. The `PATH` variable for CGI scripts is often very minimal, so you need to use the actual absolute pathname of the interpreter.

Occasionally, a user's environment is so full that the **/usr/bin/env** program fails; or there's no env program at all. In that case, you can try the following hack (due to Alex Rezinsky):

```
#! /bin/sh
""":"
exec python $0 ${1+"$@"}
"""
```

The minor disadvantage is that this defines the script's ___doc___ string. However, you can fix that by adding

```
__doc__ = """...Whatever..."""
```

4.1.4 Is there a curses/termcap package for Python?

For Unix variants: The standard Python source distribution comes with a curses module in the Modules subdirectory, though it's not compiled by default. (Note that this is not available in the Windows distribution – there is no curses module for Windows.)

The `curses` module supports basic curses features as well as many additional functions from ncurses and SYSV curses such as colour, alternative character set support, pads, and mouse support. This means the module isn't compatible with operating systems that only have BSD curses, but there don't seem to be any currently maintained OSes that fall into this category.

For Windows: use the consolelib module.

4.1.5 Is there an equivalent to C's onexit() in Python?

The `atexit` module provides a register function that is similar to C's `onexit()`.

4.1.6 Why don't my signal handlers work?

The most common problem is that the signal handler is declared with the wrong argument list. It is called as

```
handler(signum, frame)
```

so it should be declared with two arguments:

```
def handler(signum, frame):
    ...
```

4.2 Common tasks

4.2.1 How do I test a Python program or component?

Python comes with two testing frameworks. The `doctest` module finds examples in the docstrings for a module and runs them, comparing the output with the expected output given in the docstring.

The `unittest` module is a fancier testing framework modelled on Java and Smalltalk testing frameworks.

To make testing easier, you should use good modular design in your program. Your program should have almost all functionality encapsulated in either functions or class methods – and this sometimes has the surprising and delightful effect of making the program run faster (because local variable accesses are faster than global accesses). Furthermore the program should avoid depending on mutating global variables, since this makes testing much more difficult to do.

The "global main logic" of your program may be as simple as

```
if __name__ == "__main__":
    main_logic()
```

at the bottom of the main module of your program.

Once your program is organized as a tractable collection of functions and class behaviours you should write test functions that exercise the behaviours. A test suite that automates a sequence of tests can be associated with each module. This sounds like a lot of work, but since Python is so terse and flexible it's surprisingly easy. You can make coding much more pleasant and fun by writing your test functions in parallel with the "production code", since this makes it easy to find bugs and even design flaws earlier.

"Support modules" that are not intended to be the main module of a program may include a self-test of the module.

```
if __name__ == "__main__":
    self_test()
```

Even programs that interact with complex external interfaces may be tested when the external interfaces are unavailable by using "fake" interfaces implemented in Python.

4.2.2 How do I create documentation from doc strings?

The `pydoc` module can create HTML from the doc strings in your Python source code. An alternative for creating API documentation purely from docstrings is epydoc. Sphinx can also include docstring content.

4.2.3 How do I get a single keypress at a time?

For Unix variants there are several solutions. It's straightforward to do this using curses, but curses is a fairly large module to learn.

4.3 Threads

4.3.1 How do I program using threads?

Be sure to use the `threading` module and not the `_thread` module. The `threading` module builds convenient abstractions on top of the low-level primitives provided by the `_thread` module.

Aahz has a set of slides from his threading tutorial that are helpful; see http://www.pythoncraft.com/OSCON2001/.

4.3.2 None of my threads seem to run: why?

As soon as the main thread exits, all threads are killed. Your main thread is running too quickly, giving the threads no time to do any work.

A simple fix is to add a sleep to the end of the program that's long enough for all the threads to finish:

```
import threading, time

def thread_task(name, n):
    for i in range(n):
        print(name, i)

for i in range(10):
    T = threading.Thread(target=thread_task, args=(str(i), i))
    T.start()

time.sleep(10)  # <---------------------------!
```

But now (on many platforms) the threads don't run in parallel, but appear to run sequentially, one at a time! The reason is that the OS thread scheduler doesn't start a new thread until the previous thread is blocked.

A simple fix is to add a tiny sleep to the start of the run function:

```
def thread_task(name, n):
    time.sleep(0.001)  # <--------------------!
    for i in range(n):
        print(name, i)

for i in range(10):
    T = threading.Thread(target=thread_task, args=(str(i), i))
    T.start()

time.sleep(10)
```

Instead of trying to guess a good delay value for `time.sleep()`, it's better to use some kind of semaphore mechanism. One idea is to use the `queue` module to create a queue object, let each thread append a token to the queue when it finishes, and let the main thread read as many tokens from the queue as there are threads.

4.3.3 How do I parcel out work among a bunch of worker threads?

The easiest way is to use the new `concurrent.futures` module, especially the `ThreadPoolExecutor` class.

Or, if you want fine control over the dispatching algorithm, you can write your own logic manually. Use the `queue` module to create a queue containing a list of jobs. The `Queue` class maintains a list of objects and has a `.put(obj)` method that adds items to the queue and a `.get()` method to return them. The class will take care of the locking necessary to ensure that each job is handed out exactly once.

Here's a trivial example:

```
import threading, queue, time

# The worker thread gets jobs off the queue.  When the queue is empty, it
# assumes there will be no more work and exits.
# (Realistically workers will run until terminated.)
def worker():
    print('Running worker')
    time.sleep(0.1)
    while True:
        try:
            arg = q.get(block=False)
```

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```
        except queue.Empty:
            print('Worker', threading.currentThread(), end=' ')
            print('queue empty')
            break
        else:
            print('Worker', threading.currentThread(), end=' ')
            print('running with argument', arg)
            time.sleep(0.5)

# Create queue
q = queue.Queue()

# Start a pool of 5 workers
for i in range(5):
    t = threading.Thread(target=worker, name='worker %i' % (i+1))
    t.start()

# Begin adding work to the queue
for i in range(50):
    q.put(i)

# Give threads time to run
print('Main thread sleeping')
time.sleep(5)
```

When run, this will produce the following output:

```
Running worker
Running worker
Running worker
Running worker
Running worker
Main thread sleeping
Worker <Thread(worker 1, started 130283832797456)> running with argument 0
Worker <Thread(worker 2, started 130283824404752)> running with argument 1
Worker <Thread(worker 3, started 130283816012048)> running with argument 2
Worker <Thread(worker 4, started 130283807619344)> running with argument 3
Worker <Thread(worker 5, started 130283799226640)> running with argument 4
Worker <Thread(worker 1, started 130283832797456)> running with argument 5
...
```

Consult the module's documentation for more details; the `Queue` class provides a featureful interface.

4.3.4 What kinds of global value mutation are thread-safe?

A *global interpreter lock* (GIL) is used internally to ensure that only one thread runs in the Python VM at a time. In general, Python offers to switch among threads only between bytecode instructions; how frequently it switches can be set via `sys.setswitchinterval()`. Each bytecode instruction and therefore all the C implementation code reached from each instruction is therefore atomic from the point of view of a Python program.

In theory, this means an exact accounting requires an exact understanding of the PVM bytecode implementation. In practice, it means that operations on shared variables of built-in data types (ints, lists, dicts, etc) that "look atomic" really are.

For example, the following operations are all atomic (L, L1, L2 are lists, D, D1, D2 are dicts, x, y are objects, i, j are ints):

```
L.append(x)
L1.extend(L2)
x = L[i]
x = L.pop()
L1[i:j] = L2
L.sort()
x = y
x.field = y
D[x] = y
D1.update(D2)
D.keys()
```

These aren't:

```
i = i+1
L.append(L[-1])
L[i] = L[j]
D[x] = D[x] + 1
```

Operations that replace other objects may invoke those other objects' `__del__()` method when their reference count reaches zero, and that can affect things. This is especially true for the mass updates to dictionaries and lists. When in doubt, use a mutex!

4.3.5 Can't we get rid of the Global Interpreter Lock?

The *global interpreter lock* (GIL) is often seen as a hindrance to Python's deployment on high-end multiprocessor server machines, because a multi-threaded Python program effectively only uses one CPU, due to the insistence that (almost) all Python code can only run while the GIL is held.

Back in the days of Python 1.5, Greg Stein actually implemented a comprehensive patch set (the "free threading" patches) that removed the GIL and replaced it with fine-grained locking. Adam Olsen recently did a similar experiment in his python-safethread project. Unfortunately, both experiments exhibited a sharp drop in single-thread performance (at least 30% slower), due to the amount of fine-grained locking necessary to compensate for the removal of the GIL.

This doesn't mean that you can't make good use of Python on multi-CPU machines! You just have to be creative with dividing the work up between multiple *processes* rather than multiple *threads*. The `ProcessPoolExecutor` class in the new `concurrent.futures` module provides an easy way of doing so; the `multiprocessing` module provides a lower-level API in case you want more control over dispatching of tasks.

Judicious use of C extensions will also help; if you use a C extension to perform a time-consuming task, the extension can release the GIL while the thread of execution is in the C code and allow other threads to get some work done. Some standard library modules such as `zlib` and `hashlib` already do this.

It has been suggested that the GIL should be a per-interpreter-state lock rather than truly global; interpreters then wouldn't be able to share objects. Unfortunately, this isn't likely to happen either. It would be a tremendous amount of work, because many object implementations currently have global state. For example, small integers and short strings are cached; these caches would have to be moved to the interpreter state. Other object types have their own free list; these free lists would have to be moved to the interpreter state. And so on.

And I doubt that it can even be done in finite time, because the same problem exists for 3rd party extensions. It is likely that 3rd party extensions are being written at a faster rate than you can convert them to store all their global state in the interpreter state.

And finally, once you have multiple interpreters not sharing any state, what have you gained over running each interpreter in a separate process?

4.4 Input and Output

4.4.1 How do I delete a file? (And other file questions...)

Use `os.remove(filename)` or `os.unlink(filename)`; for documentation, see the `os` module. The two functions are identical; `unlink()` is simply the name of the Unix system call for this function.

To remove a directory, use `os.rmdir()`; use `os.mkdir()` to create one. `os.makedirs(path)` will create any intermediate directories in `path` that don't exist. `os.removedirs(path)` will remove intermediate directories as long as they're empty; if you want to delete an entire directory tree and its contents, use `shutil.rmtree()`.

To rename a file, use `os.rename(old_path, new_path)`.

To truncate a file, open it using `f = open(filename, "rb+")`, and use `f.truncate(offset)`; offset defaults to the current seek position. There's also `os.ftruncate(fd, offset)` for files opened with `os.open()`, where *fd* is the file descriptor (a small integer).

The `shutil` module also contains a number of functions to work on files including `copyfile()`, `copytree()`, and `rmtree()`.

4.4.2 How do I copy a file?

The `shutil` module contains a `copyfile()` function. Note that on MacOS 9 it doesn't copy the resource fork and Finder info.

4.4.3 How do I read (or write) binary data?

To read or write complex binary data formats, it's best to use the `struct` module. It allows you to take a string containing binary data (usually numbers) and convert it to Python objects; and vice versa.

For example, the following code reads two 2-byte integers and one 4-byte integer in big-endian format from a file:

```
import struct

with open(filename, "rb") as f:
    s = f.read(8)
    x, y, z = struct.unpack(">hhl", s)
```

The '>' in the format string forces big-endian data; the letter 'h' reads one "short integer" (2 bytes), and 'l' reads one "long integer" (4 bytes) from the string.

For data that is more regular (e.g. a homogeneous list of ints or floats), you can also use the `array` module.

Note: To read and write binary data, it is mandatory to open the file in binary mode (here, passing `"rb"` to `open()`). If you use `"r"` instead (the default), the file will be open in text mode and `f.read()` will return `str` objects rather than `bytes` objects.

4.4.4 I can't seem to use os.read() on a pipe created with os.popen(); why?

`os.read()` is a low-level function which takes a file descriptor, a small integer representing the opened file. `os.popen()` creates a high-level file object, the same type returned by the built-in `open()` function. Thus, to read n bytes from a pipe p created with `os.popen()`, you need to use `p.read(n)`.

4.4.5 How do I access the serial (RS232) port?

For Win32, POSIX (Linux, BSD, etc.), Jython:

http://pyserial.sourceforge.net

For Unix, see a Usenet post by Mitch Chapman:

https://groups.google.com/groups?selm=34A04430.CF9@ohioee.com

4.4.6 Why doesn't closing sys.stdout (stdin, stderr) really close it?

Python *file objects* are a high-level layer of abstraction on low-level C file descriptors.

For most file objects you create in Python via the built-in `open()` function, `f.close()` marks the Python file object as being closed from Python's point of view, and also arranges to close the underlying C file descriptor. This also happens automatically in `f`'s destructor, when `f` becomes garbage.

But stdin, stdout and stderr are treated specially by Python, because of the special status also given to them by C. Running `sys.stdout.close()` marks the Python-level file object as being closed, but does *not* close the associated C file descriptor.

To close the underlying C file descriptor for one of these three, you should first be sure that's what you really want to do (e.g., you may confuse extension modules trying to do I/O). If it is, use `os.close()`:

```
os.close(stdin.fileno())
os.close(stdout.fileno())
os.close(stderr.fileno())
```

Or you can use the numeric constants 0, 1 and 2, respectively.

4.5 Network/Internet Programming

4.5.1 What WWW tools are there for Python?

See the chapters titled internet and netdata in the Library Reference Manual. Python has many modules that will help you build server-side and client-side web systems.

A summary of available frameworks is maintained by Paul Boddie at https://wiki.python.org/moin/WebProgramming.

Cameron Laird maintains a useful set of pages about Python web technologies at http://phaseit.net/claird/comp.lang.python/web_python.

4.5.2 How can I mimic CGI form submission (METHOD=POST)?

I would like to retrieve web pages that are the result of POSTing a form. Is there existing code that would let me do this easily?

Yes. Here's a simple example that uses urllib.request:

```
#!/usr/local/bin/python

import urllib.request

# build the query string
```

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```
qs = "First=Josephine&MI=Q&Last=Public"

# connect and send the server a path
req = urllib.request.urlopen('http://www.some-server.out-there'
                             '/cgi-bin/some-cgi-script', data=qs)
with req:
    msg, hdrs = req.read(), req.info()
```

Note that in general for percent-encoded POST operations, query strings must be quoted using `urllib.parse.urlencode()`. For example, to send `name=Guy Steele, Jr.`:

```
>>> import urllib.parse
>>> urllib.parse.urlencode({'name': 'Guy Steele, Jr.'})
'name=Guy+Steele%2C+Jr.'
```

See also:

urllib-howto for extensive examples.

4.5.3 What module should I use to help with generating HTML?

You can find a collection of useful links on the Web Programming wiki page.

4.5.4 How do I send mail from a Python script?

Use the standard library module `smtplib`.

Here's a very simple interactive mail sender that uses it. This method will work on any host that supports an SMTP listener.

```
import sys, smtplib

fromaddr = input("From: ")
toaddrs  = input("To: ").split(',')
print("Enter message, end with ^D:")
msg = ''
while True:
    line = sys.stdin.readline()
    if not line:
        break
    msg += line

# The actual mail send
server = smtplib.SMTP('localhost')
server.sendmail(fromaddr, toaddrs, msg)
server.quit()
```

A Unix-only alternative uses sendmail. The location of the sendmail program varies between systems; sometimes it is `/usr/lib/sendmail`, sometimes `/usr/sbin/sendmail`. The sendmail manual page will help you out. Here's some sample code:

```
import os

SENDMAIL = "/usr/sbin/sendmail"  # sendmail location
p = os.popen("%s -t -i" % SENDMAIL, "w")
```

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```
p.write("To: receiver@example.com\n")
p.write("Subject: test\n")
p.write("\n")  # blank line separating headers from body
p.write("Some text\n")
p.write("some more text\n")
sts = p.close()
if sts != 0:
    print("Sendmail exit status", sts)
```

4.5.5 How do I avoid blocking in the connect() method of a socket?

The `select` module is commonly used to help with asynchronous I/O on sockets.

To prevent the TCP connect from blocking, you can set the socket to non-blocking mode. Then when you do the `connect()`, you will either connect immediately (unlikely) or get an exception that contains the error number as `.errno`. `errno.EINPROGRESS` indicates that the connection is in progress, but hasn't finished yet. Different OSes will return different values, so you're going to have to check what's returned on your system.

You can use the `connect_ex()` method to avoid creating an exception. It will just return the errno value. To poll, you can call `connect_ex()` again later – `0` or `errno.EISCONN` indicate that you're connected – or you can pass this socket to select to check if it's writable.

Note: The `asyncore` module presents a framework-like approach to the problem of writing non-blocking networking code. The third-party Twisted library is a popular and feature-rich alternative.

4.6 Databases

4.6.1 Are there any interfaces to database packages in Python?

Yes.

Interfaces to disk-based hashes such as `DBM` and `GDBM` are also included with standard Python. There is also the `sqlite3` module, which provides a lightweight disk-based relational database.

Support for most relational databases is available. See the DatabaseProgramming wiki page for details.

4.6.2 How do you implement persistent objects in Python?

The `pickle` library module solves this in a very general way (though you still can't store things like open files, sockets or windows), and the `shelve` library module uses pickle and (g)dbm to create persistent mappings containing arbitrary Python objects.

4.7 Mathematics and Numerics

4.7.1 How do I generate random numbers in Python?

The standard module `random` implements a random number generator. Usage is simple:

```
import random
random.random()
```

This returns a random floating point number in the range [0, 1).

There are also many other specialized generators in this module, such as:

- `randrange(a, b)` chooses an integer in the range [a, b).
- `uniform(a, b)` chooses a floating point number in the range [a, b).
- `normalvariate(mean, sdev)` samples the normal (Gaussian) distribution.

Some higher-level functions operate on sequences directly, such as:

- `choice(S)` chooses random element from a given sequence
- `shuffle(L)` shuffles a list in-place, i.e. permutes it randomly

There's also a `Random` class you can instantiate to create independent multiple random number generators.

CHAPTER

FIVE

EXTENDING/EMBEDDING FAQ

5.1 Can I create my own functions in C?

Yes, you can create built-in modules containing functions, variables, exceptions and even new types in C. This is explained in the document extending-index.

Most intermediate or advanced Python books will also cover this topic.

5.2 Can I create my own functions in C++?

Yes, using the C compatibility features found in C++. Place `extern "C" { ... }` around the Python include files and put `extern "C"` before each function that is going to be called by the Python interpreter. Global or static C++ objects with constructors are probably not a good idea.

5.3 Writing C is hard; are there any alternatives?

There are a number of alternatives to writing your own C extensions, depending on what you're trying to do.

Cython and its relative Pyrex are compilers that accept a slightly modified form of Python and generate the corresponding C code. Cython and Pyrex make it possible to write an extension without having to learn Python's C API.

If you need to interface to some C or C++ library for which no Python extension currently exists, you can try wrapping the library's data types and functions with a tool such as SWIG. SIP, CXX Boost, or Weave are also alternatives for wrapping C++ libraries.

5.4 How can I execute arbitrary Python statements from C?

The highest-level function to do this is `PyRun_SimpleString()` which takes a single string argument to be executed in the context of the module `__main__` and returns `0` for success and `-1` when an exception occurred (including `SyntaxError`). If you want more control, use `PyRun_String()`; see the source for `PyRun_SimpleString()` in `Python/pythonrun.c`.

5.5 How can I evaluate an arbitrary Python expression from C?

Call the function `PyRun_String()` from the previous question with the start symbol `Py_eval_input`; it parses an expression, evaluates it and returns its value.

5.6 How do I extract C values from a Python object?

That depends on the object's type. If it's a tuple, `PyTuple_Size()` returns its length and `PyTuple_GetItem()` returns the item at a specified index. Lists have similar functions, `PyListSize()` and `PyList_GetItem()`.

For bytes, `PyBytes_Size()` returns its length and `PyBytes_AsStringAndSize()` provides a pointer to its value and its length. Note that Python bytes objects may contain null bytes so C's `strlen()` should not be used.

To test the type of an object, first make sure it isn't *NULL*, and then use `PyBytes_Check()`, `PyTuple_Check()`, `PyList_Check()`, etc.

There is also a high-level API to Python objects which is provided by the so-called 'abstract' interface – read `Include/abstract.h` for further details. It allows interfacing with any kind of Python sequence using calls like `PySequence_Length()`, `PySequence_GetItem()`, etc. as well as many other useful protocols such as numbers (`PyNumber_Index()` et al.) and mappings in the PyMapping APIs.

5.7 How do I use Py_BuildValue() to create a tuple of arbitrary length?

You can't. Use `PyTuple_Pack()` instead.

5.8 How do I call an object's method from C?

The `PyObject_CallMethod()` function can be used to call an arbitrary method of an object. The parameters are the object, the name of the method to call, a format string like that used with `Py_BuildValue()`, and the argument values:

```
PyObject *
PyObject_CallMethod(PyObject *object, const char *method_name,
                    const char *arg_format, ...);
```

This works for any object that has methods – whether built-in or user-defined. You are responsible for eventually `Py_DECREF()`'ing the return value.

To call, e.g., a file object's "seek" method with arguments 10, 0 (assuming the file object pointer is "f"):

```
res = PyObject_CallMethod(f, "seek", "(ii)", 10, 0);
if (res == NULL) {
        ... an exception occurred ...
}
else {
        Py_DECREF(res);
}
```

Note that since `PyObject_CallObject()` *always* wants a tuple for the argument list, to call a function without arguments, pass "()" for the format, and to call a function with one argument, surround the argument in parentheses, e.g. "(i)".

5.9 How do I catch the output from PyErr_Print() (or anything that prints to stdout/stderr)?

In Python code, define an object that supports the `write()` method. Assign this object to `sys.stdout` and `sys.stderr`. Call print_error, or just allow the standard traceback mechanism to work. Then, the output will go wherever your `write()` method sends it.

The easiest way to do this is to use the `io.StringIO` class:

```
>>> import io, sys
>>> sys.stdout = io.StringIO()
>>> print('foo')
>>> print('hello world!')
>>> sys.stderr.write(sys.stdout.getvalue())
foo
hello world!
```

A custom object to do the same would look like this:

```
>>> import io, sys
>>> class StdoutCatcher(io.TextIOBase):
...     def __init__(self):
...         self.data = []
...     def write(self, stuff):
...         self.data.append(stuff)
...
>>> import sys
>>> sys.stdout = StdoutCatcher()
>>> print('foo')
>>> print('hello world!')
>>> sys.stderr.write(''.join(sys.stdout.data))
foo
hello world!
```

5.10 How do I access a module written in Python from C?

You can get a pointer to the module object as follows:

```
module = PyImport_ImportModule("<modulename>");
```

If the module hasn't been imported yet (i.e. it is not yet present in `sys.modules`), this initializes the module; otherwise it simply returns the value of `sys.modules["<modulename>"]`. Note that it doesn't enter the module into any namespace – it only ensures it has been initialized and is stored in `sys.modules`.

You can then access the module's attributes (i.e. any name defined in the module) as follows:

```
attr = PyObject_GetAttrString(module, "<attrname>");
```

Calling `PyObject_SetAttrString()` to assign to variables in the module also works.

5.11 How do I interface to C++ objects from Python?

Depending on your requirements, there are many approaches. To do this manually, begin by reading the "Extending and Embedding" document. Realize that for the Python run-time system, there isn't a whole

lot of difference between C and C++ – so the strategy of building a new Python type around a C structure (pointer) type will also work for C++ objects.

For C++ libraries, see *Writing C is hard; are there any alternatives?*.

5.12 I added a module using the Setup file and the make fails; why?

Setup must end in a newline, if there is no newline there, the build process fails. (Fixing this requires some ugly shell script hackery, and this bug is so minor that it doesn't seem worth the effort.)

5.13 How do I debug an extension?

When using GDB with dynamically loaded extensions, you can't set a breakpoint in your extension until your extension is loaded.

In your `.gdbinit` file (or interactively), add the command:

```
br _PyImport_LoadDynamicModule
```

Then, when you run GDB:

```
$ gdb /local/bin/python
gdb) run myscript.py
gdb) continue # repeat until your extension is loaded
gdb) finish   # so that your extension is loaded
gdb) br myfunction.c:50
gdb) continue
```

5.14 I want to compile a Python module on my Linux system, but some files are missing. Why?

Most packaged versions of Python don't include the `/usr/lib/python2.x/config/` directory, which contains various files required for compiling Python extensions.

For Red Hat, install the python-devel RPM to get the necessary files.

For Debian, run `apt-get install python-dev`.

5.15 How do I tell "incomplete input" from "invalid input"?

Sometimes you want to emulate the Python interactive interpreter's behavior, where it gives you a continuation prompt when the input is incomplete (e.g. you typed the start of an "if" statement or you didn't close your parentheses or triple string quotes), but it gives you a syntax error message immediately when the input is invalid.

In Python you can use the `codeop` module, which approximates the parser's behavior sufficiently. IDLE uses this, for example.

The easiest way to do it in C is to call `PyRun_InteractiveLoop()` (perhaps in a separate thread) and let the Python interpreter handle the input for you. You can also set the `PyOS_ReadlineFunctionPointer()` to point at your custom input function. See `Modules/readline.c` and `Parser/myreadline.c` for more hints.

However sometimes you have to run the embedded Python interpreter in the same thread as your rest application and you can't allow the `PyRun_InteractiveLoop()` to stop while waiting for user input. The one solution then is to call `PyParser_ParseString()` and test for `e.error` equal to `E_EOF`, which means the input is incomplete). Here's a sample code fragment, untested, inspired by code from Alex Farber:

```
#include <Python.h>
#include <node.h>
#include <errcode.h>
#include <grammar.h>
#include <parsetok.h>
#include <compile.h>

int testcomplete(char *code)
  /* code should end in \n */
  /* return -1 for error, 0 for incomplete, 1 for complete */
{
  node *n;
  perrdetail e;

  n = PyParser_ParseString(code, &_PyParser_Grammar,
                           Py_file_input, &e);
  if (n == NULL) {
    if (e.error == E_EOF)
      return 0;
    return -1;
  }

  PyNode_Free(n);
  return 1;
}
```

Another solution is trying to compile the received string with `Py_CompileString()`. If it compiles without errors, try to execute the returned code object by calling `PyEval_EvalCode()`. Otherwise save the input for later. If the compilation fails, find out if it's an error or just more input is required - by extracting the message string from the exception tuple and comparing it to the string "unexpected EOF while parsing". Here is a complete example using the GNU readline library (you may want to ignore **SIGINT** while calling readline()):

```
#include <stdio.h>
#include <readline.h>

#include <Python.h>
#include <object.h>
#include <compile.h>
#include <eval.h>

int main (int argc, char* argv[])
{
  int i, j, done = 0;                           /* lengths of line, code */
  char ps1[] = ">>> ";
  char ps2[] = "... ";
  char *prompt = ps1;
  char *msg, *line, *code = NULL;
  PyObject *src, *glb, *loc;
  PyObject *exc, *val, *trb, *obj, *dum;

  Py_Initialize ();
```

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```
loc = PyDict_New ();
glb = PyDict_New ();
PyDict_SetItemString (glb, "__builtins__", PyEval_GetBuiltins ());

while (!done)
{
  line = readline (prompt);

  if (NULL == line)                         /* Ctrl-D pressed */
  {
    done = 1;
  }
  else
  {
    i = strlen (line);

    if (i > 0)
      add_history (line);                   /* save non-empty lines */

    if (NULL == code)                       /* nothing in code yet */
      j = 0;
    else
      j = strlen (code);

    code = realloc (code, i + j + 2);
    if (NULL == code)                       /* out of memory */
      exit (1);

    if (0 == j)                             /* code was empty, so */
      code[0] = '\0';                       /* keep strncat happy */

    strncat (code, line, i);                /* append line to code */
    code[i + j] = '\n';                     /* append '\n' to code */
    code[i + j + 1] = '\0';

    src = Py_CompileString (code, "<stdin>", Py_single_input);

    if (NULL != src)                        /* compiled just fine - */
    {
      if (ps1  == prompt ||                 /* ">>> " or */
          '\n' == code[i + j - 1])          /* "... " and double '\n' */
      {                                             /* so execute it */
        dum = PyEval_EvalCode (src, glb, loc);
        Py_XDECREF (dum);
        Py_XDECREF (src);
        free (code);
        code = NULL;
        if (PyErr_Occurred ())
          PyErr_Print ();
        prompt = ps1;
      }
    }                                       /* syntax error or E_EOF? */
    else if (PyErr_ExceptionMatches (PyExc_SyntaxError))
    {
      PyErr_Fetch (&exc, &val, &trb);       /* clears exception! */
```

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```
        if (PyArg_ParseTuple (val, "sO", &msg, &obj) &&
            !strcmp (msg, "unexpected EOF while parsing")) /* E_EOF */
        {
          Py_XDECREF (exc);
          Py_XDECREF (val);
          Py_XDECREF (trb);
          prompt = ps2;
        }
        else                                    /* some other syntax error */
        {
          PyErr_Restore (exc, val, trb);
          PyErr_Print ();
          free (code);
          code = NULL;
          prompt = ps1;
        }
      }
      else                                      /* some non-syntax error */
      {
        PyErr_Print ();
        free (code);
        code = NULL;
        prompt = ps1;
      }

      free (line);
    }
  }

  Py_XDECREF(glb);
  Py_XDECREF(loc);
  Py_Finalize();
  exit(0);
}
```

5.16 How do I find undefined g++ symbols __builtin_new or __pure_virtual?

To dynamically load g++ extension modules, you must recompile Python, relink it using g++ (change LINKCC in the Python Modules Makefile), and link your extension module using g++ (e.g., `g++ -shared -o mymodule.so mymodule.o`).

5.17 Can I create an object class with some methods implemented in C and others in Python (e.g. through inheritance)?

Yes, you can inherit from built-in classes such as `int`, `list`, `dict`, etc.

The Boost Python Library (BPL, http://www.boost.org/libs/python/doc/index.html) provides a way of doing this from C++ (i.e. you can inherit from an extension class written in C++ using the BPL).

CHAPTER

SIX

PYTHON ON WINDOWS FAQ

6.1 How do I run a Python program under Windows?

This is not necessarily a straightforward question. If you are already familiar with running programs from the Windows command line then everything will seem obvious; otherwise, you might need a little more guidance.

Python Development on XP

This series of screencasts aims to get you up and running with Python on Windows XP. The knowledge is distilled into 1.5 hours and will get you up and running with the right Python distribution, coding in your choice of IDE, and debugging and writing solid code with unit-tests.

Unless you use some sort of integrated development environment, you will end up *typing* Windows commands into what is variously referred to as a "DOS window" or "Command prompt window". Usually you can create such a window from your Start menu; under Windows 7 the menu selection is *Start* → *Programs* → *Accessories* → *Command Prompt*. You should be able to recognize when you have started such a window because you will see a Windows "command prompt", which usually looks like this:

```
C:\>
```

The letter may be different, and there might be other things after it, so you might just as easily see something like:

```
D:\YourName\Projects\Python>
```

depending on how your computer has been set up and what else you have recently done with it. Once you have started such a window, you are well on the way to running Python programs.

You need to realize that your Python scripts have to be processed by another program called the Python *interpreter*. The interpreter reads your script, compiles it into bytecodes, and then executes the bytecodes to run your program. So, how do you arrange for the interpreter to handle your Python?

First, you need to make sure that your command window recognises the word "python" as an instruction to start the interpreter. If you have opened a command window, you should try entering the command `python` and hitting return:

```
C:\Users\YourName> python
```

You should then see something like:

```
Python 3.3.0 (v3.3.0:bd8afb90ebf2, Sep 29 2012, 10:55:48) [MSC v.1600 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

You have started the interpreter in "interactive mode". That means you can enter Python statements or expressions interactively and have them executed or evaluated while you wait. This is one of Python's strongest features. Check it by entering a few expressions of your choice and seeing the results:

```
>>> print("Hello")
Hello
>>> "Hello" * 3
'HelloHelloHello'
```

Many people use the interactive mode as a convenient yet highly programmable calculator. When you want to end your interactive Python session, hold the `Ctrl` key down while you enter a `Z`, then hit the "`Enter`" key to get back to your Windows command prompt.

You may also find that you have a Start-menu entry such as *Start → Programs → Python 3.3 → Python (command line)* that results in you seeing the `>>>` prompt in a new window. If so, the window will disappear after you enter the `Ctrl-Z` character; Windows is running a single "python" command in the window, and closes it when you terminate the interpreter.

If the `python` command, instead of displaying the interpreter prompt `>>>`, gives you a message like:

```
'python' is not recognized as an internal or external command, operable program or batch file.
```

Adding Python to DOS Path

Python is not added to the DOS path by default. This screencast will walk you through the steps to add the correct entry to the *System Path*, allowing Python to be executed from the command-line by all users.

or:

```
Bad command or filename
```

then you need to make sure that your computer knows where to find the Python interpreter. To do this you will have to modify a setting called PATH, which is a list of directories where Windows will look for programs.

You should arrange for Python's installation directory to be added to the PATH of every command window as it starts. If you installed Python fairly recently then the command

```
dir C:\py*
```

will probably tell you where it is installed; the usual location is something like `C:\Python33`. Otherwise you will be reduced to a search of your whole disk … use *Tools* → *Find* or hit the *Search* button and look for "python.exe". Supposing you discover that Python is installed in the `C:\Python33` directory (the default at the time of writing), you should make sure that entering the command

```
c:\Python33\python
```

starts up the interpreter as above (and don't forget you'll need a "`Ctrl-Z`" and an "`Enter`" to get out of it). Once you have verified the directory, you can add it to the system path to make it easier to start Python by just running the `python` command. This is currently an option in the installer as of CPython 3.3.

More information about environment variables can be found on the Using Python on Windows page.

6.2 How do I make Python scripts executable?

On Windows, the standard Python installer already associates the .py extension with a file type (Python.File) and gives that file type an open command that runs the interpreter (`D:\Program Files\Python\python.exe "%1" %*`). This is enough to make scripts executable from the command prompt as 'foo.py'. If you'd rather be able to execute the script by simple typing 'foo' with no extension you need to add .py to the PATHEXT environment variable.

6.3 Why does Python sometimes take so long to start?

Usually Python starts very quickly on Windows, but occasionally there are bug reports that Python suddenly begins to take a long time to start up. This is made even more puzzling because Python will work fine on other Windows systems which appear to be configured identically.

The problem may be caused by a misconfiguration of virus checking software on the problem machine. Some virus scanners have been known to introduce startup overhead of two orders of magnitude when the scanner is configured to monitor all reads from the filesystem. Try checking the configuration of virus scanning software on your systems to ensure that they are indeed configured identically. McAfee, when configured to scan all file system read activity, is a particular offender.

6.4 How do I make an executable from a Python script?

See cx_Freeze for a distutils extension that allows you to create console and GUI executables from Python code. py2exe, the most popular extension for building Python 2.x-based executables, does not yet support Python 3 but a version that does is in development.

6.5 Is a `*.pyd` file the same as a DLL?

Yes, .pyd files are dll's, but there are a few differences. If you have a DLL named `foo.pyd`, then it must have a function `PyInit_foo()`. You can then write Python "import foo", and Python will search for foo.pyd (as well as foo.py, foo.pyc) and if it finds it, will attempt to call `PyInit_foo()` to initialize it. You do not link your .exe with foo.lib, as that would cause Windows to require the DLL to be present.

Note that the search path for foo.pyd is PYTHONPATH, not the same as the path that Windows uses to search for foo.dll. Also, foo.pyd need not be present to run your program, whereas if you linked your program with a dll, the dll is required. Of course, foo.pyd is required if you want to say `import foo`. In a DLL,

linkage is declared in the source code with `__declspec(dllexport)`. In a .pyd, linkage is defined in a list of available functions.

6.6 How can I embed Python into a Windows application?

Embedding the Python interpreter in a Windows app can be summarized as follows:

1. Do _not_ build Python into your .exe file directly. On Windows, Python must be a DLL to handle importing modules that are themselves DLL's. (This is the first key undocumented fact.) Instead, link to `python`*NN*`.dll`; it is typically installed in `C:\Windows\System`. *NN* is the Python version, a number such as "33" for Python 3.3.

   You can link to Python in two different ways. Load-time linking means linking against `python`*NN*`.lib`, while run-time linking means linking against `python`*NN*`.dll`. (General note: `python`*NN*`.lib` is the so-called "import lib" corresponding to `python`*NN*`.dll`. It merely defines symbols for the linker.)

   Run-time linking greatly simplifies link options; everything happens at run time. Your code must load `python`*NN*`.dll` using the Windows `LoadLibraryEx()` routine. The code must also use access routines and data in `python`*NN*`.dll` (that is, Python's C API's) using pointers obtained by the Windows `GetProcAddress()` routine. Macros can make using these pointers transparent to any C code that calls routines in Python's C API.

   Borland note: convert `python`*NN*`.lib` to OMF format using Coff2Omf.exe first.

2. If you use SWIG, it is easy to create a Python "extension module" that will make the app's data and methods available to Python. SWIG will handle just about all the grungy details for you. The result is C code that you link *into* your .exe file (!) You do _not_ have to create a DLL file, and this also simplifies linking.

3. SWIG will create an init function (a C function) whose name depends on the name of the extension module. For example, if the name of the module is leo, the init function will be called initleo(). If you use SWIG shadow classes, as you should, the init function will be called initleoc(). This initializes a mostly hidden helper class used by the shadow class.

   The reason you can link the C code in step 2 into your .exe file is that calling the initialization function is equivalent to importing the module into Python! (This is the second key undocumented fact.)

4. In short, you can use the following code to initialize the Python interpreter with your extension module.

```
#include "python.h"
...
Py_Initialize();  // Initialize Python.
initmyAppc();  // Initialize (import) the helper class.
PyRun_SimpleString("import myApp");  // Import the shadow class.
```

5. There are two problems with Python's C API which will become apparent if you use a compiler other than MSVC, the compiler used to build pythonNN.dll.

   Problem 1: The so-called "Very High Level" functions that take FILE * arguments will not work in a multi-compiler environment because each compiler's notion of a struct FILE will be different. From an implementation standpoint these are very _low_ level functions.

   Problem 2: SWIG generates the following code when generating wrappers to void functions:

```
Py_INCREF(Py_None);
_resultobj = Py_None;
return _resultobj;
```

Alas, Py_None is a macro that expands to a reference to a complex data structure called _Py_NoneStruct inside pythonNN.dll. Again, this code will fail in a mult-compiler environment. Replace such code by:

```
return Py_BuildValue("");
```

It may be possible to use SWIG's `%typemap` command to make the change automatically, though I have not been able to get this to work (I'm a complete SWIG newbie).

6. Using a Python shell script to put up a Python interpreter window from inside your Windows app is not a good idea; the resulting window will be independent of your app's windowing system. Rather, you (or the wxPythonWindow class) should create a "native" interpreter window. It is easy to connect that window to the Python interpreter. You can redirect Python's i/o to _any_ object that supports read and write, so all you need is a Python object (defined in your extension module) that contains read() and write() methods.

6.7 How do I keep editors from inserting tabs into my Python source?

The FAQ does not recommend using tabs, and the Python style guide, **PEP 8**, recommends 4 spaces for distributed Python code; this is also the Emacs python-mode default.

Under any editor, mixing tabs and spaces is a bad idea. MSVC is no different in this respect, and is easily configured to use spaces: Take *Tools* → *Options* → *Tabs*, and for file type "Default" set "Tab size" and "Indent size" to 4, and select the "Insert spaces" radio button.

Python raises `IndentationError` or `TabError` if mixed tabs and spaces are causing problems in leading whitespace. You may also run the `tabnanny` module to check a directory tree in batch mode.

6.8 How do I check for a keypress without blocking?

Use the msvcrt module. This is a standard Windows-specific extension module. It defines a function `kbhit()` which checks whether a keyboard hit is present, and `getch()` which gets one character without echoing it.

6.9 How do I emulate os.kill() in Windows?

Prior to Python 2.7 and 3.2, to terminate a process, you can use `ctypes`:

```
import ctypes

def kill(pid):
    """kill function for Win32"""
    kernel32 = ctypes.windll.kernel32
    handle = kernel32.OpenProcess(1, 0, pid)
    return (0 != kernel32.TerminateProcess(handle, 0))
```

In 2.7 and 3.2, `os.kill()` is implemented similar to the above function, with the additional feature of being able to send `Ctrl+C` and `Ctrl+Break` to console subprocesses which are designed to handle those signals. See `os.kill()` for further details.

6.10 How do I extract the downloaded documentation on Windows?

Sometimes, when you download the documentation package to a Windows machine using a web browser, the file extension of the saved file ends up being .EXE. This is a mistake; the extension should be .TGZ.

Simply rename the downloaded file to have the .TGZ extension, and WinZip will be able to handle it. (If your copy of WinZip doesn't, get a newer one from https://www.winzip.com.)

CHAPTER

SEVEN

GRAPHIC USER INTERFACE FAQ

7.1 General GUI Questions

7.2 What platform-independent GUI toolkits exist for Python?

Depending on what platform(s) you are aiming at, there are several. Some of them haven't been ported to Python 3 yet. At least *Tkinter* and *Qt* are known to be Python 3-compatible.

7.2.1 Tkinter

Standard builds of Python include an object-oriented interface to the Tcl/Tk widget set, called tkinter. This is probably the easiest to install (since it comes included with most binary distributions of Python) and use. For more info about Tk, including pointers to the source, see the Tcl/Tk home page. Tcl/Tk is fully portable to the Mac OS X, Windows, and Unix platforms.

7.2.2 wxWidgets

wxWidgets (https://www.wxwidgets.org) is a free, portable GUI class library written in C++ that provides a native look and feel on a number of platforms, with Windows, Mac OS X, GTK, X11, all listed as current stable targets. Language bindings are available for a number of languages including Python, Perl, Ruby, etc.

wxPython is the Python binding for wxwidgets. While it often lags slightly behind the official wxWidgets releases, it also offers a number of features via pure Python extensions that are not available in other language bindings. There is an active wxPython user and developer community.

Both wxWidgets and wxPython are free, open source, software with permissive licences that allow their use in commercial products as well as in freeware or shareware.

7.2.3 Qt

There are bindings available for the Qt toolkit (using either PyQt or PySide) and for KDE (PyKDE4). PyQt is currently more mature than PySide, but you must buy a PyQt license from Riverbank Computing if you want to write proprietary applications. PySide is free for all applications.

Qt 4.5 upwards is licensed under the LGPL license; also, commercial licenses are available from The Qt Company.

7.2.4 Gtk+

The GObject introspection bindings for Python allow you to write GTK+ 3 applications. There is also a Python GTK+ 3 Tutorial.

The older PyGtk bindings for the Gtk+ 2 toolkit have been implemented by James Henstridge; see <http://www.pygtk.org>.

7.2.5 Kivy

Kivy is a cross-platform GUI library supporting both desktop operating systems (Windows, macOS, Linux) and mobile devices (Android, iOS). It is written in Python and Cython, and can use a range of windowing backends.

Kivy is free and open source software distributed under the MIT license.

7.2.6 FLTK

Python bindings for the FLTK toolkit, a simple yet powerful and mature cross-platform windowing system, are available from the PyFLTK project.

7.2.7 OpenGL

For OpenGL bindings, see PyOpenGL.

7.3 What platform-specific GUI toolkits exist for Python?

By installing the PyObjc Objective-C bridge, Python programs can use Mac OS X's Cocoa libraries.

Pythonwin by Mark Hammond includes an interface to the Microsoft Foundation Classes and a Python programming environment that's written mostly in Python using the MFC classes.

7.4 Tkinter questions

7.4.1 How do I freeze Tkinter applications?

Freeze is a tool to create stand-alone applications. When freezing Tkinter applications, the applications will not be truly stand-alone, as the application will still need the Tcl and Tk libraries.

One solution is to ship the application with the Tcl and Tk libraries, and point to them at run-time using the `TCL_LIBRARY` and `TK_LIBRARY` environment variables.

To get truly stand-alone applications, the Tcl scripts that form the library have to be integrated into the application as well. One tool supporting that is SAM (stand-alone modules), which is part of the Tix distribution (http://tix.sourceforge.net/).

Build Tix with SAM enabled, perform the appropriate call to `Tclsam_init()`, etc. inside Python's `Modules/tkappinit.c`, and link with libtclsam and libtksam (you might include the Tix libraries as well).

7.4.2 Can I have Tk events handled while waiting for I/O?

On platforms other than Windows, yes, and you don't even need threads! But you'll have to restructure your I/O code a bit. Tk has the equivalent of Xt's `XtAddInput()` call, which allows you to register a callback function which will be called from the Tk mainloop when I/O is possible on a file descriptor. See tkinter-file-handlers.

7.4.3 I can't get key bindings to work in Tkinter: why?

An often-heard complaint is that event handlers bound to events with the `bind()` method don't get handled even when the appropriate key is pressed.

The most common cause is that the widget to which the binding applies doesn't have "keyboard focus". Check out the Tk documentation for the focus command. Usually a widget is given the keyboard focus by clicking in it (but not for labels; see the takefocus option).

CHAPTER

EIGHT

"WHY IS PYTHON INSTALLED ON MY COMPUTER?" FAQ

8.1 What is Python?

Python is a programming language. It's used for many different applications. It's used in some high schools and colleges as an introductory programming language because Python is easy to learn, but it's also used by professional software developers at places such as Google, NASA, and Lucasfilm Ltd.

If you wish to learn more about Python, start with the Beginner's Guide to Python.

8.2 Why is Python installed on my machine?

If you find Python installed on your system but don't remember installing it, there are several possible ways it could have gotten there.

- Perhaps another user on the computer wanted to learn programming and installed it; you'll have to figure out who's been using the machine and might have installed it.
- A third-party application installed on the machine might have been written in Python and included a Python installation. There are many such applications, from GUI programs to network servers and administrative scripts.
- Some Windows machines also have Python installed. At this writing we're aware of computers from Hewlett-Packard and Compaq that include Python. Apparently some of HP/Compaq's administrative tools are written in Python.
- Many Unix-compatible operating systems, such as Mac OS X and some Linux distributions, have Python installed by default; it's included in the base installation.

8.3 Can I delete Python?

That depends on where Python came from.

If someone installed it deliberately, you can remove it without hurting anything. On Windows, use the Add/Remove Programs icon in the Control Panel.

If Python was installed by a third-party application, you can also remove it, but that application will no longer work. You should use that application's uninstaller rather than removing Python directly.

If Python came with your operating system, removing it is not recommended. If you remove it, whatever tools were written in Python will no longer run, and some of them might be important to you. Reinstalling the whole system would then be required to fix things again.

APPENDIX

A

GLOSSARY

>>> The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

... The default Python prompt of the interactive shell when entering code for an indented code block, when within a pair of matching left and right delimiters (parentheses, square brackets, curly braces or triple quotes), or after specifying a decorator.

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See 2to3-reference.

abstract base class Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with magic methods). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections.abc` module), numbers (in the `numbers` module), streams (in the `io` module), import finders and loaders (in the `importlib.abc` module). You can create your own ABCs with the `abc` module.

annotation A label associated with a variable, a class attribute or a function parameter or return value, used by convention as a *type hint*.

Annotations of local variables cannot be accessed at runtime, but annotations of global variables, class attributes, and functions are stored in the `__annotations__` special attribute of modules, classes, and functions, respectively.

See *variable annotation*, *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

argument A value passed to a *function* (or *method*) when calling the function. There are two kinds of argument:

- *keyword argument*: an argument preceded by an identifier (e.g. `name=`) in a function call or passed as a value in a dictionary preceded by `**`. For example, `3` and `5` are both keyword arguments in the following calls to `complex()`:

```
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- *positional argument*: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an *iterable* preceded by `*`. For example, `3` and `5` are both positional arguments in the following calls:

```
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the calls section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the *parameter* glossary entry, the FAQ question on *the difference between arguments and parameters*, and **PEP 362**.

asynchronous context manager An object which controls the environment seen in an `async with` statement by defining `__aenter__()` and `__aexit__()` methods. Introduced by **PEP 492**.

asynchronous generator A function which returns an *asynchronous generator iterator*. It looks like a coroutine function defined with `async def` except that it contains `yield` expressions for producing a series of values usable in an `async for` loop.

Usually refers to a asynchronous generator function, but may refer to an *asynchronous generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

An asynchronous generator function may contain `await` expressions as well as `async for`, and `async with` statements.

asynchronous generator iterator An object created by a *asynchronous generator* function.

This is an *asynchronous iterator* which when called using the `__anext__()` method returns an awaitable object which will execute that the body of the asynchronous generator function until the next `yield` expression.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *asynchronous generator iterator* effectively resumes with another awaitable returned by `__anext__()`, it picks up where it left off. See **PEP 492** and **PEP 525**.

asynchronous iterable An object, that can be used in an `async for` statement. Must return an *asynchronous iterator* from its `__aiter__()` method. Introduced by **PEP 492**.

asynchronous iterator An object that implements `__aiter__()` and `__anext__()` methods. `__anext__` must return an *awaitable* object. `async for` resolves awaitable returned from asynchronous iterator's `__anext__()` method until it raises `StopAsyncIteration` exception. Introduced by **PEP 492**.

attribute A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

awaitable An object that can be used in an `await` expression. Can be a *coroutine* or an object with an `__await__()` method. See also **PEP 492**.

BDFL Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

binary file A *file object* able to read and write *bytes-like objects*. Examples of binary files are files opened in binary mode (`'rb'`, `'wb'` or `'rb+'`), `sys.stdin.buffer`, `sys.stdout.buffer`, and instances of `io.BytesIO` and `gzip.GzipFile`.

See also *text file* for a file object able to read and write `str` objects.

bytes-like object An object that supports the bufferobjects and can export a C-*contiguous* buffer. This includes all `bytes`, `bytearray`, and `array.array` objects, as well as many common `memoryview` objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as "read-write bytes-like objects". Example mutable buffer objects include `bytearray` and a `memoryview` of a `bytearray`. Other operations require the binary data to be stored in immutable objects ("read-only bytes-like objects"); examples of these include `bytes` and a `memoryview` of a `bytes` object.

bytecode Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for the dis module.

class A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

class variable A variable defined in a class and intended to be modified only at class level (i.e., not in an instance of the class).

coercion The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer `3`, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

complex number An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of `-1`), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

context manager An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See **PEP 343**.

contiguous A buffer is considered contiguous exactly if it is either *C-contiguous* or *Fortran contiguous*. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be laid out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

coroutine Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the `async def` statement. See also **PEP 492**.

coroutine function A function which returns a *coroutine* object. A coroutine function may be defined with the `async def` statement, and may contain `await`, `async for`, and `async with` keywords. These were introduced by **PEP 492**.

CPython The canonical implementation of the Python programming language, as distributed on python.org. The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

decorator A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)
```

(continues on next page)

(continued from previous page)

```
@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for function definitions and class definitions for more about decorators.

descriptor Any object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using *a.b* to get, set or delete an attribute looks up the object named *b* in the class dictionary for *a*, but if *b* is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see descriptors.

dictionary An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

dictionary view The objects returned from `dict.keys()`, `dict.values()`, and `dict.items()` are called dictionary views. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use `list(dictview)`. See dict-views.

docstring A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

duck-typing A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note, however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

EAFP Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

expression A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statement*s which cannot be used as expressions, such as `if`. Assignments are also statements, not expressions.

extension module A module written in C or C++, using Python's C API to interact with the core and with user code.

f-string String literals prefixed with `'f'` or `'F'` are commonly called "f-strings" which is short for formatted string literals. See also **PEP 498**.

file object An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw *binary files*, buffered *binary files* and *text files*. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the

`open()` function.

file-like object A synonym for *file object*.

finder An object that tries to find the *loader* for a module that is being imported.

Since Python 3.3, there are two types of finder: *meta path finders* for use with `sys.meta_path`, and *path entry finders* for use with `sys.path_hooks`.

See **PEP 302**, **PEP 420** and **PEP 451** for much more detail.

floor division Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See **PEP 238**.

function A series of statements which returns some value to a caller. It can also be passed zero or more *arguments* which may be used in the execution of the body. See also *parameter*, *method*, and the function section.

function annotation An *annotation* of a function parameter or return value.

Function annotations are usually used for *type hints*: for example this function is expected to take two `int` arguments and is also expected to have an `int` return value:

```
def sum_two_numbers(a: int, b: int) -> int:
   return a + b
```

Function annotation syntax is explained in section function.

See *variable annotation* and **PEP 484**, which describe this functionality.

___future___ A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

garbage collection The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles. The garbage collector can be controlled using the `gc` module.

generator A function which returns a *generator iterator*. It looks like a normal function except that it contains `yield` expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the `next()` function.

Usually refers to a generator function, but may refer to a *generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

generator iterator An object created by a *generator* function.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *generator iterator* resumes, it picks up where it left off (in contrast to functions which start fresh on every invocation).

generator expression An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))         # sum of squares 0, 1, 4, ... 81
285
```

generic function A function composed of multiple functions implementing the same operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the *single dispatch* glossary entry, the `functools.singledispatch()` decorator, and **PEP 443**.

GIL See *global interpreter lock*.

global interpreter lock The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a "free-threaded" interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

hash-based pyc A bytecode cache file that uses the hash rather than the last-modified time of the corresponding source file to determine its validity. See pyc-invalidation.

hashable An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python's immutable built-in objects are hashable; mutable containers (such as lists or dictionaries) are not. Objects which are instances of user-defined classes are hashable by default. They all compare unequal (except with themselves), and their hash value is derived from their `id()`.

IDLE An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

immutable An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

import path A list of locations (or *path entries*) that are searched by the *path based finder* for modules to import. During import, this list of locations usually comes from `sys.path`, but for subpackages it may also come from the parent package's `__path__` attribute.

importing The process by which Python code in one module is made available to Python code in another module.

importer An object that both finds and loads a module; both a *finder* and *loader* object.

interactive Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer's main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

interpreted Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically

have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the *garbage collector*. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the `__main__` module or the script being run has finished executing.

iterable An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict`, *file objects*, and objects of any classes you define with an `__iter__()` method or with a `__getitem__()` method that implements *Sequence* semantics.

Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

iterator An object representing a stream of data. Repeated calls to the iterator's `__next__()` method (or passing it to the built-in function `next()`) return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `__next__()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in typeiter.

key function A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.merge()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example. the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the Sorting HOW TO for examples of how to create and use key functions.

keyword argument See *argument*.

lambda An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [parameters]: expression`

LBYL Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between "the looking" and "the leaping". For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

list A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements is O(1).

list comprehension A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ['{:#04x}'.format(x) for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

loader An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details and `importlib.abc.Loader` for an *abstract base class*.

mapping A container object that supports arbitrary key lookups and implements the methods specified in the `Mapping` or `MutableMapping` abstract base classes. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

meta path finder A *finder* returned by a search of `sys.meta_path`. Meta path finders are related to, but different from *path entry finders*.

See `importlib.abc.MetaPathFinder` for the methods that meta path finders implement.

metaclass The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in metaclasses.

method A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

method resolution order Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order for details of the algorithm used by the Python interpreter since the 2.3 release.

module An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects. Modules are loaded into Python by the process of *importing*.

See also *package*.

module spec A namespace containing the import-related information used to load a module. An instance of `importlib.machinery.ModuleSpec`.

MRO See *method resolution order*.

mutable Mutable objects can change their value but keep their `id()`. See also *immutable*.

named tuple Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

namespace The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `builtins.open` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.islice()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

namespace package A **PEP 420** *package* which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a *regular package* because they have no `__init__.py` file.

See also *module*.

nested scope The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The `nonlocal` allows writing to outer scopes.

new-style class Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python's newer, versatile features like `__slots__`, descriptors, properties, `__getattribute__()`, class methods, and static methods.

object Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

package A Python *module* which can contain submodules or recursively, subpackages. Technically, a package is a Python module with an `__path__` attribute.

See also *regular package* and *namespace package*.

parameter A named entity in a *function* (or method) definition that specifies an *argument* (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- *positional-or-keyword*: specifies an argument that can be passed either *positionally* or as a *keyword argument*. This is the default kind of parameter, for example *foo* and *bar* in the following:

```
def func(foo, bar=None): ...
```

- *positional-only*: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. `abs()`).
- *keyword-only*: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare `*` in the parameter list of the function definition before them, for example *kw_only1* and *kw_only2* in the following:

```
def func(arg, *, kw_only1, kw_only2): ...
```

- *var-positional*: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `*`, for example *args* in the following:

```
def func(*args, **kwargs): ...
```

- *var-keyword*: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `**`, for example *kwargs* in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the *argument* glossary entry, the FAQ question on *the difference between arguments and parameters*, the `inspect.Parameter` class, the function section, and **PEP 362**.

path entry A single location on the *import path* which the *path based finder* consults to find modules for importing.

path entry finder A *finder* returned by a callable on `sys.path_hooks` (i.e. a *path entry hook*) which knows how to locate modules given a *path entry*.

See `importlib.abc.PathEntryFinder` for the methods that path entry finders implement.

path entry hook A callable on the `sys.path_hook` list which returns a *path entry finder* if it knows how to find modules on a specific *path entry*.

path based finder One of the default *meta path finders* which searches an *import path* for modules.

path-like object An object representing a file system path. A path-like object is either a `str` or `bytes` object representing a path, or an object implementing the `os.PathLike` protocol. An object that supports the `os.PathLike` protocol can be converted to a `str` or `bytes` file system path by calling the `os.fspath()` function; `os.fsdecode()` and `os.fsencode()` can be used to guarantee a `str` or `bytes` result instead, respectively. Introduced by **PEP 519**.

PEP Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python or its processes or environment. PEPs should provide a concise technical specification and a rationale for proposed features.

PEPs are intended to be the primary mechanisms for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible for building consensus within the community and documenting dissenting opinions.

See **PEP 1**.

portion A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in **PEP 420**.

positional argument See *argument*.

provisional API A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a "solution of last resort" - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See **PEP 411** for more details.

provisional package See *provisional API*.

Python 3000 Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

Pythonic An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print(piece)
```

qualified name A dotted name showing the "path" from a module's global scope to a class, function or method defined in that module, as defined in **PEP 3155**. For top-level functions and classes, the qualified name is the same as the object's name:

```
>>> class C:
...     class D:
...         def meth(self):
...             pass
...
>>> C.__qualname__
'C'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```

When used to refer to modules, the *fully qualified name* means the entire dotted path to the module, including any parent packages, e.g. `email.mime.text`:

```
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

reference count The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

regular package A traditional *package*, such as a directory containing an `__init__.py` file.

See also *namespace package*.

___slots___ A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

sequence An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `__len__()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `bytes`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

The `collections.abc.Sequence` abstract base class defines a much richer interface that goes beyond just `__getitem__()` and `__len__()`, adding `count()`, `index()`, `__contains__()`, and `__reversed__()`. Types that implement this expanded interface can be registered explicitly using `register()`.

single dispatch A form of *generic function* dispatch where the implementation is chosen based on the type of a single argument.

slice An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally.

special method A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in specialnames.

statement A statement is part of a suite (a "block" of code). A statement is either an *expression* or one of several constructs with a keyword, such as `if`, `while` or `for`.

struct sequence A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

text encoding A codec which encodes Unicode strings to bytes.

text file A *file object* able to read and write `str` objects. Often, a text file actually accesses a byte-oriented datastream and handles the *text encoding* automatically. Examples of text files are files opened in text mode (`'r'` or `'w'`), `sys.stdin`, `sys.stdout`, and instances of `io.StringIO`.

See also *binary file* for a file object able to read and write *bytes-like objects*.

triple-quoted string A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

type The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

type alias A synonym for a type, created by assigning the type to an identifier.

Type aliases are useful for simplifying *type hints*. For example:

```
from typing import List, Tuple

def remove_gray_shades(
        colors: List[Tuple[int, int, int]]) -> List[Tuple[int, int, int]]:
    pass
```

could be made more readable like this:

```
from typing import List, Tuple

Color = Tuple[int, int, int]

def remove_gray_shades(colors: List[Color]) -> List[Color]:
    pass
```

See `typing` and **PEP 484**, which describe this functionality.

type hint An *annotation* that specifies the expected type for a variable, a class attribute, or a function parameter or return value.

Type hints are optional and are not enforced by Python but they are useful to static type analysis tools, and aid IDEs with code completion and refactoring.

Type hints of global variables, class attributes, and functions, but not local variables, can be accessed using `typing.get_type_hints()`.

See `typing` and **PEP 484**, which describe this functionality.

universal newlines A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old

Macintosh convention `'\r'`. See **PEP 278** and **PEP 3116**, as well as `bytes.splitlines()` for an additional use.

variable annotation An *annotation* of a variable or a class attribute.

When annotating a variable or a class attribute, assignment is optional:

```
class C:
    field: 'annotation'
```

Variable annotations are usually used for *type hints*: for example this variable is expected to take `int` values:

```
count: int = 0
```

Variable annotation syntax is explained in section annassign.

See *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

virtual environment A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also `venv`.

virtual machine A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

Zen of Python Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing "`import this`" at the interactive prompt.

APPENDIX

B

ABOUT THESE DOCUMENTS

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the reporting-bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the Docutils project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.

B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See Misc/ACKS in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!

APPENDIX

C

HISTORY AND LICENSE

C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see https://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see https://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see https://opensource.org/ for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2 and above	2.1.1	2001-now	PSF	yes

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```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.

Before using, initialize the state by using init_genrand(seed)
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http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html
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```

C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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Modified by Jack Jansen, CWI, July 1995:
- Use binascii module to do the actual line-by-line conversion
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- Arguments more compliant with Python standard
```

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Original location:
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Solution inspired by code from:
   Samuel Neves (supercop/crypto_auth/siphash24/little)
   djb (supercop/crypto_auth/siphash24/little2)
   Jean-Philippe Aumasson (https://131002.net/siphash/siphash24.c)
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C.3.11 strtod and dtoa

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   */
```

C.3.13 expat

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C.3.14 libffi

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C.3.15 zlib

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jloup@gzip.org          madler@alumni.caltech.edu
```

C.3.16 cfuhash

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```
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C.3.17 libmpdec

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APPENDIX

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Extending and Embedding Python

Release 3.7.0

Guido van Rossum
and the Python development team

July 07, 2018

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This document describes how to write modules in C or C++ to extend the Python interpreter with new modules. Those modules can not only define new functions but also new object types and their methods. The document also describes how to embed the Python interpreter in another application, for use as an extension language. Finally, it shows how to compile and link extension modules so that they can be loaded dynamically (at run time) into the interpreter, if the underlying operating system supports this feature.

This document assumes basic knowledge about Python. For an informal introduction to the language, see tutorial-index. reference-index gives a more formal definition of the language. library-index documents the existing object types, functions and modules (both built-in and written in Python) that give the language its wide application range.

For a detailed description of the whole Python/C API, see the separate c-api-index.

CHAPTER

ONE

RECOMMENDED THIRD PARTY TOOLS

This guide only covers the basic tools for creating extensions provided as part of this version of CPython. Third party tools like Cython, cffi, SWIG and Numba offer both simpler and more sophisticated approaches to creating C and C++ extensions for Python.

See also:

Python Packaging User Guide: Binary Extensions The Python Packaging User Guide not only covers several available tools that simplify the creation of binary extensions, but also discusses the various reasons why creating an extension module may be desirable in the first place.

CHAPTER

TWO

CREATING EXTENSIONS WITHOUT THIRD PARTY TOOLS

This section of the guide covers creating C and C++ extensions without assistance from third party tools. It is intended primarily for creators of those tools, rather than being a recommended way to create your own C extensions.

2.1 Extending Python with C or C++

It is quite easy to add new built-in modules to Python, if you know how to program in C. Such *extension modules* can do two things that can't be done directly in Python: they can implement new built-in object types, and they can call C library functions and system calls.

To support extensions, the Python API (Application Programmers Interface) defines a set of functions, macros and variables that provide access to most aspects of the Python run-time system. The Python API is incorporated in a C source file by including the header `"Python.h"`.

The compilation of an extension module depends on its intended use as well as on your system setup; details are given in later chapters.

Note: The C extension interface is specific to CPython, and extension modules do not work on other Python implementations. In many cases, it is possible to avoid writing C extensions and preserve portability to other implementations. For example, if your use case is calling C library functions or system calls, you should consider using the `ctypes` module or the cffi library rather than writing custom C code. These modules let you write Python code to interface with C code and are more portable between implementations of Python than writing and compiling a C extension module.

2.1.1 A Simple Example

Let's create an extension module called `spam` (the favorite food of Monty Python fans...) and let's say we want to create a Python interface to the C library function `system()`[1]. This function takes a null-terminated character string as argument and returns an integer. We want this function to be callable from Python as follows:

```
>>> import spam
>>> status = spam.system("ls -l")
```

Begin by creating a file `spammodule.c`. (Historically, if a module is called `spam`, the C file containing its implementation is called `spammodule.c`; if the module name is very long, like `spammify`, the module name can be just `spammify.c`.)

[1] An interface for this function already exists in the standard module `os` — it was chosen as a simple and straightforward example.

The first line of our file can be:

```
#include <Python.h>
```

which pulls in the Python API (you can add a comment describing the purpose of the module and a copyright notice if you like).

Note: Since Python may define some pre-processor definitions which affect the standard headers on some systems, you *must* include `Python.h` before any standard headers are included.

All user-visible symbols defined by `Python.h` have a prefix of `Py` or `PY`, except those defined in standard header files. For convenience, and since they are used extensively by the Python interpreter, `"Python.h"` includes a few standard header files: `<stdio.h>`, `<string.h>`, `<errno.h>`, and `<stdlib.h>`. If the latter header file does not exist on your system, it declares the functions `malloc()`, `free()` and `realloc()` directly.

The next thing we add to our module file is the C function that will be called when the Python expression `spam.system(string)` is evaluated (we'll see shortly how it ends up being called):

```
static PyObject *
spam_system(PyObject *self, PyObject *args)
{
    const char *command;
    int sts;

    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = system(command);
    return PyLong_FromLong(sts);
}
```

There is a straightforward translation from the argument list in Python (for example, the single expression `"ls -l"`) to the arguments passed to the C function. The C function always has two arguments, conventionally named *self* and *args*.

The *self* argument points to the module object for module-level functions; for a method it would point to the object instance.

The *args* argument will be a pointer to a Python tuple object containing the arguments. Each item of the tuple corresponds to an argument in the call's argument list. The arguments are Python objects — in order to do anything with them in our C function we have to convert them to C values. The function `PyArg_ParseTuple()` in the Python API checks the argument types and converts them to C values. It uses a template string to determine the required types of the arguments as well as the types of the C variables into which to store the converted values. More about this later.

`PyArg_ParseTuple()` returns true (nonzero) if all arguments have the right type and its components have been stored in the variables whose addresses are passed. It returns false (zero) if an invalid argument list was passed. In the latter case it also raises an appropriate exception so the calling function can return *NULL* immediately (as we saw in the example).

2.1.2 Intermezzo: Errors and Exceptions

An important convention throughout the Python interpreter is the following: when a function fails, it should set an exception condition and return an error value (usually a *NULL* pointer). Exceptions are stored in a static global variable inside the interpreter; if this variable is *NULL* no exception has occurred. A second global variable stores the "associated value" of the exception (the second argument to `raise`). A third variable contains the stack traceback in case the error originated in Python code. These three variables are

the C equivalents of the result in Python of `sys.exc_info()` (see the section on module `sys` in the Python Library Reference). It is important to know about them to understand how errors are passed around.

The Python API defines a number of functions to set various types of exceptions.

The most common one is `PyErr_SetString()`. Its arguments are an exception object and a C string. The exception object is usually a predefined object like `PyExc_ZeroDivisionError`. The C string indicates the cause of the error and is converted to a Python string object and stored as the "associated value" of the exception.

Another useful function is `PyErr_SetFromErrno()`, which only takes an exception argument and constructs the associated value by inspection of the global variable `errno`. The most general function is `PyErr_SetObject()`, which takes two object arguments, the exception and its associated value. You don't need to `Py_INCREF()` the objects passed to any of these functions.

You can test non-destructively whether an exception has been set with `PyErr_Occurred()`. This returns the current exception object, or *NULL* if no exception has occurred. You normally don't need to call `PyErr_Occurred()` to see whether an error occurred in a function call, since you should be able to tell from the return value.

When a function *f* that calls another function *g* detects that the latter fails, *f* should itself return an error value (usually *NULL* or `-1`). It should *not* call one of the `PyErr_*()` functions — one has already been called by *g*. *f*'s caller is then supposed to also return an error indication to *its* caller, again *without* calling `PyErr_*()`, and so on — the most detailed cause of the error was already reported by the function that first detected it. Once the error reaches the Python interpreter's main loop, this aborts the currently executing Python code and tries to find an exception handler specified by the Python programmer.

(There are situations where a module can actually give a more detailed error message by calling another `PyErr_*()` function, and in such cases it is fine to do so. As a general rule, however, this is not necessary, and can cause information about the cause of the error to be lost: most operations can fail for a variety of reasons.)

To ignore an exception set by a function call that failed, the exception condition must be cleared explicitly by calling `PyErr_Clear()`. The only time C code should call `PyErr_Clear()` is if it doesn't want to pass the error on to the interpreter but wants to handle it completely by itself (possibly by trying something else, or pretending nothing went wrong).

Every failing `malloc()` call must be turned into an exception — the direct caller of `malloc()` (or `realloc()`) must call `PyErr_NoMemory()` and return a failure indicator itself. All the object-creating functions (for example, `PyLong_FromLong()`) already do this, so this note is only relevant to those who call `malloc()` directly.

Also note that, with the important exception of `PyArg_ParseTuple()` and friends, functions that return an integer status usually return a positive value or zero for success and `-1` for failure, like Unix system calls.

Finally, be careful to clean up garbage (by making `Py_XDECREF()` or `Py_DECREF()` calls for objects you have already created) when you return an error indicator!

The choice of which exception to raise is entirely yours. There are predeclared C objects corresponding to all built-in Python exceptions, such as `PyExc_ZeroDivisionError`, which you can use directly. Of course, you should choose exceptions wisely — don't use `PyExc_TypeError` to mean that a file couldn't be opened (that should probably be `PyExc_IOError`). If something's wrong with the argument list, the `PyArg_ParseTuple()` function usually raises `PyExc_TypeError`. If you have an argument whose value must be in a particular range or must satisfy other conditions, `PyExc_ValueError` is appropriate.

You can also define a new exception that is unique to your module. For this, you usually declare a static object variable at the beginning of your file:

```
static PyObject *SpamError;
```

and initialize it in your module's initialization function (`PyInit_spam()`) with an exception object (leaving out the error checking for now):

```
PyMODINIT_FUNC
PyInit_spam(void)
{
    PyObject *m;

    m = PyModule_Create(&spammodule);
    if (m == NULL)
        return NULL;

    SpamError = PyErr_NewException("spam.error", NULL, NULL);
    Py_INCREF(SpamError);
    PyModule_AddObject(m, "error", SpamError);
    return m;
}
```

Note that the Python name for the exception object is `spam.error`. The `PyErr_NewException()` function may create a class with the base class being `Exception` (unless another class is passed in instead of *NULL*), described in bltin-exceptions.

Note also that the `SpamError` variable retains a reference to the newly created exception class; this is intentional! Since the exception could be removed from the module by external code, an owned reference to the class is needed to ensure that it will not be discarded, causing `SpamError` to become a dangling pointer. Should it become a dangling pointer, C code which raises the exception could cause a core dump or other unintended side effects.

We discuss the use of `PyMODINIT_FUNC` as a function return type later in this sample.

The `spam.error` exception can be raised in your extension module using a call to `PyErr_SetString()` as shown below:

```
static PyObject *
spam_system(PyObject *self, PyObject *args)
{
    const char *command;
    int sts;

    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = system(command);
    if (sts < 0) {
        PyErr_SetString(SpamError, "System command failed");
        return NULL;
    }
    return PyLong_FromLong(sts);
}
```

2.1.3 Back to the Example

Going back to our example function, you should now be able to understand this statement:

```
if (!PyArg_ParseTuple(args, "s", &command))
    return NULL;
```

It returns *NULL* (the error indicator for functions returning object pointers) if an error is detected in the argument list, relying on the exception set by `PyArg_ParseTuple()`. Otherwise the string value of the

argument has been copied to the local variable `command`. This is a pointer assignment and you are not supposed to modify the string to which it points (so in Standard C, the variable `command` should properly be declared as `const char *command`).

The next statement is a call to the Unix function `system()`, passing it the string we just got from `PyArg_ParseTuple()`:

```
sts = system(command);
```

Our `spam.system()` function must return the value of `sts` as a Python object. This is done using the function `PyLong_FromLong()`.

```
return PyLong_FromLong(sts);
```

In this case, it will return an integer object. (Yes, even integers are objects on the heap in Python!)

If you have a C function that returns no useful argument (a function returning `void`), the corresponding Python function must return `None`. You need this idiom to do so (which is implemented by the `Py_RETURN_NONE` macro):

```
Py_INCREF(Py_None);
return Py_None;
```

`Py_None` is the C name for the special Python object `None`. It is a genuine Python object rather than a *NULL* pointer, which means "error" in most contexts, as we have seen.

2.1.4 The Module's Method Table and Initialization Function

I promised to show how `spam_system()` is called from Python programs. First, we need to list its name and address in a "method table":

```
static PyMethodDef SpamMethods[] = {
    ...
    {"system",  spam_system, METH_VARARGS,
     "Execute a shell command."},
    ...
    {NULL, NULL, 0, NULL}        /* Sentinel */
};
```

Note the third entry (`METH_VARARGS`). This is a flag telling the interpreter the calling convention to be used for the C function. It should normally always be `METH_VARARGS` or `METH_VARARGS | METH_KEYWORDS`; a value of `0` means that an obsolete variant of `PyArg_ParseTuple()` is used.

When using only `METH_VARARGS`, the function should expect the Python-level parameters to be passed in as a tuple acceptable for parsing via `PyArg_ParseTuple()`; more information on this function is provided below.

The `METH_KEYWORDS` bit may be set in the third field if keyword arguments should be passed to the function. In this case, the C function should accept a third `PyObject *` parameter which will be a dictionary of keywords. Use `PyArg_ParseTupleAndKeywords()` to parse the arguments to such a function.

The method table must be referenced in the module definition structure:

```
static struct PyModuleDef spammodule = {
    PyModuleDef_HEAD_INIT,
    "spam",   /* name of module */
    spam_doc, /* module documentation, may be NULL */
    -1,       /* size of per-interpreter state of the module,
```

(continues on next page)

(continued from previous page)

```
                or -1 if the module keeps state in global variables. */
    SpamMethods
};
```

This structure, in turn, must be passed to the interpreter in the module's initialization function. The initialization function must be named `PyInit_name()`, where *name* is the name of the module, and should be the only non-`static` item defined in the module file:

```
PyMODINIT_FUNC
PyInit_spam(void)
{
    return PyModule_Create(&spammodule);
}
```

Note that PyMODINIT_FUNC declares the function as `PyObject *` return type, declares any special linkage declarations required by the platform, and for C++ declares the function as `extern "C"`.

When the Python program imports module `spam` for the first time, `PyInit_spam()` is called. (See below for comments about embedding Python.) It calls `PyModule_Create()`, which returns a module object, and inserts built-in function objects into the newly created module based upon the table (an array of `PyMethodDef` structures) found in the module definition. `PyModule_Create()` returns a pointer to the module object that it creates. It may abort with a fatal error for certain errors, or return *NULL* if the module could not be initialized satisfactorily. The init function must return the module object to its caller, so that it then gets inserted into `sys.modules`.

When embedding Python, the `PyInit_spam()` function is not called automatically unless there's an entry in the `PyImport_Inittab` table. To add the module to the initialization table, use `PyImport_AppendInittab()`, optionally followed by an import of the module:

```
int
main(int argc, char *argv[])
{
    wchar_t *program = Py_DecodeLocale(argv[0], NULL);
    if (program == NULL) {
        fprintf(stderr, "Fatal error: cannot decode argv[0]\n");
        exit(1);
    }

    /* Add a built-in module, before Py_Initialize */
    PyImport_AppendInittab("spam", PyInit_spam);

    /* Pass argv[0] to the Python interpreter */
    Py_SetProgramName(program);

    /* Initialize the Python interpreter.  Required. */
    Py_Initialize();

    /* Optionally import the module; alternatively,
       import can be deferred until the embedded script
       imports it. */
    PyImport_ImportModule("spam");

    ...

    PyMem_RawFree(program);
    return 0;
}
```

Note: Removing entries from `sys.modules` or importing compiled modules into multiple interpreters within a process (or following a `fork()` without an intervening `exec()`) can create problems for some extension modules. Extension module authors should exercise caution when initializing internal data structures.

A more substantial example module is included in the Python source distribution as `Modules/xxmodule.c`. This file may be used as a template or simply read as an example.

Note: Unlike our `spam` example, `xxmodule` uses *multi-phase initialization* (new in Python 3.5), where a PyModuleDef structure is returned from `PyInit_spam`, and creation of the module is left to the import machinery. For details on multi-phase initialization, see **PEP 489**.

2.1.5 Compilation and Linkage

There are two more things to do before you can use your new extension: compiling and linking it with the Python system. If you use dynamic loading, the details may depend on the style of dynamic loading your system uses; see the chapters about building extension modules (chapter *Building C and C++ Extensions*) and additional information that pertains only to building on Windows (chapter *Building C and C++ Extensions on Windows*) for more information about this.

If you can't use dynamic loading, or if you want to make your module a permanent part of the Python interpreter, you will have to change the configuration setup and rebuild the interpreter. Luckily, this is very simple on Unix: just place your file (`spammodule.c` for example) in the `Modules/` directory of an unpacked source distribution, add a line to the file `Modules/Setup.local` describing your file:

```
spam spammodule.o
```

and rebuild the interpreter by running `make` in the toplevel directory. You can also run `make` in the `Modules/` subdirectory, but then you must first rebuild `Makefile` there by running '`make` Makefile'. (This is necessary each time you change the `Setup` file.)

If your module requires additional libraries to link with, these can be listed on the line in the configuration file as well, for instance:

```
spam spammodule.o -lX11
```

2.1.6 Calling Python Functions from C

So far we have concentrated on making C functions callable from Python. The reverse is also useful: calling Python functions from C. This is especially the case for libraries that support so-called "callback" functions. If a C interface makes use of callbacks, the equivalent Python often needs to provide a callback mechanism to the Python programmer; the implementation will require calling the Python callback functions from a C callback. Other uses are also imaginable.

Fortunately, the Python interpreter is easily called recursively, and there is a standard interface to call a Python function. (I won't dwell on how to call the Python parser with a particular string as input — if you're interested, have a look at the implementation of the `-c` command line option in `Modules/main.c` from the Python source code.)

Calling a Python function is easy. First, the Python program must somehow pass you the Python function object. You should provide a function (or some other interface) to do this. When this function is called, save a pointer to the Python function object (be careful to `Py_INCREF()` it!) in a global variable — or wherever you see fit. For example, the following function might be part of a module definition:

```
static PyObject *my_callback = NULL;

static PyObject *
my_set_callback(PyObject *dummy, PyObject *args)
{
    PyObject *result = NULL;
    PyObject *temp;

    if (PyArg_ParseTuple(args, "O:set_callback", &temp)) {
        if (!PyCallable_Check(temp)) {
            PyErr_SetString(PyExc_TypeError, "parameter must be callable");
            return NULL;
        }
        Py_XINCREF(temp);         /* Add a reference to new callback */
        Py_XDECREF(my_callback);  /* Dispose of previous callback */
        my_callback = temp;       /* Remember new callback */
        /* Boilerplate to return "None" */
        Py_INCREF(Py_None);
        result = Py_None;
    }
    return result;
}
```

This function must be registered with the interpreter using the `METH_VARARGS` flag; this is described in section *The Module's Method Table and Initialization Function*. The `PyArg_ParseTuple()` function and its arguments are documented in section *Extracting Parameters in Extension Functions*.

The macros `Py_XINCREF()` and `Py_XDECREF()` increment/decrement the reference count of an object and are safe in the presence of *NULL* pointers (but note that *temp* will not be *NULL* in this context). More info on them in section *Reference Counts*.

Later, when it is time to call the function, you call the C function `PyObject_CallObject()`. This function has two arguments, both pointers to arbitrary Python objects: the Python function, and the argument list. The argument list must always be a tuple object, whose length is the number of arguments. To call the Python function with no arguments, pass in NULL, or an empty tuple; to call it with one argument, pass a singleton tuple. `Py_BuildValue()` returns a tuple when its format string consists of zero or more format codes between parentheses. For example:

```
int arg;
PyObject *arglist;
PyObject *result;
...
arg = 123;
...
/* Time to call the callback */
arglist = Py_BuildValue("(i)", arg);
result = PyObject_CallObject(my_callback, arglist);
Py_DECREF(arglist);
```

`PyObject_CallObject()` returns a Python object pointer: this is the return value of the Python function. `PyObject_CallObject()` is "reference-count-neutral" with respect to its arguments. In the example a new tuple was created to serve as the argument list, which is `Py_DECREF()`-ed immediately after the `PyObject_CallObject()` call.

The return value of `PyObject_CallObject()` is "new": either it is a brand new object, or it is an existing object whose reference count has been incremented. So, unless you want to save it in a global variable, you should somehow `Py_DECREF()` the result, even (especially!) if you are not interested in its value.

Before you do this, however, it is important to check that the return value isn't *NULL*. If it is, the Python

function terminated by raising an exception. If the C code that called `PyObject_CallObject()` is called from Python, it should now return an error indication to its Python caller, so the interpreter can print a stack trace, or the calling Python code can handle the exception. If this is not possible or desirable, the exception should be cleared by calling `PyErr_Clear()`. For example:

```
if (result == NULL)
    return NULL; /* Pass error back */
...use result...
Py_DECREF(result);
```

Depending on the desired interface to the Python callback function, you may also have to provide an argument list to `PyObject_CallObject()`. In some cases the argument list is also provided by the Python program, through the same interface that specified the callback function. It can then be saved and used in the same manner as the function object. In other cases, you may have to construct a new tuple to pass as the argument list. The simplest way to do this is to call `Py_BuildValue()`. For example, if you want to pass an integral event code, you might use the following code:

```
PyObject *arglist;
...
arglist = Py_BuildValue("(l)", eventcode);
result = PyObject_CallObject(my_callback, arglist);
Py_DECREF(arglist);
if (result == NULL)
    return NULL; /* Pass error back */
/* Here maybe use the result */
Py_DECREF(result);
```

Note the placement of `Py_DECREF(arglist)` immediately after the call, before the error check! Also note that strictly speaking this code is not complete: `Py_BuildValue()` may run out of memory, and this should be checked.

You may also call a function with keyword arguments by using `PyObject_Call()`, which supports arguments and keyword arguments. As in the above example, we use `Py_BuildValue()` to construct the dictionary.

```
PyObject *dict;
...
dict = Py_BuildValue("{s:i}", "name", val);
result = PyObject_Call(my_callback, NULL, dict);
Py_DECREF(dict);
if (result == NULL)
    return NULL; /* Pass error back */
/* Here maybe use the result */
Py_DECREF(result);
```

2.1.7 Extracting Parameters in Extension Functions

The `PyArg_ParseTuple()` function is declared as follows:

```
int PyArg_ParseTuple(PyObject *arg, const char *format, ...);
```

The *arg* argument must be a tuple object containing an argument list passed from Python to a C function. The *format* argument must be a format string, whose syntax is explained in arg-parsing in the Python/C API Reference Manual. The remaining arguments must be addresses of variables whose type is determined by the format string.

Note that while `PyArg_ParseTuple()` checks that the Python arguments have the required types, it cannot check the validity of the addresses of C variables passed to the call: if you make mistakes there, your code

will probably crash or at least overwrite random bits in memory. So be careful!

Note that any Python object references which are provided to the caller are *borrowed* references; do not decrement their reference count!

Some example calls:

```
#define PY_SSIZE_T_CLEAN  /* Make "s#" use Py_ssize_t rather than int. */
#include <Python.h>
```

```
int ok;
int i, j;
long k, l;
const char *s;
Py_ssize_t size;

ok = PyArg_ParseTuple(args, ""); /* No arguments */
    /* Python call: f() */
```

```
ok = PyArg_ParseTuple(args, "s", &s); /* A string */
    /* Possible Python call: f('whoops!') */
```

```
ok = PyArg_ParseTuple(args, "lls", &k, &l, &s); /* Two longs and a string */
    /* Possible Python call: f(1, 2, 'three') */
```

```
ok = PyArg_ParseTuple(args, "(ii)s#", &i, &j, &s, &size);
    /* A pair of ints and a string, whose size is also returned */
    /* Possible Python call: f((1, 2), 'three') */
```

```
{
    const char *file;
    const char *mode = "r";
    int bufsize = 0;
    ok = PyArg_ParseTuple(args, "s|si", &file, &mode, &bufsize);
    /* A string, and optionally another string and an integer */
    /* Possible Python calls:
       f('spam')
       f('spam', 'w')
       f('spam', 'wb', 100000) */
}
```

```
{
    int left, top, right, bottom, h, v;
    ok = PyArg_ParseTuple(args, "((ii)(ii))(ii)",
             &left, &top, &right, &bottom, &h, &v);
    /* A rectangle and a point */
    /* Possible Python call:
       f(((0, 0), (400, 300)), (10, 10)) */
}
```

```
{
    Py_complex c;
    ok = PyArg_ParseTuple(args, "D:myfunction", &c);
    /* a complex, also providing a function name for errors */
    /* Possible Python call: myfunction(1+2j) */
}
```

2.1.8 Keyword Parameters for Extension Functions

The `PyArg_ParseTupleAndKeywords()` function is declared as follows:

```
int PyArg_ParseTupleAndKeywords(PyObject *arg, PyObject *kwdict,
                                const char *format, char *kwlist[], ...);
```

The *arg* and *format* parameters are identical to those of the `PyArg_ParseTuple()` function. The *kwdict* parameter is the dictionary of keywords received as the third parameter from the Python runtime. The *kwlist* parameter is a *NULL*-terminated list of strings which identify the parameters; the names are matched with the type information from *format* from left to right. On success, `PyArg_ParseTupleAndKeywords()` returns true, otherwise it returns false and raises an appropriate exception.

Note: Nested tuples cannot be parsed when using keyword arguments! Keyword parameters passed in which are not present in the *kwlist* will cause `TypeError` to be raised.

Here is an example module which uses keywords, based on an example by Geoff Philbrick (philbrick@hks.com):

```
#include "Python.h"

static PyObject *
keywdarg_parrot(PyObject *self, PyObject *args, PyObject *keywds)
{
    int voltage;
    const char *state = "a stiff";
    const char *action = "voom";
    const char *type = "Norwegian Blue";

    static char *kwlist[] = {"voltage", "state", "action", "type", NULL};

    if (!PyArg_ParseTupleAndKeywords(args, keywds, "i|sss", kwlist,
                                     &voltage, &state, &action, &type))
        return NULL;

    printf("-- This parrot wouldn't %s if you put %i Volts through it.\n",
           action, voltage);
    printf("-- Lovely plumage, the %s -- It's %s!\n", type, state);

    Py_RETURN_NONE;
}

static PyMethodDef keywdarg_methods[] = {
    /* The cast of the function is necessary since PyCFunction values
     * only take two PyObject* parameters, and keywdarg_parrot() takes
     * three.
     */
    {"parrot", (PyCFunction)keywdarg_parrot, METH_VARARGS | METH_KEYWORDS,
     "Print a lovely skit to standard output."},
    {NULL, NULL, 0, NULL}   /* sentinel */
};

static struct PyModuleDef keywdargmodule = {
    PyModuleDef_HEAD_INIT,
    "keywdarg",
    NULL,
```

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```
    -1,
    keywdarg_methods
};

PyMODINIT_FUNC
PyInit_keywdarg(void)
{
    return PyModule_Create(&keywdargmodule);
}
```

2.1.9 Building Arbitrary Values

This function is the counterpart to `PyArg_ParseTuple()`. It is declared as follows:

```
PyObject *Py_BuildValue(const char *format, ...);
```

It recognizes a set of format units similar to the ones recognized by `PyArg_ParseTuple()`, but the arguments (which are input to the function, not output) must not be pointers, just values. It returns a new Python object, suitable for returning from a C function called from Python.

One difference with `PyArg_ParseTuple()`: while the latter requires its first argument to be a tuple (since Python argument lists are always represented as tuples internally), `Py_BuildValue()` does not always build a tuple. It builds a tuple only if its format string contains two or more format units. If the format string is empty, it returns `None`; if it contains exactly one format unit, it returns whatever object is described by that format unit. To force it to return a tuple of size 0 or one, parenthesize the format string.

Examples (to the left the call, to the right the resulting Python value):

```
Py_BuildValue("")                        None
Py_BuildValue("i", 123)                  123
Py_BuildValue("iii", 123, 456, 789)      (123, 456, 789)
Py_BuildValue("s", "hello")              'hello'
Py_BuildValue("y", "hello")              b'hello'
Py_BuildValue("ss", "hello", "world")    ('hello', 'world')
Py_BuildValue("s#", "hello", 4)          'hell'
Py_BuildValue("y#", "hello", 4)          b'hell'
Py_BuildValue("()")                      ()
Py_BuildValue("(i)", 123)                (123,)
Py_BuildValue("(ii)", 123, 456)          (123, 456)
Py_BuildValue("(i,i)", 123, 456)         (123, 456)
Py_BuildValue("[i,i]", 123, 456)         [123, 456]
Py_BuildValue("{s:i,s:i}",
              "abc", 123, "def", 456)    {'abc': 123, 'def': 456}
Py_BuildValue("((ii)(ii)) (ii)",
              1, 2, 3, 4, 5, 6)          (((1, 2), (3, 4)), (5, 6))
```

2.1.10 Reference Counts

In languages like C or C++, the programmer is responsible for dynamic allocation and deallocation of memory on the heap. In C, this is done using the functions `malloc()` and `free()`. In C++, the operators `new` and `delete` are used with essentially the same meaning and we'll restrict the following discussion to the C case.

Every block of memory allocated with `malloc()` should eventually be returned to the pool of available memory by exactly one call to `free()`. It is important to call `free()` at the right time. If a block's address

is forgotten but `free()` is not called for it, the memory it occupies cannot be reused until the program terminates. This is called a *memory leak*. On the other hand, if a program calls `free()` for a block and then continues to use the block, it creates a conflict with re-use of the block through another `malloc()` call. This is called *using freed memory*. It has the same bad consequences as referencing uninitialized data — core dumps, wrong results, mysterious crashes.

Common causes of memory leaks are unusual paths through the code. For instance, a function may allocate a block of memory, do some calculation, and then free the block again. Now a change in the requirements for the function may add a test to the calculation that detects an error condition and can return prematurely from the function. It's easy to forget to free the allocated memory block when taking this premature exit, especially when it is added later to the code. Such leaks, once introduced, often go undetected for a long time: the error exit is taken only in a small fraction of all calls, and most modern machines have plenty of virtual memory, so the leak only becomes apparent in a long-running process that uses the leaking function frequently. Therefore, it's important to prevent leaks from happening by having a coding convention or strategy that minimizes this kind of errors.

Since Python makes heavy use of `malloc()` and `free()`, it needs a strategy to avoid memory leaks as well as the use of freed memory. The chosen method is called *reference counting*. The principle is simple: every object contains a counter, which is incremented when a reference to the object is stored somewhere, and which is decremented when a reference to it is deleted. When the counter reaches zero, the last reference to the object has been deleted and the object is freed.

An alternative strategy is called *automatic garbage collection*. (Sometimes, reference counting is also referred to as a garbage collection strategy, hence my use of "automatic" to distinguish the two.) The big advantage of automatic garbage collection is that the user doesn't need to call `free()` explicitly. (Another claimed advantage is an improvement in speed or memory usage — this is no hard fact however.) The disadvantage is that for C, there is no truly portable automatic garbage collector, while reference counting can be implemented portably (as long as the functions `malloc()` and `free()` are available — which the C Standard guarantees). Maybe some day a sufficiently portable automatic garbage collector will be available for C. Until then, we'll have to live with reference counts.

While Python uses the traditional reference counting implementation, it also offers a cycle detector that works to detect reference cycles. This allows applications to not worry about creating direct or indirect circular references; these are the weakness of garbage collection implemented using only reference counting. Reference cycles consist of objects which contain (possibly indirect) references to themselves, so that each object in the cycle has a reference count which is non-zero. Typical reference counting implementations are not able to reclaim the memory belonging to any objects in a reference cycle, or referenced from the objects in the cycle, even though there are no further references to the cycle itself.

The cycle detector is able to detect garbage cycles and can reclaim them. The `gc` module exposes a way to run the detector (the `collect()` function), as well as configuration interfaces and the ability to disable the detector at runtime. The cycle detector is considered an optional component; though it is included by default, it can be disabled at build time using the `--without-cycle-gc` option to the `configure` script on Unix platforms (including Mac OS X). If the cycle detector is disabled in this way, the `gc` module will not be available.

Reference Counting in Python

There are two macros, `Py_INCREF(x)` and `Py_DECREF(x)`, which handle the incrementing and decrementing of the reference count. `Py_DECREF()` also frees the object when the count reaches zero. For flexibility, it doesn't call `free()` directly — rather, it makes a call through a function pointer in the object's *type object*. For this purpose (and others), every object also contains a pointer to its type object.

The big question now remains: when to use `Py_INCREF(x)` and `Py_DECREF(x)`? Let's first introduce some terms. Nobody "owns" an object; however, you can *own a reference* to an object. An object's reference count is now defined as the number of owned references to it. The owner of a reference is responsible for calling `Py_DECREF()` when the reference is no longer needed. Ownership of a reference can be transferred.

There are three ways to dispose of an owned reference: pass it on, store it, or call `Py_DECREF()`. Forgetting to dispose of an owned reference creates a memory leak.

It is also possible to *borrow*[2] a reference to an object. The borrower of a reference should not call `Py_DECREF()`. The borrower must not hold on to the object longer than the owner from which it was borrowed. Using a borrowed reference after the owner has disposed of it risks using freed memory and should be avoided completely[3].

The advantage of borrowing over owning a reference is that you don't need to take care of disposing of the reference on all possible paths through the code — in other words, with a borrowed reference you don't run the risk of leaking when a premature exit is taken. The disadvantage of borrowing over owning is that there are some subtle situations where in seemingly correct code a borrowed reference can be used after the owner from which it was borrowed has in fact disposed of it.

A borrowed reference can be changed into an owned reference by calling `Py_INCREF()`. This does not affect the status of the owner from which the reference was borrowed — it creates a new owned reference, and gives full owner responsibilities (the new owner must dispose of the reference properly, as well as the previous owner).

Ownership Rules

Whenever an object reference is passed into or out of a function, it is part of the function's interface specification whether ownership is transferred with the reference or not.

Most functions that return a reference to an object pass on ownership with the reference. In particular, all functions whose function it is to create a new object, such as `PyLong_FromLong()` and `Py_BuildValue()`, pass ownership to the receiver. Even if the object is not actually new, you still receive ownership of a new reference to that object. For instance, `PyLong_FromLong()` maintains a cache of popular values and can return a reference to a cached item.

Many functions that extract objects from other objects also transfer ownership with the reference, for instance `PyObject_GetAttrString()`. The picture is less clear, here, however, since a few common routines are exceptions: `PyTuple_GetItem()`, `PyList_GetItem()`, `PyDict_GetItem()`, and `PyDict_GetItemString()` all return references that you borrow from the tuple, list or dictionary.

The function `PyImport_AddModule()` also returns a borrowed reference, even though it may actually create the object it returns: this is possible because an owned reference to the object is stored in `sys.modules`.

When you pass an object reference into another function, in general, the function borrows the reference from you — if it needs to store it, it will use `Py_INCREF()` to become an independent owner. There are exactly two important exceptions to this rule: `PyTuple_SetItem()` and `PyList_SetItem()`. These functions take over ownership of the item passed to them — even if they fail! (Note that `PyDict_SetItem()` and friends don't take over ownership — they are "normal.")

When a C function is called from Python, it borrows references to its arguments from the caller. The caller owns a reference to the object, so the borrowed reference's lifetime is guaranteed until the function returns. Only when such a borrowed reference must be stored or passed on, it must be turned into an owned reference by calling `Py_INCREF()`.

The object reference returned from a C function that is called from Python must be an owned reference — ownership is transferred from the function to its caller.

[2] The metaphor of "borrowing" a reference is not completely correct: the owner still has a copy of the reference.

[3] Checking that the reference count is at least 1 **does not work** — the reference count itself could be in freed memory and may thus be reused for another object!

Thin Ice

There are a few situations where seemingly harmless use of a borrowed reference can lead to problems. These all have to do with implicit invocations of the interpreter, which can cause the owner of a reference to dispose of it.

The first and most important case to know about is using `Py_DECREF()` on an unrelated object while borrowing a reference to a list item. For instance:

```
void
bug(PyObject *list)
{
    PyObject *item = PyList_GetItem(list, 0);

    PyList_SetItem(list, 1, PyLong_FromLong(0L));
    PyObject_Print(item, stdout, 0); /* BUG! */
}
```

This function first borrows a reference to `list[0]`, then replaces `list[1]` with the value `0`, and finally prints the borrowed reference. Looks harmless, right? But it's not!

Let's follow the control flow into `PyList_SetItem()`. The list owns references to all its items, so when item 1 is replaced, it has to dispose of the original item 1. Now let's suppose the original item 1 was an instance of a user-defined class, and let's further suppose that the class defined a `__del__()` method. If this class instance has a reference count of 1, disposing of it will call its `__del__()` method.

Since it is written in Python, the `__del__()` method can execute arbitrary Python code. Could it perhaps do something to invalidate the reference to `item` in `bug()`? You bet! Assuming that the list passed into `bug()` is accessible to the `__del__()` method, it could execute a statement to the effect of `del list[0]`, and assuming this was the last reference to that object, it would free the memory associated with it, thereby invalidating `item`.

The solution, once you know the source of the problem, is easy: temporarily increment the reference count. The correct version of the function reads:

```
void
no_bug(PyObject *list)
{
    PyObject *item = PyList_GetItem(list, 0);

    Py_INCREF(item);
    PyList_SetItem(list, 1, PyLong_FromLong(0L));
    PyObject_Print(item, stdout, 0);
    Py_DECREF(item);
}
```

This is a true story. An older version of Python contained variants of this bug and someone spent a considerable amount of time in a C debugger to figure out why his `__del__()` methods would fail…

The second case of problems with a borrowed reference is a variant involving threads. Normally, multiple threads in the Python interpreter can't get in each other's way, because there is a global lock protecting Python's entire object space. However, it is possible to temporarily release this lock using the macro `Py_BEGIN_ALLOW_THREADS`, and to re-acquire it using `Py_END_ALLOW_THREADS`. This is common around blocking I/O calls, to let other threads use the processor while waiting for the I/O to complete. Obviously, the following function has the same problem as the previous one:

```
void
bug(PyObject *list)
{
```

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```
    PyObject *item = PyList_GetItem(list, 0);
    Py_BEGIN_ALLOW_THREADS
    ...some blocking I/O call...
    Py_END_ALLOW_THREADS
    PyObject_Print(item, stdout, 0); /* BUG! */
}
```

NULL Pointers

In general, functions that take object references as arguments do not expect you to pass them *NULL* pointers, and will dump core (or cause later core dumps) if you do so. Functions that return object references generally return *NULL* only to indicate that an exception occurred. The reason for not testing for *NULL* arguments is that functions often pass the objects they receive on to other function — if each function were to test for *NULL*, there would be a lot of redundant tests and the code would run more slowly.

It is better to test for *NULL* only at the "source:" when a pointer that may be *NULL* is received, for example, from `malloc()` or from a function that may raise an exception.

The macros `Py_INCREF()` and `Py_DECREF()` do not check for *NULL* pointers — however, their variants `Py_XINCREF()` and `Py_XDECREF()` do.

The macros for checking for a particular object type (`Pytype_Check()`) don't check for *NULL* pointers — again, there is much code that calls several of these in a row to test an object against various different expected types, and this would generate redundant tests. There are no variants with *NULL* checking.

The C function calling mechanism guarantees that the argument list passed to C functions (`args` in the examples) is never *NULL* — in fact it guarantees that it is always a tuple[4].

It is a severe error to ever let a *NULL* pointer "escape" to the Python user.

2.1.11 Writing Extensions in C++

It is possible to write extension modules in C++. Some restrictions apply. If the main program (the Python interpreter) is compiled and linked by the C compiler, global or static objects with constructors cannot be used. This is not a problem if the main program is linked by the C++ compiler. Functions that will be called by the Python interpreter (in particular, module initialization functions) have to be declared using `extern "C"`. It is unnecessary to enclose the Python header files in `extern "C" {...}` — they use this form already if the symbol `__cplusplus` is defined (all recent C++ compilers define this symbol).

2.1.12 Providing a C API for an Extension Module

Many extension modules just provide new functions and types to be used from Python, but sometimes the code in an extension module can be useful for other extension modules. For example, an extension module could implement a type "collection" which works like lists without order. Just like the standard Python list type has a C API which permits extension modules to create and manipulate lists, this new collection type should have a set of C functions for direct manipulation from other extension modules.

At first sight this seems easy: just write the functions (without declaring them `static`, of course), provide an appropriate header file, and document the C API. And in fact this would work if all extension modules were always linked statically with the Python interpreter. When modules are used as shared libraries, however, the symbols defined in one module may not be visible to another module. The details of visibility depend on the operating system; some systems use one global namespace for the Python interpreter and all extension modules (Windows, for example), whereas others require an explicit list of imported symbols at module link

[4] These guarantees don't hold when you use the "old" style calling convention — this is still found in much existing code.

time (AIX is one example), or offer a choice of different strategies (most Unices). And even if symbols are globally visible, the module whose functions one wishes to call might not have been loaded yet!

Portability therefore requires not to make any assumptions about symbol visibility. This means that all symbols in extension modules should be declared `static`, except for the module's initialization function, in order to avoid name clashes with other extension modules (as discussed in section *The Module's Method Table and Initialization Function*). And it means that symbols that *should* be accessible from other extension modules must be exported in a different way.

Python provides a special mechanism to pass C-level information (pointers) from one extension module to another one: Capsules. A Capsule is a Python data type which stores a pointer (`void *`). Capsules can only be created and accessed via their C API, but they can be passed around like any other Python object. In particular, they can be assigned to a name in an extension module's namespace. Other extension modules can then import this module, retrieve the value of this name, and then retrieve the pointer from the Capsule.

There are many ways in which Capsules can be used to export the C API of an extension module. Each function could get its own Capsule, or all C API pointers could be stored in an array whose address is published in a Capsule. And the various tasks of storing and retrieving the pointers can be distributed in different ways between the module providing the code and the client modules.

Whichever method you choose, it's important to name your Capsules properly. The function `PyCapsule_New()` takes a name parameter (`const char *`); you're permitted to pass in a *NULL* name, but we strongly encourage you to specify a name. Properly named Capsules provide a degree of runtime type-safety; there is no feasible way to tell one unnamed Capsule from another.

In particular, Capsules used to expose C APIs should be given a name following this convention:

```
modulename.attributename
```

The convenience function `PyCapsule_Import()` makes it easy to load a C API provided via a Capsule, but only if the Capsule's name matches this convention. This behavior gives C API users a high degree of certainty that the Capsule they load contains the correct C API.

The following example demonstrates an approach that puts most of the burden on the writer of the exporting module, which is appropriate for commonly used library modules. It stores all C API pointers (just one in the example!) in an array of `void` pointers which becomes the value of a Capsule. The header file corresponding to the module provides a macro that takes care of importing the module and retrieving its C API pointers; client modules only have to call this macro before accessing the C API.

The exporting module is a modification of the `spam` module from section *A Simple Example*. The function `spam.system()` does not call the C library function `system()` directly, but a function `PySpam_System()`, which would of course do something more complicated in reality (such as adding "spam" to every command). This function `PySpam_System()` is also exported to other extension modules.

The function `PySpam_System()` is a plain C function, declared `static` like everything else:

```
static int
PySpam_System(const char *command)
{
    return system(command);
}
```

The function `spam_system()` is modified in a trivial way:

```
static PyObject *
spam_system(PyObject *self, PyObject *args)
{
    const char *command;
    int sts;
```

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```
    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = PySpam_System(command);
    return PyLong_FromLong(sts);
}
```

In the beginning of the module, right after the line

```
#include "Python.h"
```

two more lines must be added:

```
#define SPAM_MODULE
#include "spammodule.h"
```

The `#define` is used to tell the header file that it is being included in the exporting module, not a client module. Finally, the module's initialization function must take care of initializing the C API pointer array:

```
PyMODINIT_FUNC
PyInit_spam(void)
{
    PyObject *m;
    static void *PySpam_API[PySpam_API_pointers];
    PyObject *c_api_object;

    m = PyModule_Create(&spammodule);
    if (m == NULL)
        return NULL;

    /* Initialize the C API pointer array */
    PySpam_API[PySpam_System_NUM] = (void *)PySpam_System;

    /* Create a Capsule containing the API pointer array's address */
    c_api_object = PyCapsule_New((void *)PySpam_API, "spam._C_API", NULL);

    if (c_api_object != NULL)
        PyModule_AddObject(m, "_C_API", c_api_object);
    return m;
}
```

Note that `PySpam_API` is declared `static`; otherwise the pointer array would disappear when `PyInit_spam()` terminates!

The bulk of the work is in the header file `spammodule.h`, which looks like this:

```
#ifndef Py_SPAMMODULE_H
#define Py_SPAMMODULE_H
#ifdef __cplusplus
extern "C" {
#endif

/* Header file for spammodule */

/* C API functions */
#define PySpam_System_NUM 0
#define PySpam_System_RETURN int
```

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```
#define PySpam_System_PROTO (const char *command)

/* Total number of C API pointers */
#define PySpam_API_pointers 1


#ifdef SPAM_MODULE
/* This section is used when compiling spammodule.c */

static PySpam_System_RETURN PySpam_System PySpam_System_PROTO;

#else
/* This section is used in modules that use spammodule's API */

static void **PySpam_API;

#define PySpam_System \
 (*(PySpam_System_RETURN (*)PySpam_System_PROTO) PySpam_API[PySpam_System_NUM])

/* Return -1 on error, 0 on success.
 * PyCapsule_Import will set an exception if there's an error.
 */
static int
import_spam(void)
{
    PySpam_API = (void **)PyCapsule_Import("spam._C_API", 0);
    return (PySpam_API != NULL) ? 0 : -1;
}

#endif

#ifdef __cplusplus
}
#endif

#endif /* !defined(Py_SPAMMODULE_H) */
```

All that a client module must do in order to have access to the function `PySpam_System()` is to call the function (or rather macro) `import_spam()` in its initialization function:

```
PyMODINIT_FUNC
PyInit_client(void)
{
    PyObject *m;

    m = PyModule_Create(&clientmodule);
    if (m == NULL)
        return NULL;
    if (import_spam() < 0)
        return NULL;
    /* additional initialization can happen here */
    return m;
}
```

The main disadvantage of this approach is that the file `spammodule.h` is rather complicated. However, the basic structure is the same for each function that is exported, so it has to be learned only once.

Finally it should be mentioned that Capsules offer additional functionality, which is especially useful for

memory allocation and deallocation of the pointer stored in a Capsule. The details are described in the Python/C API Reference Manual in the section capsules and in the implementation of Capsules (files `Include/pycapsule.h` and `Objects/pycapsule.c` in the Python source code distribution).

2.2 Defining Extension Types: Tutorial

Python allows the writer of a C extension module to define new types that can be manipulated from Python code, much like the built-in `str` and `list` types. The code for all extension types follows a pattern, but there are some details that you need to understand before you can get started. This document is a gentle introduction to the topic.

2.2.1 The Basics

The *CPython* runtime sees all Python objects as variables of type `PyObject*`, which serves as a "base type" for all Python objects. The `PyObject` structure itself only contains the object's *reference count* and a pointer to the object's "type object". This is where the action is; the type object determines which (C) functions get called by the interpreter when, for instance, an attribute gets looked up on an object, a method called, or it is multiplied by another object. These C functions are called "type methods".

So, if you want to define a new extension type, you need to create a new type object.

This sort of thing can only be explained by example, so here's a minimal, but complete, module that defines a new type named `Custom` inside a C extension module `custom`:

Note: What we're showing here is the traditional way of defining *static* extension types. It should be adequate for most uses. The C API also allows defining heap-allocated extension types using the `PyType_FromSpec()` function, which isn't covered in this tutorial.

```
#include <Python.h>

typedef struct {
    PyObject_HEAD
    /* Type-specific fields go here. */
} CustomObject;

static PyTypeObject CustomType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "custom.Custom",
    .tp_doc = "Custom objects",
    .tp_basicsize = sizeof(CustomObject),
    .tp_itemsize = 0,
    .tp_flags = Py_TPFLAGS_DEFAULT,
    .tp_new = PyType_GenericNew,
};

static PyModuleDef custommodule = {
    PyModuleDef_HEAD_INIT,
    .m_name = "custom",
    .m_doc = "Example module that creates an extension type.",
    .m_size = -1,
};

PyMODINIT_FUNC
```

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```
PyInit_custom(void)
{
    PyObject *m;
    if (PyType_Ready(&CustomType) < 0)
        return NULL;

    m = PyModule_Create(&custommodule);
    if (m == NULL)
        return NULL;

    Py_INCREF(&CustomType);
    PyModule_AddObject(m, "Custom", (PyObject *) &CustomType);
    return m;
}
```

Now that's quite a bit to take in at once, but hopefully bits will seem familiar from the previous chapter. This file defines three things:

1. What a `Custom` **object** contains: this is the `CustomObject` struct, which is allocated once for each `Custom` instance.
2. How the `Custom` **type** behaves: this is the `CustomType` struct, which defines a set of flags and function pointers that the interpreter inspects when specific operations are requested.
3. How to initialize the `custom` module: this is the `PyInit_custom` function and the associated `custommodule` struct.

The first bit is:

```
typedef struct {
    PyObject_HEAD
} CustomObject;
```

This is what a Custom object will contain. `PyObject_HEAD` is mandatory at the start of each object struct and defines a field called `ob_base` of type `PyObject`, containing a pointer to a type object and a reference count (these can be accessed using the macros `Py_REFCNT` and `Py_TYPE` respectively). The reason for the macro is to abstract away the layout and to enable additional fields in debug builds.

Note: There is no semicolon above after the `PyObject_HEAD` macro. Be wary of adding one by accident: some compilers will complain.

Of course, objects generally store additional data besides the standard `PyObject_HEAD` boilerplate; for example, here is the definition for standard Python floats:

```
typedef struct {
    PyObject_HEAD
    double ob_fval;
} PyFloatObject;
```

The second bit is the definition of the type object.

```
static PyTypeObject CustomType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "custom.Custom",
    .tp_doc = "Custom objects",
    .tp_basicsize = sizeof(CustomObject),
```

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```
    .tp_itemsize = 0,
    .tp_new = PyType_GenericNew,
};
```

Note: We recommend using C99-style designated initializers as above, to avoid listing all the `PyTypeObject` fields that you don't care about and also to avoid caring about the fields' declaration order.

The actual definition of `PyTypeObject` in `object.h` has many more fields than the definition above. The remaining fields will be filled with zeros by the C compiler, and it's common practice to not specify them explicitly unless you need them.

We're going to pick it apart, one field at a time:

```
PyVarObject_HEAD_INIT(NULL, 0)
```

This line is mandatory boilerplate to initialize the `ob_base` field mentioned above.

```
.tp_name = "custom.Custom",
```

The name of our type. This will appear in the default textual representation of our objects and in some error messages, for example:

```
>>> "" + custom.Custom()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: can only concatenate str (not "custom.Custom") to str
```

Note that the name is a dotted name that includes both the module name and the name of the type within the module. The module in this case is `custom` and the type is `Custom`, so we set the type name to `custom.Custom`. Using the real dotted import path is important to make your type compatible with the `pydoc` and `pickle` modules.

```
.tp_basicsize = sizeof(CustomObject),
.tp_itemsize = 0,
```

This is so that Python knows how much memory to allocate when creating new `Custom` instances. `tp_itemsize` is only used for variable-sized objects and should otherwise be zero.

Note: If you want your type to be subclassable from Python, and your type has the same `tp_basicsize` as its base type, you may have problems with multiple inheritance. A Python subclass of your type will have to list your type first in its `__bases__`, or else it will not be able to call your type's `__new__()` method without getting an error. You can avoid this problem by ensuring that your type has a larger value for `tp_basicsize` than its base type does. Most of the time, this will be true anyway, because either your base type will be `object`, or else you will be adding data members to your base type, and therefore increasing its size.

We set the class flags to `Py_TPFLAGS_DEFAULT`.

```
.tp_flags = Py_TPFLAGS_DEFAULT,
```

All types should include this constant in their flags. It enables all of the members defined until at least Python 3.3. If you need further members, you will need to OR the corresponding flags.

We provide a doc string for the type in `tp_doc`.

```
.tp_doc = "Custom objects",
```

To enable object creation, we have to provide a `tp_new` handler. This is the equivalent of the Python method `__new__()`, but has to be specified explicitly. In this case, we can just use the default implementation provided by the API function `PyType_GenericNew()`.

```
.tp_new = PyType_GenericNew,
```

Everything else in the file should be familiar, except for some code in `PyInit_custom()`:

```
if (PyType_Ready(&CustomType) < 0)
    return;
```

This initializes the `Custom` type, filling in a number of members to the appropriate default values, including `ob_type` that we initially set to *NULL*.

```
PyModule_AddObject(m, "Custom", (PyObject *) &CustomType);
```

This adds the type to the module dictionary. This allows us to create `Custom` instances by calling the `Custom` class:

```
>>> import custom
>>> mycustom = custom.Custom()
```

That's it! All that remains is to build it; put the above code in a file called `custom.c` and:

```
from distutils.core import setup, Extension
setup(name="custom", version="1.0",
      ext_modules=[Extension("custom", ["custom.c"])])
```

in a file called `setup.py`; then typing

```
$ python setup.py build
```

at a shell should produce a file `custom.so` in a subdirectory; move to that directory and fire up Python — you should be able to `import custom` and play around with Custom objects.

That wasn't so hard, was it?

Of course, the current Custom type is pretty uninteresting. It has no data and doesn't do anything. It can't even be subclassed.

Note: While this documentation showcases the standard `distutils` module for building C extensions, it is recommended in real-world use cases to use the newer and better-maintained `setuptools` library. Documentation on how to do this is out of scope for this document and can be found in the Python Packaging User's Guide.

2.2.2 Adding data and methods to the Basic example

Let's extend the basic example to add some data and methods. Let's also make the type usable as a base class. We'll create a new module, `custom2` that adds these capabilities:

```
#include <Python.h>
#include "structmember.h"
```

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```
typedef struct {
    PyObject_HEAD
    PyObject *first; /* first name */
    PyObject *last;  /* last name */
    int number;
} CustomObject;

static void
Custom_dealloc(CustomObject *self)
{
    Py_XDECREF(self->first);
    Py_XDECREF(self->last);
    Py_TYPE(self)->tp_free((PyObject *) self);
}

static PyObject *
Custom_new(PyTypeObject *type, PyObject *args, PyObject *kwds)
{
    CustomObject *self;
    self = (CustomObject *) type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyUnicode_FromString("");
        if (self->first == NULL) {
            Py_DECREF(self);
            return NULL;
        }
        self->last = PyUnicode_FromString("");
        if (self->last == NULL) {
            Py_DECREF(self);
            return NULL;
        }
        self->number = 0;
    }
    return (PyObject *) self;
}

static int
Custom_init(CustomObject *self, PyObject *args, PyObject *kwds)
{
    static char *kwlist[] = {"first", "last", "number", NULL};
    PyObject *first = NULL, *last = NULL, *tmp;

    if (!PyArg_ParseTupleAndKeywords(args, kwds, "|OOi", kwlist,
                                     &first, &last,
                                     &self->number))
        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_XDECREF(tmp);
    }
    if (last) {
        tmp = self->last;
        Py_INCREF(last);
```

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```
        self->last = last;
        Py_XDECREF(tmp);
    }
    return 0;
}

static PyMemberDef Custom_members[] = {
    {"first", T_OBJECT_EX, offsetof(CustomObject, first), 0,
     "first name"},
    {"last", T_OBJECT_EX, offsetof(CustomObject, last), 0,
     "last name"},
    {"number", T_INT, offsetof(CustomObject, number), 0,
     "custom number"},
    {NULL}  /* Sentinel */
};

static PyObject *
Custom_name(CustomObject *self, PyObject *Py_UNUSED(ignored))
{
    if (self->first == NULL) {
        PyErr_SetString(PyExc_AttributeError, "first");
        return NULL;
    }
    if (self->last == NULL) {
        PyErr_SetString(PyExc_AttributeError, "last");
        return NULL;
    }
    return PyUnicode_FromFormat("%S %S", self->first, self->last);
}

static PyMethodDef Custom_methods[] = {
    {"name", (PyCFunction) Custom_name, METH_NOARGS,
     "Return the name, combining the first and last name"
    },
    {NULL}  /* Sentinel */
};

static PyTypeObject CustomType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "custom2.Custom",
    .tp_doc = "Custom objects",
    .tp_basicsize = sizeof(CustomObject),
    .tp_itemsize = 0,
    .tp_flags = Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE,
    .tp_new = Custom_new,
    .tp_init = (initproc) Custom_init,
    .tp_dealloc = (destructor) Custom_dealloc,
    .tp_members = Custom_members,
    .tp_methods = Custom_methods,
};

static PyModuleDef custommodule = {
    PyModuleDef_HEAD_INIT,
    .m_name = "custom2",
    .m_doc = "Example module that creates an extension type.",
    .m_size = -1,
```

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```
};

PyMODINIT_FUNC
PyInit_custom2(void)
{
    PyObject *m;
    if (PyType_Ready(&CustomType) < 0)
        return NULL;

    m = PyModule_Create(&custommodule);
    if (m == NULL)
        return NULL;

    Py_INCREF(&CustomType);
    PyModule_AddObject(m, "Custom", (PyObject *) &CustomType);
    return m;
}
```

This version of the module has a number of changes.

We've added an extra include:

```
#include <structmember.h>
```

This include provides declarations that we use to handle attributes, as described a bit later.

The `Custom` type now has three data attributes in its C struct, *first*, *last*, and *number*. The *first* and *last* variables are Python strings containing first and last names. The *number* attribute is a C integer.

The object structure is updated accordingly:

```
typedef struct {
    PyObject_HEAD
    PyObject *first; /* first name */
    PyObject *last;  /* last name */
    int number;
} CustomObject;
```

Because we now have data to manage, we have to be more careful about object allocation and deallocation. At a minimum, we need a deallocation method:

```
static void
Custom_dealloc(CustomObject *self)
{
    Py_XDECREF(self->first);
    Py_XDECREF(self->last);
    Py_TYPE(self)->tp_free((PyObject *) self);
}
```

which is assigned to the `tp_dealloc` member:

```
.tp_dealloc = (destructor) Custom_dealloc,
```

This method first clears the reference counts of the two Python attributes. `Py_XDECREF()` correctly handles the case where its argument is *NULL* (which might happen here if `tp_new` failed midway). It then calls the `tp_free` member of the object's type (computed by `Py_TYPE(self)`) to free the object's memory. Note that the object's type might not be `CustomType`, because the object may be an instance of a subclass.

Note: The explicit cast to `destructor` above is needed because we defined `Custom_dealloc` to take a `CustomObject *` argument, but the `tp_dealloc` function pointer expects to receive a `PyObject *` argument. Otherwise, the compiler will emit a warning. This is object-oriented polymorphism, in C!

We want to make sure that the first and last names are initialized to empty strings, so we provide a `tp_new` implementation:

```
static PyObject *
Custom_new(PyTypeObject *type, PyObject *args, PyObject *kwds)
{
    CustomObject *self;
    self = (CustomObject *) type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyUnicode_FromString("");
        if (self->first == NULL) {
            Py_DECREF(self);
            return NULL;
        }
        self->last = PyUnicode_FromString("");
        if (self->last == NULL) {
            Py_DECREF(self);
            return NULL;
        }
        self->number = 0;
    }
    return (PyObject *) self;
}
```

and install it in the `tp_new` member:

```
.tp_new = Custom_new,
```

The `tp_new` handler is responsible for creating (as opposed to initializing) objects of the type. It is exposed in Python as the `__new__()` method. It is not required to define a `tp_new` member, and indeed many extension types will simply reuse `PyType_GenericNew()` as done in the first version of the `Custom` type above. In this case, we use the `tp_new` handler to initialize the `first` and `last` attributes to non-*NULL* default values.

`tp_new` is passed the type being instantiated (not necessarily `CustomType`, if a subclass is instantiated) and any arguments passed when the type was called, and is expected to return the instance created. `tp_new` handlers always accept positional and keyword arguments, but they often ignore the arguments, leaving the argument handling to initializer (a.k.a. `tp_init` in C or `__init__` in Python) methods.

Note: `tp_new` shouldn't call `tp_init` explicitly, as the interpreter will do it itself.

The `tp_new` implementation calls the `tp_alloc` slot to allocate memory:

```
self = (CustomObject *) type->tp_alloc(type, 0);
```

Since memory allocation may fail, we must check the `tp_alloc` result against *NULL* before proceeding.

Note: We didn't fill the `tp_alloc` slot ourselves. Rather `PyType_Ready()` fills it for us by inheriting it from our base class, which is `object` by default. Most types use the default allocation strategy.

Note: If you are creating a co-operative `tp_new` (one that calls a base type's `tp_new` or `__new__()`), you must *not* try to determine what method to call using method resolution order at runtime. Always statically determine what type you are going to call, and call its `tp_new` directly, or via `type->tp_base->tp_new`. If you do not do this, Python subclasses of your type that also inherit from other Python-defined classes may not work correctly. (Specifically, you may not be able to create instances of such subclasses without getting a `TypeError`.)

We also define an initialization function which accepts arguments to provide initial values for our instance:

```
static int
Custom_init(CustomObject *self, PyObject *args, PyObject *kwds)
{
    static char *kwlist[] = {"first", "last", "number", NULL};
    PyObject *first = NULL, *last = NULL, *tmp;

    if (!PyArg_ParseTupleAndKeywords(args, kwds, "|OOi", kwlist,
                                     &first, &last,
                                     &self->number))
        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_XDECREF(tmp);
    }
    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_XDECREF(tmp);
    }
    return 0;
}
```

by filling the `tp_init` slot.

```
.tp_init = (initproc) Custom_init,
```

The `tp_init` slot is exposed in Python as the `__init__()` method. It is used to initialize an object after it's created. Initializers always accept positional and keyword arguments, and they should return either `0` on success or `-1` on error.

Unlike the `tp_new` handler, there is no guarantee that `tp_init` is called at all (for example, the `pickle` module by default doesn't call `__init__()` on unpickled instances). It can also be called multiple times. Anyone can call the `__init__()` method on our objects. For this reason, we have to be extra careful when assigning the new attribute values. We might be tempted, for example to assign the `first` member like this:

```
if (first) {
    Py_XDECREF(self->first);
    Py_INCREF(first);
    self->first = first;
}
```

But this would be risky. Our type doesn't restrict the type of the `first` member, so it could be any kind of object. It could have a destructor that causes code to be executed that tries to access the `first` member;

or that destructor could release the *Global interpreter Lock* and let arbitrary code run in other threads that accesses and modifies our object.

To be paranoid and protect ourselves against this possibility, we almost always reassign members before decrementing their reference counts. When don't we have to do this?

- when we absolutely know that the reference count is greater than 1;
- when we know that deallocation of the object[1] will neither release the *GIL* nor cause any calls back into our type's code;
- when decrementing a reference count in a `tp_dealloc` handler on a type which doesn't support cyclic garbage collection[2].

We want to expose our instance variables as attributes. There are a number of ways to do that. The simplest way is to define member definitions:

```
static PyMemberDef Custom_members[] = {
    {"first", T_OBJECT_EX, offsetof(CustomObject, first), 0,
     "first name"},
    {"last", T_OBJECT_EX, offsetof(CustomObject, last), 0,
     "last name"},
    {"number", T_INT, offsetof(CustomObject, number), 0,
     "custom number"},
    {NULL}  /* Sentinel */
};
```

and put the definitions in the `tp_members` slot:

```
.tp_members = Custom_members,
```

Each member definition has a member name, type, offset, access flags and documentation string. See the *Generic Attribute Management* section below for details.

A disadvantage of this approach is that it doesn't provide a way to restrict the types of objects that can be assigned to the Python attributes. We expect the first and last names to be strings, but any Python objects can be assigned. Further, the attributes can be deleted, setting the C pointers to *NULL*. Even though we can make sure the members are initialized to non-*NULL* values, the members can be set to *NULL* if the attributes are deleted.

We define a single method, `Custom.name()`, that outputs the objects name as the concatenation of the first and last names.

```
static PyObject *
Custom_name(CustomObject *self)
{
    if (self->first == NULL) {
        PyErr_SetString(PyExc_AttributeError, "first");
        return NULL;
    }
    if (self->last == NULL) {
        PyErr_SetString(PyExc_AttributeError, "last");
        return NULL;
    }
    return PyUnicode_FromFormat("%S %S", self->first, self->last);
}
```

The method is implemented as a C function that takes a `Custom` (or `Custom` subclass) instance as the first argument. Methods always take an instance as the first argument. Methods often take positional and

[1] This is true when we know that the object is a basic type, like a string or a float.
[2] We relied on this in the `tp_dealloc` handler in this example, because our type doesn't support garbage collection.

keyword arguments as well, but in this case we don't take any and don't need to accept a positional argument tuple or keyword argument dictionary. This method is equivalent to the Python method:

```
def name(self):
    return "%s %s" % (self.first, self.last)
```

Note that we have to check for the possibility that our `first` and `last` members are *NULL*. This is because they can be deleted, in which case they are set to *NULL*. It would be better to prevent deletion of these attributes and to restrict the attribute values to be strings. We'll see how to do that in the next section.

Now that we've defined the method, we need to create an array of method definitions:

```
static PyMethodDef Custom_methods[] = {
    {"name", (PyCFunction) Custom_name, METH_NOARGS,
     "Return the name, combining the first and last name"
    },
    {NULL}  /* Sentinel */
};
```

(note that we used the `METH_NOARGS` flag to indicate that the method is expecting no arguments other than *self*)

and assign it to the `tp_methods` slot:

```
.tp_methods = Custom_methods,
```

Finally, we'll make our type usable as a base class for subclassing. We've written our methods carefully so far so that they don't make any assumptions about the type of the object being created or used, so all we need to do is to add the `Py_TPFLAGS_BASETYPE` to our class flag definition:

```
.tp_flags = Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE,
```

We rename `PyInit_custom()` to `PyInit_custom2()`, update the module name in the `PyModuleDef` struct, and update the full class name in the `PyTypeObject` struct.

Finally, we update our `setup.py` file to build the new module:

```
from distutils.core import setup, Extension
setup(name="custom", version="1.0",
      ext_modules=[
         Extension("custom", ["custom.c"]),
         Extension("custom2", ["custom2.c"]),
         ])
```

2.2.3 Providing finer control over data attributes

In this section, we'll provide finer control over how the `first` and `last` attributes are set in the `Custom` example. In the previous version of our module, the instance variables `first` and `last` could be set to non-string values or even deleted. We want to make sure that these attributes always contain strings.

```
#include <Python.h>
#include "structmember.h"

typedef struct {
    PyObject_HEAD
    PyObject *first; /* first name */
    PyObject *last;  /* last name */
```

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```
    int number;
} CustomObject;

static void
Custom_dealloc(CustomObject *self)
{
    Py_XDECREF(self->first);
    Py_XDECREF(self->last);
    Py_TYPE(self)->tp_free((PyObject *) self);
}

static PyObject *
Custom_new(PyTypeObject *type, PyObject *args, PyObject *kwds)
{
    CustomObject *self;
    self = (CustomObject *) type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyUnicode_FromString("");
        if (self->first == NULL) {
            Py_DECREF(self);
            return NULL;
        }
        self->last = PyUnicode_FromString("");
        if (self->last == NULL) {
            Py_DECREF(self);
            return NULL;
        }
        self->number = 0;
    }
    return (PyObject *) self;
}

static int
Custom_init(CustomObject *self, PyObject *args, PyObject *kwds)
{
    static char *kwlist[] = {"first", "last", "number", NULL};
    PyObject *first = NULL, *last = NULL, *tmp;

    if (!PyArg_ParseTupleAndKeywords(args, kwds, "|UUi", kwlist,
                                     &first, &last,
                                     &self->number))
        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_DECREF(tmp);
    }
    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_DECREF(tmp);
    }
    return 0;
```

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```
}

static PyMemberDef Custom_members[] = {
    {"number", T_INT, offsetof(CustomObject, number), 0,
     "custom number"},
    {NULL}  /* Sentinel */
};

static PyObject *
Custom_getfirst(CustomObject *self, void *closure)
{
    Py_INCREF(self->first);
    return self->first;
}

static int
Custom_setfirst(CustomObject *self, PyObject *value, void *closure)
{
    PyObject *tmp;
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete the first attribute");
        return -1;
    }
    if (!PyUnicode_Check(value)) {
        PyErr_SetString(PyExc_TypeError,
                        "The first attribute value must be a string");
        return -1;
    }
    tmp = self->first;
    Py_INCREF(value);
    self->first = value;
    Py_DECREF(tmp);
    return 0;
}

static PyObject *
Custom_getlast(CustomObject *self, void *closure)
{
    Py_INCREF(self->last);
    return self->last;
}

static int
Custom_setlast(CustomObject *self, PyObject *value, void *closure)
{
    PyObject *tmp;
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete the last attribute");
        return -1;
    }
    if (!PyUnicode_Check(value)) {
        PyErr_SetString(PyExc_TypeError,
                        "The last attribute value must be a string");
        return -1;
    }
    tmp = self->last;
```

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```
    Py_INCREF(value);
    self->last = value;
    Py_DECREF(tmp);
    return 0;
}

static PyGetSetDef Custom_getsetters[] = {
    {"first", (getter) Custom_getfirst, (setter) Custom_setfirst,
     "first name", NULL},
    {"last", (getter) Custom_getlast, (setter) Custom_setlast,
     "last name", NULL},
    {NULL}  /* Sentinel */
};

static PyObject *
Custom_name(CustomObject *self, PyObject *Py_UNUSED(ignored))
{
    return PyUnicode_FromFormat("%S %S", self->first, self->last);
}

static PyMethodDef Custom_methods[] = {
    {"name", (PyCFunction) Custom_name, METH_NOARGS,
     "Return the name, combining the first and last name"
    },
    {NULL}  /* Sentinel */
};

static PyTypeObject CustomType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "custom3.Custom",
    .tp_doc = "Custom objects",
    .tp_basicsize = sizeof(CustomObject),
    .tp_itemsize = 0,
    .tp_flags = Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE,
    .tp_new = Custom_new,
    .tp_init = (initproc) Custom_init,
    .tp_dealloc = (destructor) Custom_dealloc,
    .tp_members = Custom_members,
    .tp_methods = Custom_methods,
    .tp_getset = Custom_getsetters,
};

static PyModuleDef custommodule = {
    PyModuleDef_HEAD_INIT,
    .m_name = "custom3",
    .m_doc = "Example module that creates an extension type.",
    .m_size = -1,
};

PyMODINIT_FUNC
PyInit_custom3(void)
{
    PyObject *m;
    if (PyType_Ready(&CustomType) < 0)
        return NULL;
```

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```
    m = PyModule_Create(&custommodule);
    if (m == NULL)
        return NULL;

    Py_INCREF(&CustomType);
    PyModule_AddObject(m, "Custom", (PyObject *) &CustomType);
    return m;
}
```

To provide greater control, over the `first` and `last` attributes, we'll use custom getter and setter functions. Here are the functions for getting and setting the `first` attribute:

```
static PyObject *
Custom_getfirst(CustomObject *self, void *closure)
{
    Py_INCREF(self->first);
    return self->first;
}

static int
Custom_setfirst(CustomObject *self, PyObject *value, void *closure)
{
    PyObject *tmp;
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete the first attribute");
        return -1;
    }
    if (!PyUnicode_Check(value)) {
        PyErr_SetString(PyExc_TypeError,
                        "The first attribute value must be a string");
        return -1;
    }
    tmp = self->first;
    Py_INCREF(value);
    self->first = value;
    Py_DECREF(tmp);
    return 0;
}
```

The getter function is passed a `Custom` object and a "closure", which is a void pointer. In this case, the closure is ignored. (The closure supports an advanced usage in which definition data is passed to the getter and setter. This could, for example, be used to allow a single set of getter and setter functions that decide the attribute to get or set based on data in the closure.)

The setter function is passed the `Custom` object, the new value, and the closure. The new value may be *NULL*, in which case the attribute is being deleted. In our setter, we raise an error if the attribute is deleted or if its new value is not a string.

We create an array of `PyGetSetDef` structures:

```
static PyGetSetDef Custom_getsetters[] = {
    {"first", (getter) Custom_getfirst, (setter) Custom_setfirst,
     "first name", NULL},
    {"last", (getter) Custom_getlast, (setter) Custom_setlast,
     "last name", NULL},
    {NULL}  /* Sentinel */
};
```

and register it in the `tp_getset` slot:

```
.tp_getset = Custom_getsetters,
```

The last item in a `PyGetSetDef` structure is the "closure" mentioned above. In this case, we aren't using a closure, so we just pass *NULL*.

We also remove the member definitions for these attributes:

```
static PyMemberDef Custom_members[] = {
    {"number", T_INT, offsetof(CustomObject, number), 0,
     "custom number"},
    {NULL}  /* Sentinel */
};
```

We also need to update the `tp_init` handler to only allow strings[3] to be passed:

```
static int
Custom_init(CustomObject *self, PyObject *args, PyObject *kwds)
{
    static char *kwlist[] = {"first", "last", "number", NULL};
    PyObject *first = NULL, *last = NULL, *tmp;

    if (!PyArg_ParseTupleAndKeywords(args, kwds, "|UUi", kwlist,
                                     &first, &last,
                                     &self->number))
        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_DECREF(tmp);
    }
    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_DECREF(tmp);
    }
    return 0;
}
```

With these changes, we can assure that the `first` and `last` members are never *NULL* so we can remove checks for *NULL* values in almost all cases. This means that most of the `Py_XDECREF()` calls can be converted to `Py_DECREF()` calls. The only place we can't change these calls is in the `tp_dealloc` implementation, where there is the possibility that the initialization of these members failed in `tp_new`.

We also rename the module initialization function and module name in the initialization function, as we did before, and we add an extra definition to the `setup.py` file.

2.2.4 Supporting cyclic garbage collection

Python has a *cyclic garbage collector (GC)* that can identify unneeded objects even when their reference counts are not zero. This can happen when objects are involved in cycles. For example, consider:

[3] We now know that the first and last members are strings, so perhaps we could be less careful about decrementing their reference counts, however, we accept instances of string subclasses. Even though deallocating normal strings won't call back into our objects, we can't guarantee that deallocating an instance of a string subclass won't call back into our objects.

```
>>> l = []
>>> l.append(l)
>>> del l
```

In this example, we create a list that contains itself. When we delete it, it still has a reference from itself. Its reference count doesn't drop to zero. Fortunately, Python's cyclic garbage collector will eventually figure out that the list is garbage and free it.

In the second version of the `Custom` example, we allowed any kind of object to be stored in the `first` or `last` attributes[4]. Besides, in the second and third versions, we allowed subclassing `Custom`, and subclasses may add arbitrary attributes. For any of those two reasons, `Custom` objects can participate in cycles:

```
>>> import custom3
>>> class Derived(custom3.Custom): pass
...
>>> n = Derived()
>>> n.some_attribute = n
```

To allow a `Custom` instance participating in a reference cycle to be properly detected and collected by the cyclic GC, our `Custom` type needs to fill two additional slots and to enable a flag that enables these slots:

```
#include <Python.h>
#include "structmember.h"

typedef struct {
    PyObject_HEAD
    PyObject *first; /* first name */
    PyObject *last;  /* last name */
    int number;
} CustomObject;

static int
Custom_traverse(CustomObject *self, visitproc visit, void *arg)
{
    Py_VISIT(self->first);
    Py_VISIT(self->last);
    return 0;
}

static int
Custom_clear(CustomObject *self)
{
    Py_CLEAR(self->first);
    Py_CLEAR(self->last);
    return 0;
}

static void
Custom_dealloc(CustomObject *self)
{
    PyObject_GC_UnTrack(self);
    Custom_clear(self);
    Py_TYPE(self)->tp_free((PyObject *) self);
}
```

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[4] Also, even with our attributes restricted to strings instances, the user could pass arbitrary `str` subclasses and therefore still create reference cycles.

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```
static PyObject *
Custom_new(PyTypeObject *type, PyObject *args, PyObject *kwds)
{
    CustomObject *self;
    self = (CustomObject *) type->tp_alloc(type, 0);
    if (self != NULL) {
        self->first = PyUnicode_FromString("");
        if (self->first == NULL) {
            Py_DECREF(self);
            return NULL;
        }
        self->last = PyUnicode_FromString("");
        if (self->last == NULL) {
            Py_DECREF(self);
            return NULL;
        }
        self->number = 0;
    }
    return (PyObject *) self;
}

static int
Custom_init(CustomObject *self, PyObject *args, PyObject *kwds)
{
    static char *kwlist[] = {"first", "last", "number", NULL};
    PyObject *first = NULL, *last = NULL, *tmp;

    if (!PyArg_ParseTupleAndKeywords(args, kwds, "|UUi", kwlist,
                                     &first, &last,
                                     &self->number))
        return -1;

    if (first) {
        tmp = self->first;
        Py_INCREF(first);
        self->first = first;
        Py_DECREF(tmp);
    }
    if (last) {
        tmp = self->last;
        Py_INCREF(last);
        self->last = last;
        Py_DECREF(tmp);
    }
    return 0;
}

static PyMemberDef Custom_members[] = {
    {"number", T_INT, offsetof(CustomObject, number), 0,
     "custom number"},
    {NULL}  /* Sentinel */
};

static PyObject *
Custom_getfirst(CustomObject *self, void *closure)
{
```

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```
    Py_INCREF(self->first);
    return self->first;
}

static int
Custom_setfirst(CustomObject *self, PyObject *value, void *closure)
{
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete the first attribute");
        return -1;
    }
    if (!PyUnicode_Check(value)) {
        PyErr_SetString(PyExc_TypeError,
                        "The first attribute value must be a string");
        return -1;
    }
    Py_INCREF(value);
    Py_CLEAR(self->first);
    self->first = value;
    return 0;
}

static PyObject *
Custom_getlast(CustomObject *self, void *closure)
{
    Py_INCREF(self->last);
    return self->last;
}

static int
Custom_setlast(CustomObject *self, PyObject *value, void *closure)
{
    if (value == NULL) {
        PyErr_SetString(PyExc_TypeError, "Cannot delete the last attribute");
        return -1;
    }
    if (!PyUnicode_Check(value)) {
        PyErr_SetString(PyExc_TypeError,
                        "The last attribute value must be a string");
        return -1;
    }
    Py_INCREF(value);
    Py_CLEAR(self->last);
    self->last = value;
    return 0;
}

static PyGetSetDef Custom_getsetters[] = {
    {"first", (getter) Custom_getfirst, (setter) Custom_setfirst,
     "first name", NULL},
    {"last", (getter) Custom_getlast, (setter) Custom_setlast,
     "last name", NULL},
    {NULL}  /* Sentinel */
};

static PyObject *
```

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```
Custom_name(CustomObject *self, PyObject *Py_UNUSED(ignored))
{
    return PyUnicode_FromFormat("%S %S", self->first, self->last);
}

static PyMethodDef Custom_methods[] = {
    {"name", (PyCFunction) Custom_name, METH_NOARGS,
     "Return the name, combining the first and last name"
    },
    {NULL}  /* Sentinel */
};

static PyTypeObject CustomType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "custom4.Custom",
    .tp_doc = "Custom objects",
    .tp_basicsize = sizeof(CustomObject),
    .tp_itemsize = 0,
    .tp_flags = Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE | Py_TPFLAGS_HAVE_GC,
    .tp_new = Custom_new,
    .tp_init = (initproc) Custom_init,
    .tp_dealloc = (destructor) Custom_dealloc,
    .tp_traverse = (traverseproc) Custom_traverse,
    .tp_clear = (inquiry) Custom_clear,
    .tp_members = Custom_members,
    .tp_methods = Custom_methods,
    .tp_getset = Custom_getsetters,
};

static PyModuleDef custommodule = {
    PyModuleDef_HEAD_INIT,
    .m_name = "custom4",
    .m_doc = "Example module that creates an extension type.",
    .m_size = -1,
};

PyMODINIT_FUNC
PyInit_custom4(void)
{
    PyObject *m;
    if (PyType_Ready(&CustomType) < 0)
        return NULL;

    m = PyModule_Create(&custommodule);
    if (m == NULL)
        return NULL;

    Py_INCREF(&CustomType);
    PyModule_AddObject(m, "Custom", (PyObject *) &CustomType);
    return m;
}
```

First, the traversal method lets the cyclic GC know about subobjects that could participate in cycles:

```
static int
Custom_traverse(CustomObject *self, visitproc visit, void *arg)
```

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```
{
    int vret;
    if (self->first) {
        vret = visit(self->first, arg);
        if (vret != 0)
            return vret;
    }
    if (self->last) {
        vret = visit(self->last, arg);
        if (vret != 0)
            return vret;
    }
    return 0;
}
```

For each subobject that can participate in cycles, we need to call the `visit()` function, which is passed to the traversal method. The `visit()` function takes as arguments the subobject and the extra argument *arg* passed to the traversal method. It returns an integer value that must be returned if it is non-zero.

Python provides a `Py_VISIT()` macro that automates calling visit functions. With `Py_VISIT()`, we can minimize the amount of boilerplate in `Custom_traverse`:

```
static int
Custom_traverse(CustomObject *self, visitproc visit, void *arg)
{
    Py_VISIT(self->first);
    Py_VISIT(self->last);
    return 0;
}
```

Note: The `tp_traverse` implementation must name its arguments exactly *visit* and *arg* in order to use `Py_VISIT()`.

Second, we need to provide a method for clearing any subobjects that can participate in cycles:

```
static int
Custom_clear(CustomObject *self)
{
    Py_CLEAR(self->first);
    Py_CLEAR(self->last);
    return 0;
}
```

Notice the use of the `Py_CLEAR()` macro. It is the recommended and safe way to clear data attributes of arbitrary types while decrementing their reference counts. If you were to call `Py_XDECREF()` instead on the attribute before setting it to *NULL*, there is a possibility that the attribute's destructor would call back into code that reads the attribute again (*especially* if there is a reference cycle).

Note: You could emulate `Py_CLEAR()` by writing:

```
PyObject *tmp;
tmp = self->first;
self->first = NULL;
Py_XDECREF(tmp);
```

Nevertheless, it is much easier and less error-prone to always use `Py_CLEAR()` when deleting an attribute. Don't try to micro-optimize at the expense of robustness!

The deallocator `Custom_dealloc` may call arbitrary code when clearing attributes. It means the circular GC can be triggered inside the function. Since the GC assumes reference count is not zero, we need to untrack the object from the GC by calling `PyObject_GC_UnTrack()` before clearing members. Here is our reimplemented deallocator using `PyObject_GC_UnTrack()` and `Custom_clear`:

```
static void
Custom_dealloc(CustomObject *self)
{
    PyObject_GC_UnTrack(self);
    Custom_clear(self);
    Py_TYPE(self)->tp_free((PyObject *) self);
}
```

Finally, we add the `Py_TPFLAGS_HAVE_GC` flag to the class flags:

```
.tp_flags = Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE | Py_TPFLAGS_HAVE_GC,
```

That's pretty much it. If we had written custom `tp_alloc` or `tp_free` handlers, we'd need to modify them for cyclic garbage collection. Most extensions will use the versions automatically provided.

2.2.5 Subclassing other types

It is possible to create new extension types that are derived from existing types. It is easiest to inherit from the built in types, since an extension can easily use the `PyTypeObject` it needs. It can be difficult to share these `PyTypeObject` structures between extension modules.

In this example we will create a `SubList` type that inherits from the built-in `list` type. The new type will be completely compatible with regular lists, but will have an additional `increment()` method that increases an internal counter:

```
>>> import sublist
>>> s = sublist.SubList(range(3))
>>> s.extend(s)
>>> print(len(s))
6
>>> print(s.increment())
1
>>> print(s.increment())
2
```

```
#include <Python.h>

typedef struct {
    PyListObject list;
    int state;
} SubListObject;

static PyObject *
SubList_increment(SubListObject *self, PyObject *unused)
{
    self->state++;
    return PyLong_FromLong(self->state);
```

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```
}

static PyMethodDef SubList_methods[] = {
    {"increment", (PyCFunction) SubList_increment, METH_NOARGS,
     PyDoc_STR("increment state counter")},
    {NULL},
};

static int
SubList_init(SubListObject *self, PyObject *args, PyObject *kwds)
{
    if (PyList_Type.tp_init((PyObject *) self, args, kwds) < 0)
        return -1;
    self->state = 0;
    return 0;
}

static PyTypeObject SubListType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    .tp_name = "sublist.SubList",
    .tp_doc = "SubList objects",
    .tp_basicsize = sizeof(SubListObject),
    .tp_itemsize = 0,
    .tp_flags = Py_TPFLAGS_DEFAULT | Py_TPFLAGS_BASETYPE,
    .tp_init = (initproc) SubList_init,
    .tp_methods = SubList_methods,
};

static PyModuleDef sublistmodule = {
    PyModuleDef_HEAD_INIT,
    .m_name = "sublist",
    .m_doc = "Example module that creates an extension type.",
    .m_size = -1,
};

PyMODINIT_FUNC
PyInit_sublist(void)
{
    PyObject *m;
    SubListType.tp_base = &PyList_Type;
    if (PyType_Ready(&SubListType) < 0)
        return NULL;

    m = PyModule_Create(&sublistmodule);
    if (m == NULL)
        return NULL;

    Py_INCREF(&SubListType);
    PyModule_AddObject(m, "SubList", (PyObject *) &SubListType);
    return m;
}
```

As you can see, the source code closely resembles the `Custom` examples in previous sections. We will break down the main differences between them.

```
typedef struct {
```

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```
    PyListObject list;
    int state;
} SubListObject;
```

The primary difference for derived type objects is that the base type's object structure must be the first value. The base type will already include the `PyObject_HEAD()` at the beginning of its structure.

When a Python object is a `SubList` instance, its `PyObject *` pointer can be safely cast to both `PyListObject *` and `SubListObject *`:

```
static int
SubList_init(SubListObject *self, PyObject *args, PyObject *kwds)
{
    if (PyList_Type.tp_init((PyObject *) self, args, kwds) < 0)
        return -1;
    self->state = 0;
    return 0;
}
```

We see above how to call through to the `__init__` method of the base type.

This pattern is important when writing a type with custom `tp_new` and `tp_dealloc` members. The `tp_new` handler should not actually create the memory for the object with its `tp_alloc`, but let the base class handle it by calling its own `tp_new`.

The `PyTypeObject` struct supports a `tp_base` specifying the type's concrete base class. Due to cross-platform compiler issues, you can't fill that field directly with a reference to `PyList_Type`; it should be done later in the module initialization function:

```
PyMODINIT_FUNC
PyInit_sublist(void)
{
    PyObject* m;
    SubListType.tp_base = &PyList_Type;
    if (PyType_Ready(&SubListType) < 0)
        return NULL;

    m = PyModule_Create(&sublistmodule);
    if (m == NULL)
        return NULL;

    Py_INCREF(&SubListType);
    PyModule_AddObject(m, "SubList", (PyObject *) &SubListType);
    return m;
}
```

Before calling `PyType_Ready()`, the type structure must have the `tp_base` slot filled in. When we are deriving an existing type, it is not necessary to fill out the `tp_alloc` slot with `PyType_GenericNew()` – the allocation function from the base type will be inherited.

After that, calling `PyType_Ready()` and adding the type object to the module is the same as with the basic `Custom` examples.

2.3 Defining Extension Types: Assorted Topics

This section aims to give a quick fly-by on the various type methods you can implement and what they do.

Here is the definition of `PyTypeObject`, with some fields only used in debug builds omitted:

```
typedef struct _typeobject {
    PyObject_VAR_HEAD
    const char *tp_name; /* For printing, in format "<module>.<name>" */
    Py_ssize_t tp_basicsize, tp_itemsize; /* For allocation */

    /* Methods to implement standard operations */

    destructor tp_dealloc;
    printfunc tp_print;
    getattrfunc tp_getattr;
    setattrfunc tp_setattr;
    PyAsyncMethods *tp_as_async; /* formerly known as tp_compare (Python 2)
                                    or tp_reserved (Python 3) */
    reprfunc tp_repr;

    /* Method suites for standard classes */

    PyNumberMethods *tp_as_number;
    PySequenceMethods *tp_as_sequence;
    PyMappingMethods *tp_as_mapping;

    /* More standard operations (here for binary compatibility) */

    hashfunc tp_hash;
    ternaryfunc tp_call;
    reprfunc tp_str;
    getattrofunc tp_getattro;
    setattrofunc tp_setattro;

    /* Functions to access object as input/output buffer */
    PyBufferProcs *tp_as_buffer;

    /* Flags to define presence of optional/expanded features */
    unsigned long tp_flags;

    const char *tp_doc; /* Documentation string */

    /* call function for all accessible objects */
    traverseproc tp_traverse;

    /* delete references to contained objects */
    inquiry tp_clear;

    /* rich comparisons */
    richcmpfunc tp_richcompare;

    /* weak reference enabler */
    Py_ssize_t tp_weaklistoffset;

    /* Iterators */
    getiterfunc tp_iter;
    iternextfunc tp_iternext;

    /* Attribute descriptor and subclassing stuff */
    struct PyMethodDef *tp_methods;
    struct PyMemberDef *tp_members;
```

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```
    struct PyGetSetDef *tp_getset;
    struct _typeobject *tp_base;
    PyObject *tp_dict;
    descrgetfunc tp_descr_get;
    descrsetfunc tp_descr_set;
    Py_ssize_t tp_dictoffset;
    initproc tp_init;
    allocfunc tp_alloc;
    newfunc tp_new;
    freefunc tp_free; /* Low-level free-memory routine */
    inquiry tp_is_gc; /* For PyObject_IS_GC */
    PyObject *tp_bases;
    PyObject *tp_mro; /* method resolution order */
    PyObject *tp_cache;
    PyObject *tp_subclasses;
    PyObject *tp_weaklist;
    destructor tp_del;

    /* Type attribute cache version tag. Added in version 2.6 */
    unsigned int tp_version_tag;

    destructor tp_finalize;

} PyTypeObject;
```

Now that's a *lot* of methods. Don't worry too much though – if you have a type you want to define, the chances are very good that you will only implement a handful of these.

As you probably expect by now, we're going to go over this and give more information about the various handlers. We won't go in the order they are defined in the structure, because there is a lot of historical baggage that impacts the ordering of the fields. It's often easiest to find an example that includes the fields you need and then change the values to suit your new type.

```
const char *tp_name; /* For printing */
```

The name of the type – as mentioned in the previous chapter, this will appear in various places, almost entirely for diagnostic purposes. Try to choose something that will be helpful in such a situation!

```
Py_ssize_t tp_basicsize, tp_itemsize; /* For allocation */
```

These fields tell the runtime how much memory to allocate when new objects of this type are created. Python has some built-in support for variable length structures (think: strings, tuples) which is where the `tp_itemsize` field comes in. This will be dealt with later.

```
const char *tp_doc;
```

Here you can put a string (or its address) that you want returned when the Python script references `obj.__doc__` to retrieve the doc string.

Now we come to the basic type methods – the ones most extension types will implement.

2.3.1 Finalization and De-allocation

```
destructor tp_dealloc;
```

This function is called when the reference count of the instance of your type is reduced to zero and the Python interpreter wants to reclaim it. If your type has memory to free or other clean-up to perform, you can put it here. The object itself needs to be freed here as well. Here is an example of this function:

```
static void
newdatatype_dealloc(newdatatypeobject *obj)
{
    free(obj->obj_UnderlyingDatatypePtr);
    Py_TYPE(obj)->tp_free(obj);
}
```

One important requirement of the deallocator function is that it leaves any pending exceptions alone. This is important since deallocators are frequently called as the interpreter unwinds the Python stack; when the stack is unwound due to an exception (rather than normal returns), nothing is done to protect the deallocators from seeing that an exception has already been set. Any actions which a deallocator performs which may cause additional Python code to be executed may detect that an exception has been set. This can lead to misleading errors from the interpreter. The proper way to protect against this is to save a pending exception before performing the unsafe action, and restoring it when done. This can be done using the `PyErr_Fetch()` and `PyErr_Restore()` functions:

```
static void
my_dealloc(PyObject *obj)
{
    MyObject *self = (MyObject *) obj;
    PyObject *cbresult;

    if (self->my_callback != NULL) {
        PyObject *err_type, *err_value, *err_traceback;

        /* This saves the current exception state */
        PyErr_Fetch(&err_type, &err_value, &err_traceback);

        cbresult = PyObject_CallObject(self->my_callback, NULL);
        if (cbresult == NULL)
            PyErr_WriteUnraisable(self->my_callback);
        else
            Py_DECREF(cbresult);

        /* This restores the saved exception state */
        PyErr_Restore(err_type, err_value, err_traceback);

        Py_DECREF(self->my_callback);
    }
    Py_TYPE(obj)->tp_free((PyObject*)self);
}
```

Note: There are limitations to what you can safely do in a deallocator function. First, if your type supports garbage collection (using `tp_traverse` and/or `tp_clear`), some of the object's members can have been cleared or finalized by the time `tp_dealloc` is called. Second, in `tp_dealloc`, your object is in an unstable state: its reference count is equal to zero. Any call to a non-trivial object or API (as in the example above) might end up calling `tp_dealloc` again, causing a double free and a crash.

Starting with Python 3.4, it is recommended not to put any complex finalization code in `tp_dealloc`, and instead use the new `tp_finalize` type method.

See also:

PEP 442 explains the new finalization scheme.

2.3.2 Object Presentation

In Python, there are two ways to generate a textual representation of an object: the `repr()` function, and the `str()` function. (The `print()` function just calls `str()`.) These handlers are both optional.

```
reprfunc tp_repr;
reprfunc tp_str;
```

The `tp_repr` handler should return a string object containing a representation of the instance for which it is called. Here is a simple example:

```
static PyObject *
newdatatype_repr(newdatatypeobject * obj)
{
    return PyUnicode_FromFormat("Repr-ified_newdatatype{{size:%d}}",
                                obj->obj_UnderlyingDatatypePtr->size);
}
```

If no `tp_repr` handler is specified, the interpreter will supply a representation that uses the type's `tp_name` and a uniquely-identifying value for the object.

The `tp_str` handler is to `str()` what the `tp_repr` handler described above is to `repr()`; that is, it is called when Python code calls `str()` on an instance of your object. Its implementation is very similar to the `tp_repr` function, but the resulting string is intended for human consumption. If `tp_str` is not specified, the `tp_repr` handler is used instead.

Here is a simple example:

```
static PyObject *
newdatatype_str(newdatatypeobject * obj)
{
    return PyUnicode_FromFormat("Stringified_newdatatype{{size:%d}}",
                                obj->obj_UnderlyingDatatypePtr->size);
}
```

2.3.3 Attribute Management

For every object which can support attributes, the corresponding type must provide the functions that control how the attributes are resolved. There needs to be a function which can retrieve attributes (if any are defined), and another to set attributes (if setting attributes is allowed). Removing an attribute is a special case, for which the new value passed to the handler is *NULL*.

Python supports two pairs of attribute handlers; a type that supports attributes only needs to implement the functions for one pair. The difference is that one pair takes the name of the attribute as a `char*`, while the other accepts a `PyObject*`. Each type can use whichever pair makes more sense for the implementation's convenience.

```
getattrfunc  tp_getattr;        /* char * version */
setattrfunc  tp_setattr;
/* ... */
getattrofunc tp_getattro;       /* PyObject * version */
setattrofunc tp_setattro;
```

If accessing attributes of an object is always a simple operation (this will be explained shortly), there are generic implementations which can be used to provide the `PyObject*` version of the attribute management functions. The actual need for type-specific attribute handlers almost completely disappeared starting with Python 2.2, though there are many examples which have not been updated to use some of the new generic mechanism that is available.

Generic Attribute Management

Most extension types only use *simple* attributes. So, what makes the attributes simple? There are only a couple of conditions that must be met:

1. The name of the attributes must be known when `PyType_Ready()` is called.
2. No special processing is needed to record that an attribute was looked up or set, nor do actions need to be taken based on the value.

Note that this list does not place any restrictions on the values of the attributes, when the values are computed, or how relevant data is stored.

When `PyType_Ready()` is called, it uses three tables referenced by the type object to create *descriptor*s which are placed in the dictionary of the type object. Each descriptor controls access to one attribute of the instance object. Each of the tables is optional; if all three are *NULL*, instances of the type will only have attributes that are inherited from their base type, and should leave the `tp_getattro` and `tp_setattro` fields *NULL* as well, allowing the base type to handle attributes.

The tables are declared as three fields of the type object:

```
struct PyMethodDef *tp_methods;
struct PyMemberDef *tp_members;
struct PyGetSetDef *tp_getset;
```

If `tp_methods` is not *NULL*, it must refer to an array of `PyMethodDef` structures. Each entry in the table is an instance of this structure:

```
typedef struct PyMethodDef {
    const char  *ml_name;       /* method name */
    PyCFunction  ml_meth;       /* implementation function */
    int          ml_flags;      /* flags */
    const char  *ml_doc;        /* docstring */
} PyMethodDef;
```

One entry should be defined for each method provided by the type; no entries are needed for methods inherited from a base type. One additional entry is needed at the end; it is a sentinel that marks the end of the array. The `ml_name` field of the sentinel must be *NULL*.

The second table is used to define attributes which map directly to data stored in the instance. A variety of primitive C types are supported, and access may be read-only or read-write. The structures in the table are defined as:

```
typedef struct PyMemberDef {
    const char *name;
    int         type;
    int         offset;
    int         flags;
    const char *doc;
} PyMemberDef;
```

For each entry in the table, a *descriptor* will be constructed and added to the type which will be able to extract a value from the instance structure. The `type` field should contain one of the type codes defined in

the `structmember.h` header; the value will be used to determine how to convert Python values to and from C values. The `flags` field is used to store flags which control how the attribute can be accessed.

The following flag constants are defined in `structmember.h`; they may be combined using bitwise-OR.

Constant	Meaning
`READONLY`	Never writable.
`READ_RESTRICTED`	Not readable in restricted mode.
`WRITE_RESTRICTED`	Not writable in restricted mode.
`RESTRICTED`	Not readable or writable in restricted mode.

An interesting advantage of using the `tp_members` table to build descriptors that are used at runtime is that any attribute defined this way can have an associated doc string simply by providing the text in the table. An application can use the introspection API to retrieve the descriptor from the class object, and get the doc string using its `__doc__` attribute.

As with the `tp_methods` table, a sentinel entry with a `name` value of *NULL* is required.

Type-specific Attribute Management

For simplicity, only the `char*` version will be demonstrated here; the type of the name parameter is the only difference between the `char*` and `PyObject*` flavors of the interface. This example effectively does the same thing as the generic example above, but does not use the generic support added in Python 2.2. It explains how the handler functions are called, so that if you do need to extend their functionality, you'll understand what needs to be done.

The `tp_getattr` handler is called when the object requires an attribute look-up. It is called in the same situations where the `__getattr__()` method of a class would be called.

Here is an example:

```
static PyObject *
newdatatype_getattr(newdatatypeobject *obj, char *name)
{
    if (strcmp(name, "data") == 0)
    {
        return PyLong_FromLong(obj->data);
    }

    PyErr_Format(PyExc_AttributeError,
                 "'%.50s' object has no attribute '%.400s'",
                 tp->tp_name, name);
    return NULL;
}
```

The `tp_setattr` handler is called when the `__setattr__()` or `__delattr__()` method of a class instance would be called. When an attribute should be deleted, the third parameter will be *NULL*. Here is an example that simply raises an exception; if this were really all you wanted, the `tp_setattr` handler should be set to *NULL*.

```
static int
newdatatype_setattr(newdatatypeobject *obj, char *name, PyObject *v)
{
    PyErr_Format(PyExc_RuntimeError, "Read-only attribute: %s", name);
    return -1;
}
```

2.3.4 Object Comparison

```
richcmpfunc tp_richcompare;
```

The `tp_richcompare` handler is called when comparisons are needed. It is analogous to the rich comparison methods, like `__lt__()`, and also called by `PyObject_RichCompare()` and `PyObject_RichCompareBool()`.

This function is called with two Python objects and the operator as arguments, where the operator is one of `Py_EQ`, `Py_NE`, `Py_LE`, `Py_GT`, `Py_LT` or `Py_GT`. It should compare the two objects with respect to the specified operator and return `Py_True` or `Py_False` if the comparison is successful, `Py_NotImplemented` to indicate that comparison is not implemented and the other object's comparison method should be tried, or *NULL* if an exception was set.

Here is a sample implementation, for a datatype that is considered equal if the size of an internal pointer is equal:

```
static PyObject *
newdatatype_richcmp(PyObject *obj1, PyObject *obj2, int op)
{
    PyObject *result;
    int c, size1, size2;

    /* code to make sure that both arguments are of type
       newdatatype omitted */

    size1 = obj1->obj_UnderlyingDatatypePtr->size;
    size2 = obj2->obj_UnderlyingDatatypePtr->size;

    switch (op) {
    case Py_LT: c = size1 <  size2; break;
    case Py_LE: c = size1 <= size2; break;
    case Py_EQ: c = size1 == size2; break;
    case Py_NE: c = size1 != size2; break;
    case Py_GT: c = size1 >  size2; break;
    case Py_GE: c = size1 >= size2; break;
    }
    result = c ? Py_True : Py_False;
    Py_INCREF(result);
    return result;
}
```

2.3.5 Abstract Protocol Support

Python supports a variety of *abstract* 'protocols;' the specific interfaces provided to use these interfaces are documented in abstract.

A number of these abstract interfaces were defined early in the development of the Python implementation. In particular, the number, mapping, and sequence protocols have been part of Python since the beginning. Other protocols have been added over time. For protocols which depend on several handler routines from the type implementation, the older protocols have been defined as optional blocks of handlers referenced by the type object. For newer protocols there are additional slots in the main type object, with a flag bit being set to indicate that the slots are present and should be checked by the interpreter. (The flag bit does not indicate that the slot values are non-*NULL*. The flag may be set to indicate the presence of a slot, but a slot may still be unfilled.)

```
PyNumberMethods   *tp_as_number;
PySequenceMethods *tp_as_sequence;
PyMappingMethods  *tp_as_mapping;
```

If you wish your object to be able to act like a number, a sequence, or a mapping object, then you place the address of a structure that implements the C type `PyNumberMethods`, `PySequenceMethods`, or `PyMappingMethods`, respectively. It is up to you to fill in this structure with appropriate values. You can find examples of the use of each of these in the `Objects` directory of the Python source distribution.

```
hashfunc tp_hash;
```

This function, if you choose to provide it, should return a hash number for an instance of your data type. Here is a simple example:

```
static Py_hash_t
newdatatype_hash(newdatatypeobject *obj)
{
    Py_hash_t result;
    result = obj->some_size + 32767 * obj->some_number;
    if (result == -1)
       result = -2;
    return result;
}
```

`Py_hash_t` is a signed integer type with a platform-varying width. Returning `-1` from `tp_hash` indicates an error, which is why you should be careful to avoid returning it when hash computation is successful, as seen above.

```
ternaryfunc tp_call;
```

This function is called when an instance of your data type is "called", for example, if `obj1` is an instance of your data type and the Python script contains `obj1('hello')`, the `tp_call` handler is invoked.

This function takes three arguments:

1. *self* is the instance of the data type which is the subject of the call. If the call is `obj1('hello')`, then *self* is `obj1`.
2. *args* is a tuple containing the arguments to the call. You can use `PyArg_ParseTuple()` to extract the arguments.
3. *kwds* is a dictionary of keyword arguments that were passed. If this is non-*NULL* and you support keyword arguments, use `PyArg_ParseTupleAndKeywords()` to extract the arguments. If you do not want to support keyword arguments and this is non-*NULL*, raise a `TypeError` with a message saying that keyword arguments are not supported.

Here is a toy `tp_call` implementation:

```
static PyObject *
newdatatype_call(newdatatypeobject *self, PyObject *args, PyObject *kwds)
{
    PyObject *result;
    const char *arg1;
    const char *arg2;
    const char *arg3;

    if (!PyArg_ParseTuple(args, "sss:call", &arg1, &arg2, &arg3)) {
        return NULL;
    }
```

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```
    result = PyUnicode_FromFormat(
        "Returning -- value: [%d] arg1: [%s] arg2: [%s] arg3: [%s]\n",
        obj->obj_UnderlyingDatatypePtr->size,
        arg1, arg2, arg3);
    return result;
}
```

```
/* Iterators */
getiterfunc tp_iter;
iternextfunc tp_iternext;
```

These functions provide support for the iterator protocol. Both handlers take exactly one parameter, the instance for which they are being called, and return a new reference. In the case of an error, they should set an exception and return *NULL*. `tp_iter` corresponds to the Python `__iter__()` method, while `tp_iternext` corresponds to the Python `__next__()` method.

Any *iterable* object must implement the `tp_iter` handler, which must return an *iterator* object. Here the same guidelines apply as for Python classes:

- For collections (such as lists and tuples) which can support multiple independent iterators, a new iterator should be created and returned by each call to `tp_iter`.
- Objects which can only be iterated over once (usually due to side effects of iteration, such as file objects) can implement `tp_iter` by returning a new reference to themselves – and should also therefore implement the `tp_iternext` handler.

Any *iterator* object should implement both `tp_iter` and `tp_iternext`. An iterator's `tp_iter` handler should return a new reference to the iterator. Its `tp_iternext` handler should return a new reference to the next object in the iteration, if there is one. If the iteration has reached the end, `tp_iternext` may return *NULL* without setting an exception, or it may set `StopIteration` *in addition* to returning *NULL*; avoiding the exception can yield slightly better performance. If an actual error occurs, `tp_iternext` should always set an exception and return *NULL*.

2.3.6 Weak Reference Support

One of the goals of Python's weak reference implementation is to allow any type to participate in the weak reference mechanism without incurring the overhead on performance-critical objects (such as numbers).

See also:

Documentation for the `weakref` module.

For an object to be weakly referencable, the extension type must do two things:

1. Include a `PyObject*` field in the C object structure dedicated to the weak reference mechanism. The object's constructor should leave it *NULL* (which is automatic when using the default `tp_alloc`).
2. Set the `tp_weaklistoffset` type member to the offset of the aforementioned field in the C object structure, so that the interpreter knows how to access and modify that field.

Concretely, here is how a trivial object structure would be augmented with the required field:

```
typedef struct {
    PyObject_HEAD
    PyObject *weakreflist;  /* List of weak references */
} TrivialObject;
```

And the corresponding member in the statically-declared type object:

```
static PyTypeObject TrivialType = {
    PyVarObject_HEAD_INIT(NULL, 0)
    /* ... other members omitted for brevity ... */
    .tp_weaklistoffset = offsetof(TrivialObject, weakreflist),
};
```

The only further addition is that `tp_dealloc` needs to clear any weak references (by calling `PyObject_ClearWeakRefs()`) if the field is non-*NULL*:

```
static void
Trivial_dealloc(TrivialObject *self)
{
    /* Clear weakrefs first before calling any destructors */
    if (self->weakreflist != NULL)
        PyObject_ClearWeakRefs((PyObject *) self);
    /* ... remainder of destruction code omitted for brevity ... */
    Py_TYPE(self)->tp_free((PyObject *) self);
}
```

2.3.7 More Suggestions

In order to learn how to implement any specific method for your new data type, get the *CPython* source code. Go to the `Objects` directory, then search the C source files for `tp_` plus the function you want (for example, `tp_richcompare`). You will find examples of the function you want to implement.

When you need to verify that an object is a concrete instance of the type you are implementing, use the `PyObject_TypeCheck()` function. A sample of its use might be something like the following:

```
if (!PyObject_TypeCheck(some_object, &MyType)) {
    PyErr_SetString(PyExc_TypeError, "arg #1 not a mything");
    return NULL;
}
```

See also:

Download CPython source releases. https://www.python.org/downloads/source/

The CPython project on GitHub, where the CPython source code is developed. https://github.com/python/cpython

2.4 Building C and C++ Extensions

A C extension for CPython is a shared library (e.g. a `.so` file on Linux, `.pyd` on Windows), which exports an *initialization function*.

To be importable, the shared library must be available on `PYTHONPATH`, and must be named after the module name, with an appropriate extension. When using distutils, the correct filename is generated automatically.

The initialization function has the signature:

PyObject* **`PyInit_modulename`**`(void)`

It returns either a fully-initialized module, or a `PyModuleDef` instance. See initializing-modules for details.

For modules with ASCII-only names, the function must be named `PyInit_<modulename>`, with `<modulename>` replaced by the name of the module. When using multi-phase-initialization, non-ASCII

module names are allowed. In this case, the initialization function name is `PyInitU_<modulename>`, with `<modulename>` encoded using Python's *punycode* encoding with hyphens replaced by underscores. In Python:

```
def initfunc_name(name):
    try:
        suffix = b'_' + name.encode('ascii')
    except UnicodeEncodeError:
        suffix = b'U_' + name.encode('punycode').replace(b'-', b'_')
    return b'PyInit' + suffix
```

It is possible to export multiple modules from a single shared library by defining multiple initialization functions. However, importing them requires using symbolic links or a custom importer, because by default only the function corresponding to the filename is found. See the *"Multiple modules in one library"* section in **PEP 489** for details.

2.4.1 Building C and C++ Extensions with distutils

Extension modules can be built using distutils, which is included in Python. Since distutils also supports creation of binary packages, users don't necessarily need a compiler and distutils to install the extension.

A distutils package contains a driver script, `setup.py`. This is a plain Python file, which, in the most simple case, could look like this:

```
from distutils.core import setup, Extension

module1 = Extension('demo',
                    sources = ['demo.c'])

setup (name = 'PackageName',
       version = '1.0',
       description = 'This is a demo package',
       ext_modules = [module1])
```

With this `setup.py`, and a file `demo.c`, running

```
python setup.py build
```

will compile `demo.c`, and produce an extension module named `demo` in the `build` directory. Depending on the system, the module file will end up in a subdirectory `build/lib.system`, and may have a name like `demo.so` or `demo.pyd`.

In the `setup.py`, all execution is performed by calling the `setup` function. This takes a variable number of keyword arguments, of which the example above uses only a subset. Specifically, the example specifies meta-information to build packages, and it specifies the contents of the package. Normally, a package will contain additional modules, like Python source modules, documentation, subpackages, etc. Please refer to the distutils documentation in distutils-index to learn more about the features of distutils; this section explains building extension modules only.

It is common to pre-compute arguments to `setup()`, to better structure the driver script. In the example above, the `ext_modules` argument to `setup()` is a list of extension modules, each of which is an instance of the `Extension`. In the example, the instance defines an extension named `demo` which is build by compiling a single source file, `demo.c`.

In many cases, building an extension is more complex, since additional preprocessor defines and libraries may be needed. This is demonstrated in the example below.

```
from distutils.core import setup, Extension

module1 = Extension('demo',
                    define_macros = [('MAJOR_VERSION', '1'),
                                     ('MINOR_VERSION', '0')],
                    include_dirs = ['/usr/local/include'],
                    libraries = ['tcl83'],
                    library_dirs = ['/usr/local/lib'],
                    sources = ['demo.c'])

setup (name = 'PackageName',
       version = '1.0',
       description = 'This is a demo package',
       author = 'Martin v. Loewis',
       author_email = 'martin@v.loewis.de',
       url = 'https://docs.python.org/extending/building',
       long_description = '''
This is really just a demo package.
''',
       ext_modules = [module1])
```

In this example, `setup()` is called with additional meta-information, which is recommended when distribution packages have to be built. For the extension itself, it specifies preprocessor defines, include directories, library directories, and libraries. Depending on the compiler, distutils passes this information in different ways to the compiler. For example, on Unix, this may result in the compilation commands

```
gcc -DNDEBUG -g -O3 -Wall -Wstrict-prototypes -fPIC -DMAJOR_VERSION=1 -DMINOR_VERSION=0 -I/usr/
↪local/include -I/usr/local/include/python2.2 -c demo.c -o build/temp.linux-i686-2.2/demo.o

gcc -shared build/temp.linux-i686-2.2/demo.o -L/usr/local/lib -ltcl83 -o build/lib.linux-i686-2.2/
↪demo.so
```

These lines are for demonstration purposes only; distutils users should trust that distutils gets the invocations right.

2.4.2 Distributing your extension modules

When an extension has been successfully build, there are three ways to use it.

End-users will typically want to install the module, they do so by running

```
python setup.py install
```

Module maintainers should produce source packages; to do so, they run

```
python setup.py sdist
```

In some cases, additional files need to be included in a source distribution; this is done through a `MANIFEST.in` file; see manifest for details.

If the source distribution has been build successfully, maintainers can also create binary distributions. Depending on the platform, one of the following commands can be used to do so.

```
python setup.py bdist_wininst
python setup.py bdist_rpm
python setup.py bdist_dumb
```

2.5 Building C and C++ Extensions on Windows

This chapter briefly explains how to create a Windows extension module for Python using Microsoft Visual C++, and follows with more detailed background information on how it works. The explanatory material is useful for both the Windows programmer learning to build Python extensions and the Unix programmer interested in producing software which can be successfully built on both Unix and Windows.

Module authors are encouraged to use the distutils approach for building extension modules, instead of the one described in this section. You will still need the C compiler that was used to build Python; typically Microsoft Visual C++.

Note: This chapter mentions a number of filenames that include an encoded Python version number. These filenames are represented with the version number shown as `XY`; in practice, `'X'` will be the major version number and `'Y'` will be the minor version number of the Python release you're working with. For example, if you are using Python 2.2.1, `XY` will actually be `22`.

2.5.1 A Cookbook Approach

There are two approaches to building extension modules on Windows, just as there are on Unix: use the `distutils` package to control the build process, or do things manually. The distutils approach works well for most extensions; documentation on using `distutils` to build and package extension modules is available in distutils-index. If you find you really need to do things manually, it may be instructive to study the project file for the winsound standard library module.

2.5.2 Differences Between Unix and Windows

Unix and Windows use completely different paradigms for run-time loading of code. Before you try to build a module that can be dynamically loaded, be aware of how your system works.

In Unix, a shared object (`.so`) file contains code to be used by the program, and also the names of functions and data that it expects to find in the program. When the file is joined to the program, all references to those functions and data in the file's code are changed to point to the actual locations in the program where the functions and data are placed in memory. This is basically a link operation.

In Windows, a dynamic-link library (`.dll`) file has no dangling references. Instead, an access to functions or data goes through a lookup table. So the DLL code does not have to be fixed up at runtime to refer to the program's memory; instead, the code already uses the DLL's lookup table, and the lookup table is modified at runtime to point to the functions and data.

In Unix, there is only one type of library file (`.a`) which contains code from several object files (`.o`). During the link step to create a shared object file (`.so`), the linker may find that it doesn't know where an identifier is defined. The linker will look for it in the object files in the libraries; if it finds it, it will include all the code from that object file.

In Windows, there are two types of library, a static library and an import library (both called `.lib`). A static library is like a Unix `.a` file; it contains code to be included as necessary. An import library is basically used only to reassure the linker that a certain identifier is legal, and will be present in the program when the DLL is loaded. So the linker uses the information from the import library to build the lookup table for using identifiers that are not included in the DLL. When an application or a DLL is linked, an import library may be generated, which will need to be used for all future DLLs that depend on the symbols in the application or DLL.

Suppose you are building two dynamic-load modules, B and C, which should share another block of code A. On Unix, you would *not* pass `A.a` to the linker for `B.so` and `C.so`; that would cause it to be included twice,

so that B and C would each have their own copy. In Windows, building `A.dll` will also build `A.lib`. You *do* pass `A.lib` to the linker for B and C. `A.lib` does not contain code; it just contains information which will be used at runtime to access A's code.

In Windows, using an import library is sort of like using `import spam`; it gives you access to spam's names, but does not create a separate copy. On Unix, linking with a library is more like `from spam import *`; it does create a separate copy.

2.5.3 Using DLLs in Practice

Windows Python is built in Microsoft Visual C++; using other compilers may or may not work (though Borland seems to). The rest of this section is MSVC++ specific.

When creating DLLs in Windows, you must pass `pythonXY.lib` to the linker. To build two DLLs, spam and ni (which uses C functions found in spam), you could use these commands:

```
cl /LD /I/python/include spam.c ../libs/pythonXY.lib
cl /LD /I/python/include ni.c spam.lib ../libs/pythonXY.lib
```

The first command created three files: `spam.obj`, `spam.dll` and `spam.lib`. `Spam.dll` does not contain any Python functions (such as `PyArg_ParseTuple()`), but it does know how to find the Python code thanks to `pythonXY.lib`.

The second command created `ni.dll` (and `.obj` and `.lib`), which knows how to find the necessary functions from spam, and also from the Python executable.

Not every identifier is exported to the lookup table. If you want any other modules (including Python) to be able to see your identifiers, you have to say `_declspec(dllexport)`, as in `void _declspec(dllexport) initspam(void)` or `PyObject _declspec(dllexport) *NiGetSpamData(void)`.

Developer Studio will throw in a lot of import libraries that you do not really need, adding about 100K to your executable. To get rid of them, use the Project Settings dialog, Link tab, to specify *ignore default libraries*. Add the correct `msvcrtxx.lib` to the list of libraries.

CHAPTER

THREE

EMBEDDING THE CPYTHON RUNTIME IN A LARGER APPLICATION

Sometimes, rather than creating an extension that runs inside the Python interpreter as the main application, it is desirable to instead embed the CPython runtime inside a larger application. This section covers some of the details involved in doing that successfully.

3.1 Embedding Python in Another Application

The previous chapters discussed how to extend Python, that is, how to extend the functionality of Python by attaching a library of C functions to it. It is also possible to do it the other way around: enrich your C/C++ application by embedding Python in it. Embedding provides your application with the ability to implement some of the functionality of your application in Python rather than C or C++. This can be used for many purposes; one example would be to allow users to tailor the application to their needs by writing some scripts in Python. You can also use it yourself if some of the functionality can be written in Python more easily.

Embedding Python is similar to extending it, but not quite. The difference is that when you extend Python, the main program of the application is still the Python interpreter, while if you embed Python, the main program may have nothing to do with Python — instead, some parts of the application occasionally call the Python interpreter to run some Python code.

So if you are embedding Python, you are providing your own main program. One of the things this main program has to do is initialize the Python interpreter. At the very least, you have to call the function `Py_Initialize()`. There are optional calls to pass command line arguments to Python. Then later you can call the interpreter from any part of the application.

There are several different ways to call the interpreter: you can pass a string containing Python statements to `PyRun_SimpleString()`, or you can pass a stdio file pointer and a file name (for identification in error messages only) to `PyRun_SimpleFile()`. You can also call the lower-level operations described in the previous chapters to construct and use Python objects.

See also:

c-api-index The details of Python's C interface are given in this manual. A great deal of necessary information can be found here.

3.1.1 Very High Level Embedding

The simplest form of embedding Python is the use of the very high level interface. This interface is intended to execute a Python script without needing to interact with the application directly. This can for example be used to perform some operation on a file.

```
#include <Python.h>

int
main(int argc, char *argv[])
{
    wchar_t *program = Py_DecodeLocale(argv[0], NULL);
    if (program == NULL) {
        fprintf(stderr, "Fatal error: cannot decode argv[0]\n");
        exit(1);
    }
    Py_SetProgramName(program);  /* optional but recommended */
    Py_Initialize();
    PyRun_SimpleString("from time import time,ctime\n"
                       "print('Today is', ctime(time()))\n");
    if (Py_FinalizeEx() < 0) {
        exit(120);
    }
    PyMem_RawFree(program);
    return 0;
}
```

The `Py_SetProgramName()` function should be called before `Py_Initialize()` to inform the interpreter about paths to Python run-time libraries. Next, the Python interpreter is initialized with `Py_Initialize()`, followed by the execution of a hard-coded Python script that prints the date and time. Afterwards, the `Py_FinalizeEx()` call shuts the interpreter down, followed by the end of the program. In a real program, you may want to get the Python script from another source, perhaps a text-editor routine, a file, or a database. Getting the Python code from a file can better be done by using the `PyRun_SimpleFile()` function, which saves you the trouble of allocating memory space and loading the file contents.

3.1.2 Beyond Very High Level Embedding: An overview

The high level interface gives you the ability to execute arbitrary pieces of Python code from your application, but exchanging data values is quite cumbersome to say the least. If you want that, you should use lower level calls. At the cost of having to write more C code, you can achieve almost anything.

It should be noted that extending Python and embedding Python is quite the same activity, despite the different intent. Most topics discussed in the previous chapters are still valid. To show this, consider what the extension code from Python to C really does:

1. Convert data values from Python to C,
2. Perform a function call to a C routine using the converted values, and
3. Convert the data values from the call from C to Python.

When embedding Python, the interface code does:

1. Convert data values from C to Python,
2. Perform a function call to a Python interface routine using the converted values, and
3. Convert the data values from the call from Python to C.

As you can see, the data conversion steps are simply swapped to accommodate the different direction of the cross-language transfer. The only difference is the routine that you call between both data conversions. When extending, you call a C routine, when embedding, you call a Python routine.

This chapter will not discuss how to convert data from Python to C and vice versa. Also, proper use of references and dealing with errors is assumed to be understood. Since these aspects do not differ from extending the interpreter, you can refer to earlier chapters for the required information.

3.1.3 Pure Embedding

The first program aims to execute a function in a Python script. Like in the section about the very high level interface, the Python interpreter does not directly interact with the application (but that will change in the next section).

The code to run a function defined in a Python script is:

```
#include <Python.h>

int
main(int argc, char *argv[])
{
    PyObject *pName, *pModule, *pFunc;
    PyObject *pArgs, *pValue;
    int i;

    if (argc < 3) {
        fprintf(stderr,"Usage: call pythonfile funcname [args]\n");
        return 1;
    }

    Py_Initialize();
    pName = PyUnicode_DecodeFSDefault(argv[1]);
    /* Error checking of pName left out */

    pModule = PyImport_Import(pName);
    Py_DECREF(pName);

    if (pModule != NULL) {
        pFunc = PyObject_GetAttrString(pModule, argv[2]);
        /* pFunc is a new reference */

        if (pFunc && PyCallable_Check(pFunc)) {
            pArgs = PyTuple_New(argc - 3);
            for (i = 0; i < argc - 3; ++i) {
                pValue = PyLong_FromLong(atoi(argv[i + 3]));
                if (!pValue) {
                    Py_DECREF(pArgs);
                    Py_DECREF(pModule);
                    fprintf(stderr, "Cannot convert argument\n");
                    return 1;
                }
                /* pValue reference stolen here: */
                PyTuple_SetItem(pArgs, i, pValue);
            }
            pValue = PyObject_CallObject(pFunc, pArgs);
            Py_DECREF(pArgs);
            if (pValue != NULL) {
                printf("Result of call: %ld\n", PyLong_AsLong(pValue));
                Py_DECREF(pValue);
            }
            else {
                Py_DECREF(pFunc);
                Py_DECREF(pModule);
                PyErr_Print();
                fprintf(stderr,"Call failed\n");
                return 1;
```

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```
            }
        }
        else {
            if (PyErr_Occurred())
                PyErr_Print();
            fprintf(stderr, "Cannot find function \"%s\"\n", argv[2]);
        }
        Py_XDECREF(pFunc);
        Py_DECREF(pModule);
    }
    else {
        PyErr_Print();
        fprintf(stderr, "Failed to load \"%s\"\n", argv[1]);
        return 1;
    }
    if (Py_FinalizeEx() < 0) {
        return 120;
    }
    return 0;
}
```

This code loads a Python script using `argv[1]`, and calls the function named in `argv[2]`. Its integer arguments are the other values of the `argv` array. If you *compile and link* this program (let's call the finished executable `call`), and use it to execute a Python script, such as:

```
def multiply(a,b):
    print("Will compute", a, "times", b)
    c = 0
    for i in range(0, a):
        c = c + b
    return c
```

then the result should be:

```
$ call multiply multiply 3 2
Will compute 3 times 2
Result of call: 6
```

Although the program is quite large for its functionality, most of the code is for data conversion between Python and C, and for error reporting. The interesting part with respect to embedding Python starts with

```
Py_Initialize();
pName = PyUnicode_DecodeFSDefault(argv[1]);
/* Error checking of pName left out */
pModule = PyImport_Import(pName);
```

After initializing the interpreter, the script is loaded using `PyImport_Import()`. This routine needs a Python string as its argument, which is constructed using the `PyUnicode_FromString()` data conversion routine.

```
pFunc = PyObject_GetAttrString(pModule, argv[2]);
/* pFunc is a new reference */

if (pFunc && PyCallable_Check(pFunc)) {
    ...
}
Py_XDECREF(pFunc);
```

Once the script is loaded, the name we're looking for is retrieved using `PyObject_GetAttrString()`. If the name exists, and the object returned is callable, you can safely assume that it is a function. The program then proceeds by constructing a tuple of arguments as normal. The call to the Python function is then made with:

```
pValue = PyObject_CallObject(pFunc, pArgs);
```

Upon return of the function, `pValue` is either *NULL* or it contains a reference to the return value of the function. Be sure to release the reference after examining the value.

3.1.4 Extending Embedded Python

Until now, the embedded Python interpreter had no access to functionality from the application itself. The Python API allows this by extending the embedded interpreter. That is, the embedded interpreter gets extended with routines provided by the application. While it sounds complex, it is not so bad. Simply forget for a while that the application starts the Python interpreter. Instead, consider the application to be a set of subroutines, and write some glue code that gives Python access to those routines, just like you would write a normal Python extension. For example:

```
static int numargs=0;

/* Return the number of arguments of the application command line */
static PyObject*
emb_numargs(PyObject *self, PyObject *args)
{
    if(!PyArg_ParseTuple(args, ":numargs"))
        return NULL;
    return PyLong_FromLong(numargs);
}

static PyMethodDef EmbMethods[] = {
    {"numargs", emb_numargs, METH_VARARGS,
     "Return the number of arguments received by the process."},
    {NULL, NULL, 0, NULL}
};

static PyModuleDef EmbModule = {
    PyModuleDef_HEAD_INIT, "emb", NULL, -1, EmbMethods,
    NULL, NULL, NULL, NULL
};

static PyObject*
PyInit_emb(void)
{
    return PyModule_Create(&EmbModule);
}
```

Insert the above code just above the `main()` function. Also, insert the following two statements before the call to `Py_Initialize()`:

```
numargs = argc;
PyImport_AppendInittab("emb", &PyInit_emb);
```

These two lines initialize the `numargs` variable, and make the `emb.numargs()` function accessible to the embedded Python interpreter. With these extensions, the Python script can do things like

```
import emb
print("Number of arguments", emb.numargs())
```

In a real application, the methods will expose an API of the application to Python.

3.1.5 Embedding Python in C++

It is also possible to embed Python in a C++ program; precisely how this is done will depend on the details of the C++ system used; in general you will need to write the main program in C++, and use the C++ compiler to compile and link your program. There is no need to recompile Python itself using C++.

3.1.6 Compiling and Linking under Unix-like systems

It is not necessarily trivial to find the right flags to pass to your compiler (and linker) in order to embed the Python interpreter into your application, particularly because Python needs to load library modules implemented as C dynamic extensions (`.so` files) linked against it.

To find out the required compiler and linker flags, you can execute the `python`*`X.Y`*`-config` script which is generated as part of the installation process (a `python3-config` script may also be available). This script has several options, of which the following will be directly useful to you:

- `pythonX.Y-config --cflags` will give you the recommended flags when compiling:

```
$ /opt/bin/python3.4-config --cflags
-I/opt/include/python3.4m -I/opt/include/python3.4m -DNDEBUG -g -fwrapv -O3 -Wall -Wstrict-
↪prototypes
```

- `pythonX.Y-config --ldflags` will give you the recommended flags when linking:

```
$ /opt/bin/python3.4-config --ldflags
-L/opt/lib/python3.4/config-3.4m -lpthread -ldl -lutil -lm -lpython3.4m -Xlinker -export-
↪dynamic
```

Note: To avoid confusion between several Python installations (and especially between the system Python and your own compiled Python), it is recommended that you use the absolute path to `python`*`X.Y`*`-config`, as in the above example.

If this procedure doesn't work for you (it is not guaranteed to work for all Unix-like platforms; however, we welcome bug reports) you will have to read your system's documentation about dynamic linking and/or examine Python's `Makefile` (use `sysconfig.get_makefile_filename()` to find its location) and compilation options. In this case, the `sysconfig` module is a useful tool to programmatically extract the configuration values that you will want to combine together. For example:

```
>>> import sysconfig
>>> sysconfig.get_config_var('LIBS')
'-lpthread -ldl  -lutil'
>>> sysconfig.get_config_var('LINKFORSHARED')
'-Xlinker -export-dynamic'
```

APPENDIX

A

GLOSSARY

>>> The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

... The default Python prompt of the interactive shell when entering code for an indented code block, when within a pair of matching left and right delimiters (parentheses, square brackets, curly braces or triple quotes), or after specifying a decorator.

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See 2to3-reference.

abstract base class Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with magic methods). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections.abc` module), numbers (in the `numbers` module), streams (in the `io` module), import finders and loaders (in the `importlib.abc` module). You can create your own ABCs with the `abc` module.

annotation A label associated with a variable, a class attribute or a function parameter or return value, used by convention as a *type hint*.

Annotations of local variables cannot be accessed at runtime, but annotations of global variables, class attributes, and functions are stored in the `__annotations__` special attribute of modules, classes, and functions, respectively.

See *variable annotation*, *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

argument A value passed to a *function* (or *method*) when calling the function. There are two kinds of argument:

- *keyword argument*: an argument preceded by an identifier (e.g. `name=`) in a function call or passed as a value in a dictionary preceded by `**`. For example, `3` and `5` are both keyword arguments in the following calls to `complex()`:

```
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- *positional argument*: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an *iterable* preceded by `*`. For example, `3` and `5` are both positional arguments in the following calls:

```
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the calls section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the *parameter* glossary entry, the FAQ question on the difference between arguments and parameters, and **PEP 362**.

asynchronous context manager An object which controls the environment seen in an `async with` statement by defining `__aenter__()` and `__aexit__()` methods. Introduced by **PEP 492**.

asynchronous generator A function which returns an *asynchronous generator iterator*. It looks like a coroutine function defined with `async def` except that it contains `yield` expressions for producing a series of values usable in an `async for` loop.

Usually refers to a asynchronous generator function, but may refer to an *asynchronous generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

An asynchronous generator function may contain `await` expressions as well as `async for`, and `async with` statements.

asynchronous generator iterator An object created by a *asynchronous generator* function.

This is an *asynchronous iterator* which when called using the `__anext__()` method returns an awaitable object which will execute that the body of the asynchronous generator function until the next `yield` expression.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *asynchronous generator iterator* effectively resumes with another awaitable returned by `__anext__()`, it picks up where it left off. See **PEP 492** and **PEP 525**.

asynchronous iterable An object, that can be used in an `async for` statement. Must return an *asynchronous iterator* from its `__aiter__()` method. Introduced by **PEP 492**.

asynchronous iterator An object that implements `__aiter__()` and `__anext__()` methods. `__anext__` must return an *awaitable* object. `async for` resolves awaitable returned from asynchronous iterator's `__anext__()` method until it raises `StopAsyncIteration` exception. Introduced by **PEP 492**.

attribute A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

awaitable An object that can be used in an `await` expression. Can be a *coroutine* or an object with an `__await__()` method. See also **PEP 492**.

BDFL Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

binary file A *file object* able to read and write *bytes-like objects*. Examples of binary files are files opened in binary mode (`'rb'`, `'wb'` or `'rb+'`), `sys.stdin.buffer`, `sys.stdout.buffer`, and instances of `io.BytesIO` and `gzip.GzipFile`.

See also *text file* for a file object able to read and write `str` objects.

bytes-like object An object that supports the bufferobjects and can export a C-*contiguous* buffer. This includes all `bytes`, `bytearray`, and `array.array` objects, as well as many common `memoryview` objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as "read-write bytes-like objects". Example mutable buffer objects include `bytearray` and a `memoryview` of a `bytearray`. Other operations require the binary data to be stored in immutable objects ("read-only bytes-like objects"); examples of these include `bytes` and a `memoryview` of a `bytes` object.

bytecode Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for the dis module.

class A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

class variable A variable defined in a class and intended to be modified only at class level (i.e., not in an instance of the class).

coercion The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer `3`, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

complex number An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of `-1`), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

context manager An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See **PEP 343**.

contiguous A buffer is considered contiguous exactly if it is either *C-contiguous* or *Fortran contiguous*. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be laid out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

coroutine Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the `async def` statement. See also **PEP 492**.

coroutine function A function which returns a *coroutine* object. A coroutine function may be defined with the `async def` statement, and may contain `await`, `async for`, and `async with` keywords. These were introduced by **PEP 492**.

CPython The canonical implementation of the Python programming language, as distributed on python.org. The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

decorator A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)
```

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```
@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for function definitions and class definitions for more about decorators.

descriptor Any object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using *a.b* to get, set or delete an attribute looks up the object named *b* in the class dictionary for *a*, but if *b* is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see descriptors.

dictionary An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

dictionary view The objects returned from `dict.keys()`, `dict.values()`, and `dict.items()` are called dictionary views. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use `list(dictview)`. See dict-views.

docstring A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

duck-typing A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note, however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

EAFP Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

expression A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statement*s which cannot be used as expressions, such as `if`. Assignments are also statements, not expressions.

extension module A module written in C or C++, using Python's C API to interact with the core and with user code.

f-string String literals prefixed with `'f'` or `'F'` are commonly called "f-strings" which is short for formatted string literals. See also **PEP 498**.

file object An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw *binary files*, buffered *binary files* and *text files*. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the

`open()` function.

file-like object A synonym for *file object*.

finder An object that tries to find the *loader* for a module that is being imported.

Since Python 3.3, there are two types of finder: *meta path finders* for use with `sys.meta_path`, and *path entry finders* for use with `sys.path_hooks`.

See **PEP 302**, **PEP 420** and **PEP 451** for much more detail.

floor division Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See **PEP 238**.

function A series of statements which returns some value to a caller. It can also be passed zero or more *arguments* which may be used in the execution of the body. See also *parameter*, *method*, and the function section.

function annotation An *annotation* of a function parameter or return value.

Function annotations are usually used for *type hints*: for example this function is expected to take two `int` arguments and is also expected to have an `int` return value:

```
def sum_two_numbers(a: int, b: int) -> int:
   return a + b
```

Function annotation syntax is explained in section function.

See *variable annotation* and **PEP 484**, which describe this functionality.

___future___ A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

garbage collection The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles. The garbage collector can be controlled using the `gc` module.

generator A function which returns a *generator iterator*. It looks like a normal function except that it contains `yield` expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the `next()` function.

Usually refers to a generator function, but may refer to a *generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

generator iterator An object created by a *generator* function.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *generator iterator* resumes, it picks up where it left off (in contrast to functions which start fresh on every invocation).

generator expression An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))         # sum of squares 0, 1, 4, ... 81
285
```

generic function A function composed of multiple functions implementing the same operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the *single dispatch* glossary entry, the `functools.singledispatch()` decorator, and **PEP 443**.

GIL See *global interpreter lock*.

global interpreter lock The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a "free-threaded" interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

hash-based pyc A bytecode cache file that uses the hash rather than the last-modified time of the corresponding source file to determine its validity. See pyc-invalidation.

hashable An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python's immutable built-in objects are hashable; mutable containers (such as lists or dictionaries) are not. Objects which are instances of user-defined classes are hashable by default. They all compare unequal (except with themselves), and their hash value is derived from their `id()`.

IDLE An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

immutable An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

import path A list of locations (or *path entries*) that are searched by the *path based finder* for modules to import. During import, this list of locations usually comes from `sys.path`, but for subpackages it may also come from the parent package's `__path__` attribute.

importing The process by which Python code in one module is made available to Python code in another module.

importer An object that both finds and loads a module; both a *finder* and *loader* object.

interactive Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer's main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

interpreted Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically

have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the *garbage collector*. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the `__main__` module or the script being run has finished executing.

iterable An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict`, *file objects*, and objects of any classes you define with an `__iter__()` method or with a `__getitem__()` method that implements *Sequence* semantics.

Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

iterator An object representing a stream of data. Repeated calls to the iterator's `__next__()` method (or passing it to the built-in function `next()`) return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `__next__()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in typeiter.

key function A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.merge()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example. the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the Sorting HOW TO for examples of how to create and use key functions.

keyword argument See *argument*.

lambda An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [parameters]: expression`

LBYL Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between "the looking" and "the leaping". For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

list A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements is O(1).

list comprehension A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ['{:#04x}'.format(x) for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

loader An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details and `importlib.abc.Loader` for an *abstract base class*.

mapping A container object that supports arbitrary key lookups and implements the methods specified in the `Mapping` or `MutableMapping` abstract base classes. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

meta path finder A *finder* returned by a search of `sys.meta_path`. Meta path finders are related to, but different from *path entry finders*.

See `importlib.abc.MetaPathFinder` for the methods that meta path finders implement.

metaclass The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in metaclasses.

method A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

method resolution order Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order for details of the algorithm used by the Python interpreter since the 2.3 release.

module An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects. Modules are loaded into Python by the process of *importing*.

See also *package*.

module spec A namespace containing the import-related information used to load a module. An instance of `importlib.machinery.ModuleSpec`.

MRO See *method resolution order*.

mutable Mutable objects can change their value but keep their `id()`. See also *immutable*.

named tuple Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

namespace The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `builtins.open` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.islice()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

namespace package A **PEP 420** *package* which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a *regular package* because they have no `__init__.py` file.

See also *module*.

nested scope The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The `nonlocal` allows writing to outer scopes.

new-style class Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python's newer, versatile features like `__slots__`, descriptors, properties, `__getattribute__()`, class methods, and static methods.

object Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

package A Python *module* which can contain submodules or recursively, subpackages. Technically, a package is a Python module with an `__path__` attribute.

See also *regular package* and *namespace package*.

parameter A named entity in a *function* (or method) definition that specifies an *argument* (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- *positional-or-keyword*: specifies an argument that can be passed either *positionally* or as a *keyword argument*. This is the default kind of parameter, for example *foo* and *bar* in the following:

```
def func(foo, bar=None): ...
```

- *positional-only*: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. `abs()`).
- *keyword-only*: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare `*` in the parameter list of the function definition before them, for example *kw_only1* and *kw_only2* in the following:

```
def func(arg, *, kw_only1, kw_only2): ...
```

- *var-positional*: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `*`, for example *args* in the following:

```
def func(*args, **kwargs): ...
```

- *var-keyword*: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `**`, for example *kwargs* in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the *argument* glossary entry, the FAQ question on the difference between arguments and parameters, the `inspect.Parameter` class, the function section, and **PEP 362**.

path entry A single location on the *import path* which the *path based finder* consults to find modules for importing.

path entry finder A *finder* returned by a callable on `sys.path_hooks` (i.e. a *path entry hook*) which knows how to locate modules given a *path entry*.

See `importlib.abc.PathEntryFinder` for the methods that path entry finders implement.

path entry hook A callable on the `sys.path_hook` list which returns a *path entry finder* if it knows how to find modules on a specific *path entry*.

path based finder One of the default *meta path finders* which searches an *import path* for modules.

path-like object An object representing a file system path. A path-like object is either a `str` or `bytes` object representing a path, or an object implementing the `os.PathLike` protocol. An object that supports the `os.PathLike` protocol can be converted to a `str` or `bytes` file system path by calling the `os.fspath()` function; `os.fsdecode()` and `os.fsencode()` can be used to guarantee a `str` or `bytes` result instead, respectively. Introduced by **PEP 519**.

PEP Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python or its processes or environment. PEPs should provide a concise technical specification and a rationale for proposed features.

PEPs are intended to be the primary mechanisms for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible for building consensus within the community and documenting dissenting opinions.

See **PEP 1**.

portion A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in **PEP 420**.

positional argument See *argument*.

provisional API A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a "solution of last resort" - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See **PEP 411** for more details.

provisional package See *provisional API*.

Python 3000 Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

Pythonic An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print(piece)
```

qualified name A dotted name showing the "path" from a module's global scope to a class, function or method defined in that module, as defined in **PEP 3155**. For top-level functions and classes, the qualified name is the same as the object's name:

```
>>> class C:
...     class D:
...         def meth(self):
...             pass
...
>>> C.__qualname__
'C'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```

When used to refer to modules, the *fully qualified name* means the entire dotted path to the module, including any parent packages, e.g. `email.mime.text`:

```
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

reference count The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

regular package A traditional *package*, such as a directory containing an `__init__.py` file.

See also *namespace package*.

___slots___ A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

sequence An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `__len__()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `bytes`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

The `collections.abc.Sequence` abstract base class defines a much richer interface that goes beyond just `__getitem__()` and `__len__()`, adding `count()`, `index()`, `__contains__()`, and `__reversed__()`. Types that implement this expanded interface can be registered explicitly using `register()`.

single dispatch A form of *generic function* dispatch where the implementation is chosen based on the type of a single argument.

slice An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally.

special method A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in specialnames.

statement A statement is part of a suite (a "block" of code). A statement is either an *expression* or one of several constructs with a keyword, such as `if`, `while` or `for`.

struct sequence A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

text encoding A codec which encodes Unicode strings to bytes.

text file A *file object* able to read and write `str` objects. Often, a text file actually accesses a byte-oriented datastream and handles the *text encoding* automatically. Examples of text files are files opened in text mode (`'r'` or `'w'`), `sys.stdin`, `sys.stdout`, and instances of `io.StringIO`.

See also *binary file* for a file object able to read and write *bytes-like objects*.

triple-quoted string A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

type The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

type alias A synonym for a type, created by assigning the type to an identifier.

Type aliases are useful for simplifying *type hints*. For example:

```
from typing import List, Tuple

def remove_gray_shades(
        colors: List[Tuple[int, int, int]]) -> List[Tuple[int, int, int]]:
    pass
```

could be made more readable like this:

```
from typing import List, Tuple

Color = Tuple[int, int, int]

def remove_gray_shades(colors: List[Color]) -> List[Color]:
    pass
```

See `typing` and **PEP 484**, which describe this functionality.

type hint An *annotation* that specifies the expected type for a variable, a class attribute, or a function parameter or return value.

Type hints are optional and are not enforced by Python but they are useful to static type analysis tools, and aid IDEs with code completion and refactoring.

Type hints of global variables, class attributes, and functions, but not local variables, can be accessed using `typing.get_type_hints()`.

See `typing` and **PEP 484**, which describe this functionality.

universal newlines A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old

Macintosh convention `'\r'`. See **PEP 278** and **PEP 3116**, as well as `bytes.splitlines()` for an additional use.

variable annotation An *annotation* of a variable or a class attribute.

When annotating a variable or a class attribute, assignment is optional:

```
class C:
    field: 'annotation'
```

Variable annotations are usually used for *type hints*: for example this variable is expected to take `int` values:

```
count: int = 0
```

Variable annotation syntax is explained in section annassign.

See *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

virtual environment A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also `venv`.

virtual machine A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

Zen of Python Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing "`import this`" at the interactive prompt.

APPENDIX

B

ABOUT THESE DOCUMENTS

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the reporting-bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the Docutils project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.

B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See Misc/ACKS in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!

APPENDIX

C

HISTORY AND LICENSE

C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see https://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see https://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see https://opensource.org/ for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2 and above	2.1.1	2001-now	PSF	yes

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```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.

Before using, initialize the state by using init_genrand(seed)
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http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html
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```

C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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Modified by Jack Jansen, CWI, July 1995:
- Use binascii module to do the actual line-by-line conversion
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- Arguments more compliant with Python standard
```

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Original location:
   https://github.com/majek/csiphash/

Solution inspired by code from:
   Samuel Neves (supercop/crypto_auth/siphash24/little)
   djb (supercop/crypto_auth/siphash24/little2)
   Jean-Philippe Aumasson (https://131002.net/siphash/siphash24.c)
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C.3.11 strtod and dtoa

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   */
```

C.3.13 expat

The pyexpat extension is built using an included copy of the expat sources unless the build is configured --with-system-expat:

```
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C.3.14 libffi

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```

C.3.15 zlib

The `zlib` extension is built using an included copy of the zlib sources if the zlib version found on the system is too old to be used for the build:

```
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Jean-loup Gailly        Mark Adler
jloup@gzip.org          madler@alumni.caltech.edu
```

C.3.16 cfuhash

The implementation of the hash table used by the `tracemalloc` is based on the cfuhash project:

```
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C.3.17 libmpdec

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```
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APPENDIX

D

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Distributing Python Modules

Release 3.7.0

Guido van Rossum
and the Python development team

July 07, 2018

Python Software Foundation
Email: docs@python.org

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Email distutils-sig@python.org

As a popular open source development project, Python has an active supporting community of contributors and users that also make their software available for other Python developers to use under open source license terms.

This allows Python users to share and collaborate effectively, benefiting from the solutions others have already created to common (and sometimes even rare!) problems, as well as potentially contributing their own solutions to the common pool.

This guide covers the distribution part of the process. For a guide to installing other Python projects, refer to the installation guide.

Note: For corporate and other institutional users, be aware that many organisations have their own policies around using and contributing to open source software. Please take such policies into account when making use of the distribution and installation tools provided with Python.

CHAPTER

ONE

KEY TERMS

- the Python Packaging Index is a public repository of open source licensed packages made available for use by other Python users
- the Python Packaging Authority are the group of developers and documentation authors responsible for the maintenance and evolution of the standard packaging tools and the associated metadata and file format standards. They maintain a variety of tools, documentation and issue trackers on both GitHub and BitBucket.
- `distutils` is the original build and distribution system first added to the Python standard library in 1998. While direct use of `distutils` is being phased out, it still laid the foundation for the current packaging and distribution infrastructure, and it not only remains part of the standard library, but its name lives on in other ways (such as the name of the mailing list used to coordinate Python packaging standards development).
- setuptools is a (largely) drop-in replacement for `distutils` first published in 2004. Its most notable addition over the unmodified `distutils` tools was the ability to declare dependencies on other packages. It is currently recommended as a more regularly updated alternative to `distutils` that offers consistent support for more recent packaging standards across a wide range of Python versions.
- wheel (in this context) is a project that adds the `bdist_wheel` command to `distutils`/setuptools. This produces a cross platform binary packaging format (called "wheels" or "wheel files" and defined in **PEP 427**) that allows Python libraries, even those including binary extensions, to be installed on a system without needing to be built locally.

CHAPTER

TWO

OPEN SOURCE LICENSING AND COLLABORATION

In most parts of the world, software is automatically covered by copyright. This means that other developers require explicit permission to copy, use, modify and redistribute the software.

Open source licensing is a way of explicitly granting such permission in a relatively consistent way, allowing developers to share and collaborate efficiently by making common solutions to various problems freely available. This leaves many developers free to spend more time focusing on the problems that are relatively unique to their specific situation.

The distribution tools provided with Python are designed to make it reasonably straightforward for developers to make their own contributions back to that common pool of software if they choose to do so.

The same distribution tools can also be used to distribute software within an organisation, regardless of whether that software is published as open source software or not.

CHAPTER

THREE

INSTALLING THE TOOLS

The standard library does not include build tools that support modern Python packaging standards, as the core development team has found that it is important to have standard tools that work consistently, even on older versions of Python.

The currently recommended build and distribution tools can be installed by invoking the `pip` module at the command line:

```
python -m pip install setuptools wheel twine
```

Note: For POSIX users (including Mac OS X and Linux users), these instructions assume the use of a *virtual environment*.

For Windows users, these instructions assume that the option to adjust the system PATH environment variable was selected when installing Python.

The Python Packaging User Guide includes more details on the currently recommended tools.

CHAPTER

FOUR

READING THE GUIDE

The Python Packaging User Guide covers the various key steps and elements involved in creating a project:

- Project structure
- Building and packaging the project
- Uploading the project to the Python Packaging Index

CHAPTER

FIVE

HOW DO I...?

These are quick answers or links for some common tasks.

5.1 ... choose a name for my project?

This isn't an easy topic, but here are a few tips:

- check the Python Packaging Index to see if the name is already in use
- check popular hosting sites like GitHub, BitBucket, etc to see if there is already a project with that name
- check what comes up in a web search for the name you're considering
- avoid particularly common words, especially ones with multiple meanings, as they can make it difficult for users to find your software when searching for it

5.2 ... create and distribute binary extensions?

This is actually quite a complex topic, with a variety of alternatives available depending on exactly what you're aiming to achieve. See the Python Packaging User Guide for more information and recommendations.

See also:

Python Packaging User Guide: Binary Extensions

APPENDIX

A

GLOSSARY

`>>>` The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

`...` The default Python prompt of the interactive shell when entering code for an indented code block, when within a pair of matching left and right delimiters (parentheses, square brackets, curly braces or triple quotes), or after specifying a decorator.

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See 2to3-reference.

abstract base class Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with magic methods). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections.abc` module), numbers (in the `numbers` module), streams (in the `io` module), import finders and loaders (in the `importlib.abc` module). You can create your own ABCs with the `abc` module.

annotation A label associated with a variable, a class attribute or a function parameter or return value, used by convention as a *type hint*.

Annotations of local variables cannot be accessed at runtime, but annotations of global variables, class attributes, and functions are stored in the `__annotations__` special attribute of modules, classes, and functions, respectively.

See *variable annotation*, *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

argument A value passed to a *function* (or *method*) when calling the function. There are two kinds of argument:

- *keyword argument*: an argument preceded by an identifier (e.g. `name=`) in a function call or passed as a value in a dictionary preceded by `**`. For example, `3` and `5` are both keyword arguments in the following calls to `complex()`:

```
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- *positional argument*: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an *iterable* preceded by `*`. For example, `3` and `5` are both positional arguments in the following calls:

```
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the calls section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the *parameter* glossary entry, the FAQ question on the difference between arguments and parameters, and **PEP 362**.

asynchronous context manager An object which controls the environment seen in an `async with` statement by defining `__aenter__()` and `__aexit__()` methods. Introduced by **PEP 492**.

asynchronous generator A function which returns an *asynchronous generator iterator*. It looks like a coroutine function defined with `async def` except that it contains `yield` expressions for producing a series of values usable in an `async for` loop.

Usually refers to a asynchronous generator function, but may refer to an *asynchronous generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

An asynchronous generator function may contain `await` expressions as well as `async for`, and `async with` statements.

asynchronous generator iterator An object created by a *asynchronous generator* function.

This is an *asynchronous iterator* which when called using the `__anext__()` method returns an awaitable object which will execute that the body of the asynchronous generator function until the next `yield` expression.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *asynchronous generator iterator* effectively resumes with another awaitable returned by `__anext__()`, it picks up where it left off. See **PEP 492** and **PEP 525**.

asynchronous iterable An object, that can be used in an `async for` statement. Must return an *asynchronous iterator* from its `__aiter__()` method. Introduced by **PEP 492**.

asynchronous iterator An object that implements `__aiter__()` and `__anext__()` methods. `__anext__` must return an *awaitable* object. `async for` resolves awaitable returned from asynchronous iterator's `__anext__()` method until it raises `StopAsyncIteration` exception. Introduced by **PEP 492**.

attribute A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

awaitable An object that can be used in an `await` expression. Can be a *coroutine* or an object with an `__await__()` method. See also **PEP 492**.

BDFL Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

binary file A *file object* able to read and write *bytes-like objects*. Examples of binary files are files opened in binary mode (`'rb'`, `'wb'` or `'rb+'`), `sys.stdin.buffer`, `sys.stdout.buffer`, and instances of `io.BytesIO` and `gzip.GzipFile`.

See also *text file* for a file object able to read and write `str` objects.

bytes-like object An object that supports the bufferobjects and can export a C-*contiguous* buffer. This includes all `bytes`, `bytearray`, and `array.array` objects, as well as many common `memoryview` objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as "read-write bytes-like objects". Example mutable buffer objects include `bytearray` and a `memoryview` of a `bytearray`. Other operations require the binary data to be stored in immutable objects ("read-only bytes-like objects"); examples of these include `bytes` and a `memoryview` of a `bytes` object.

bytecode Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for the dis module.

class A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

class variable A variable defined in a class and intended to be modified only at class level (i.e., not in an instance of the class).

coercion The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer `3`, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

complex number An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of `-1`), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

context manager An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See **PEP 343**.

contiguous A buffer is considered contiguous exactly if it is either *C-contiguous* or *Fortran contiguous*. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be laid out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

coroutine Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the `async def` statement. See also **PEP 492**.

coroutine function A function which returns a *coroutine* object. A coroutine function may be defined with the `async def` statement, and may contain `await`, `async for`, and `async with` keywords. These were introduced by **PEP 492**.

CPython The canonical implementation of the Python programming language, as distributed on python.org. The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

decorator A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)
```

(continues on next page)

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```
@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for function definitions and class definitions for more about decorators.

descriptor Any object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using *a.b* to get, set or delete an attribute looks up the object named *b* in the class dictionary for *a*, but if *b* is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see descriptors.

dictionary An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

dictionary view The objects returned from `dict.keys()`, `dict.values()`, and `dict.items()` are called dictionary views. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use `list(dictview)`. See dict-views.

docstring A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

duck-typing A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note, however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

EAFP Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

expression A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statement*s which cannot be used as expressions, such as `if`. Assignments are also statements, not expressions.

extension module A module written in C or C++, using Python's C API to interact with the core and with user code.

f-string String literals prefixed with `'f'` or `'F'` are commonly called "f-strings" which is short for formatted string literals. See also **PEP 498**.

file object An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw *binary files*, buffered *binary files* and *text files*. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the

`open()` function.

file-like object A synonym for *file object*.

finder An object that tries to find the *loader* for a module that is being imported.

Since Python 3.3, there are two types of finder: *meta path finders* for use with `sys.meta_path`, and *path entry finders* for use with `sys.path_hooks`.

See **PEP 302**, **PEP 420** and **PEP 451** for much more detail.

floor division Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See **PEP 238**.

function A series of statements which returns some value to a caller. It can also be passed zero or more *arguments* which may be used in the execution of the body. See also *parameter*, *method*, and the function section.

function annotation An *annotation* of a function parameter or return value.

Function annotations are usually used for *type hints*: for example this function is expected to take two `int` arguments and is also expected to have an `int` return value:

```
def sum_two_numbers(a: int, b: int) -> int:
   return a + b
```

Function annotation syntax is explained in section function.

See *variable annotation* and **PEP 484**, which describe this functionality.

___future___ A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

garbage collection The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles. The garbage collector can be controlled using the `gc` module.

generator A function which returns a *generator iterator*. It looks like a normal function except that it contains `yield` expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the `next()` function.

Usually refers to a generator function, but may refer to a *generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

generator iterator An object created by a *generator* function.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *generator iterator* resumes, it picks up where it left off (in contrast to functions which start fresh on every invocation).

generator expression An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))         # sum of squares 0, 1, 4, ... 81
285
```

generic function A function composed of multiple functions implementing the same operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the *single dispatch* glossary entry, the `functools.singledispatch()` decorator, and **PEP 443**.

GIL See *global interpreter lock*.

global interpreter lock The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a "free-threaded" interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

hash-based pyc A bytecode cache file that uses the hash rather than the last-modified time of the corresponding source file to determine its validity. See pyc-invalidation.

hashable An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python's immutable built-in objects are hashable; mutable containers (such as lists or dictionaries) are not. Objects which are instances of user-defined classes are hashable by default. They all compare unequal (except with themselves), and their hash value is derived from their `id()`.

IDLE An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

immutable An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

import path A list of locations (or *path entries*) that are searched by the *path based finder* for modules to import. During import, this list of locations usually comes from `sys.path`, but for subpackages it may also come from the parent package's `__path__` attribute.

importing The process by which Python code in one module is made available to Python code in another module.

importer An object that both finds and loads a module; both a *finder* and *loader* object.

interactive Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer's main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

interpreted Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically

have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the *garbage collector*. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the `__main__` module or the script being run has finished executing.

iterable An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict`, *file objects*, and objects of any classes you define with an `__iter__()` method or with a `__getitem__()` method that implements *Sequence* semantics.

Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

iterator An object representing a stream of data. Repeated calls to the iterator's `__next__()` method (or passing it to the built-in function `next()`) return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `__next__()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in typeiter.

key function A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.merge()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example. the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the Sorting HOW TO for examples of how to create and use key functions.

keyword argument See *argument*.

lambda An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [parameters]: expression`

LBYL Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between "the looking" and "the leaping". For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

list A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements is O(1).

list comprehension A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ['{:#04x}'.format(x) for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

loader An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details and `importlib.abc.Loader` for an *abstract base class*.

mapping A container object that supports arbitrary key lookups and implements the methods specified in the `Mapping` or `MutableMapping` abstract base classes. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

meta path finder A *finder* returned by a search of `sys.meta_path`. Meta path finders are related to, but different from *path entry finders*.

See `importlib.abc.MetaPathFinder` for the methods that meta path finders implement.

metaclass The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in metaclasses.

method A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

method resolution order Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order for details of the algorithm used by the Python interpreter since the 2.3 release.

module An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects. Modules are loaded into Python by the process of *importing*.

See also *package*.

module spec A namespace containing the import-related information used to load a module. An instance of `importlib.machinery.ModuleSpec`.

MRO See *method resolution order*.

mutable Mutable objects can change their value but keep their `id()`. See also *immutable*.

named tuple Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

namespace The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `builtins.open` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.islice()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

namespace package A **PEP 420** *package* which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a *regular package* because they have no `__init__.py` file.

See also *module*.

nested scope The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The `nonlocal` allows writing to outer scopes.

new-style class Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python's newer, versatile features like `__slots__`, descriptors, properties, `__getattribute__()`, class methods, and static methods.

object Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

package A Python *module* which can contain submodules or recursively, subpackages. Technically, a package is a Python module with an `__path__` attribute.

See also *regular package* and *namespace package*.

parameter A named entity in a *function* (or method) definition that specifies an *argument* (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- *positional-or-keyword*: specifies an argument that can be passed either *positionally* or as a *keyword argument*. This is the default kind of parameter, for example *foo* and *bar* in the following:

```
def func(foo, bar=None): ...
```

- *positional-only*: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. `abs()`).
- *keyword-only*: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare `*` in the parameter list of the function definition before them, for example *kw_only1* and *kw_only2* in the following:

```
def func(arg, *, kw_only1, kw_only2): ...
```

- *var-positional*: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `*`, for example *args* in the following:

```
def func(*args, **kwargs): ...
```

- *var-keyword*: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `**`, for example *kwargs* in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the *argument* glossary entry, the FAQ question on the difference between arguments and parameters, the `inspect.Parameter` class, the function section, and **PEP 362**.

path entry A single location on the *import path* which the *path based finder* consults to find modules for importing.

path entry finder A *finder* returned by a callable on `sys.path_hooks` (i.e. a *path entry hook*) which knows how to locate modules given a *path entry*.

See `importlib.abc.PathEntryFinder` for the methods that path entry finders implement.

path entry hook A callable on the `sys.path_hook` list which returns a *path entry finder* if it knows how to find modules on a specific *path entry*.

path based finder One of the default *meta path finders* which searches an *import path* for modules.

path-like object An object representing a file system path. A path-like object is either a `str` or `bytes` object representing a path, or an object implementing the `os.PathLike` protocol. An object that supports the `os.PathLike` protocol can be converted to a `str` or `bytes` file system path by calling the `os.fspath()` function; `os.fsdecode()` and `os.fsencode()` can be used to guarantee a `str` or `bytes` result instead, respectively. Introduced by **PEP 519**.

PEP Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python or its processes or environment. PEPs should provide a concise technical specification and a rationale for proposed features.

PEPs are intended to be the primary mechanisms for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible for building consensus within the community and documenting dissenting opinions.

See **PEP 1**.

portion A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in **PEP 420**.

positional argument See *argument*.

provisional API A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a "solution of last resort" - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See **PEP 411** for more details.

provisional package See *provisional API*.

Python 3000 Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

Pythonic An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print(piece)
```

qualified name A dotted name showing the "path" from a module's global scope to a class, function or method defined in that module, as defined in **PEP 3155**. For top-level functions and classes, the qualified name is the same as the object's name:

```
>>> class C:
...     class D:
...         def meth(self):
...             pass
...
>>> C.__qualname__
'C'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```

When used to refer to modules, the *fully qualified name* means the entire dotted path to the module, including any parent packages, e.g. `email.mime.text`:

```
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

reference count The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

regular package A traditional *package*, such as a directory containing an `__init__.py` file.

See also *namespace package*.

___slots___ A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

sequence An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `__len__()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `bytes`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

The `collections.abc.Sequence` abstract base class defines a much richer interface that goes beyond just `__getitem__()` and `__len__()`, adding `count()`, `index()`, `__contains__()`, and `__reversed__()`. Types that implement this expanded interface can be registered explicitly using `register()`.

single dispatch A form of *generic function* dispatch where the implementation is chosen based on the type of a single argument.

slice An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally.

special method A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in specialnames.

statement A statement is part of a suite (a "block" of code). A statement is either an *expression* or one of several constructs with a keyword, such as `if`, `while` or `for`.

struct sequence A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

text encoding A codec which encodes Unicode strings to bytes.

text file A *file object* able to read and write `str` objects. Often, a text file actually accesses a byte-oriented datastream and handles the *text encoding* automatically. Examples of text files are files opened in text mode (`'r'` or `'w'`), `sys.stdin`, `sys.stdout`, and instances of `io.StringIO`.

See also *binary file* for a file object able to read and write *bytes-like objects*.

triple-quoted string A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

type The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

type alias A synonym for a type, created by assigning the type to an identifier.

Type aliases are useful for simplifying *type hints*. For example:

```
from typing import List, Tuple

def remove_gray_shades(
        colors: List[Tuple[int, int, int]]) -> List[Tuple[int, int, int]]:
    pass
```

could be made more readable like this:

```
from typing import List, Tuple

Color = Tuple[int, int, int]

def remove_gray_shades(colors: List[Color]) -> List[Color]:
    pass
```

See `typing` and **PEP 484**, which describe this functionality.

type hint An *annotation* that specifies the expected type for a variable, a class attribute, or a function parameter or return value.

Type hints are optional and are not enforced by Python but they are useful to static type analysis tools, and aid IDEs with code completion and refactoring.

Type hints of global variables, class attributes, and functions, but not local variables, can be accessed using `typing.get_type_hints()`.

See `typing` and **PEP 484**, which describe this functionality.

universal newlines A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old

Macintosh convention `'\r'`. See **PEP 278** and **PEP 3116**, as well as `bytes.splitlines()` for an additional use.

variable annotation An *annotation* of a variable or a class attribute.

When annotating a variable or a class attribute, assignment is optional:

```
class C:
    field: 'annotation'
```

Variable annotations are usually used for *type hints*: for example this variable is expected to take `int` values:

```
count: int = 0
```

Variable annotation syntax is explained in section annassign.

See *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

virtual environment A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also `venv`.

virtual machine A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

Zen of Python Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing "`import this`" at the interactive prompt.

APPENDIX

B

ABOUT THESE DOCUMENTS

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the reporting-bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the Docutils project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.

B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See Misc/ACKS in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!

APPENDIX

C

HISTORY AND LICENSE

C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see https://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see https://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

All Python releases are Open Source (see https://opensource.org/ for the Open Source Definition). Historically, most, but not all, Python releases have also been GPL-compatible; the table below summarizes the various releases.

Release	Derived from	Year	Owner	GPL compatible?
0.9.0 thru 1.2	n/a	1991-1995	CWI	yes
1.3 thru 1.5.2	1.2	1995-1999	CNRI	yes
1.6	1.5.2	2000	CNRI	no
2.0	1.6	2000	BeOpen.com	no
1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
2.0.1	2.0+1.6.1	2001	PSF	yes
2.1.1	2.1+2.0.1	2001	PSF	yes
2.1.2	2.1.1	2002	PSF	yes
2.1.3	2.1.2	2002	PSF	yes
2.2 and above	2.1.1	2001-now	PSF	yes

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```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.

Before using, initialize the state by using init_genrand(seed)
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http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html
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```

C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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Modified by Jack Jansen, CWI, July 1995:
- Use binascii module to do the actual line-by-line conversion
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- Arguments more compliant with Python standard
```

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Original location:
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Solution inspired by code from:
   Samuel Neves (supercop/crypto_auth/siphash24/little)
   djb (supercop/crypto_auth/siphash24/little2)
   Jean-Philippe Aumasson (https://131002.net/siphash/siphash24.c)
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C.3.13 expat

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jloup@gzip.org          madler@alumni.caltech.edu
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C.3.16 cfuhash

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C.3.17 libmpdec

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The Python/C API

Release 3.7.0

Guido van Rossum
and the Python development team

July 07, 2018

Python Software Foundation
Email: docs@python.org

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This manual documents the API used by C and C++ programmers who want to write extension modules or embed Python. It is a companion to extending-index, which describes the general principles of extension writing but does not document the API functions in detail.

CHAPTER

ONE

INTRODUCTION

The Application Programmer's Interface to Python gives C and C++ programmers access to the Python interpreter at a variety of levels. The API is equally usable from C++, but for brevity it is generally referred to as the Python/C API. There are two fundamentally different reasons for using the Python/C API. The first reason is to write *extension modules* for specific purposes; these are C modules that extend the Python interpreter. This is probably the most common use. The second reason is to use Python as a component in a larger application; this technique is generally referred to as *embedding* Python in an application.

Writing an extension module is a relatively well-understood process, where a "cookbook" approach works well. There are several tools that automate the process to some extent. While people have embedded Python in other applications since its early existence, the process of embedding Python is less straightforward than writing an extension.

Many API functions are useful independent of whether you're embedding or extending Python; moreover, most applications that embed Python will need to provide a custom extension as well, so it's probably a good idea to become familiar with writing an extension before attempting to embed Python in a real application.

1.1 Coding standards

If you're writing C code for inclusion in CPython, you **must** follow the guidelines and standards defined in PEP 7. These guidelines apply regardless of the version of Python you are contributing to. Following these conventions is not necessary for your own third party extension modules, unless you eventually expect to contribute them to Python.

1.2 Include Files

All function, type and macro definitions needed to use the Python/C API are included in your code by the following line:

```
#include "Python.h"
```

This implies inclusion of the following standard headers: `<stdio.h>`, `<string.h>`, `<errno.h>`, `<limits.h>`, `<assert.h>` and `<stdlib.h>` (if available).

Note: Since Python may define some pre-processor definitions which affect the standard headers on some systems, you *must* include `Python.h` before any standard headers are included.

All user visible names defined by Python.h (except those defined by the included standard headers) have one of the prefixes `Py` or `_Py`. Names beginning with `_Py` are for internal use by the Python implementation and should not be used by extension writers. Structure member names do not have a reserved prefix.

Important: user code should never define names that begin with `Py` or `_Py`. This confuses the reader, and jeopardizes the portability of the user code to future Python versions, which may define additional names beginning with one of these prefixes.

The header files are typically installed with Python. On Unix, these are located in the directories *prefix*`/include/pythonversion/` and *exec_prefix*`/include/pythonversion/`, where `prefix` and `exec_prefix` are defined by the corresponding parameters to Python's `configure` script and *version* is `'%d.%d' % sys.version_info[:2]`. On Windows, the headers are installed in *prefix*`/include`, where `prefix` is the installation directory specified to the installer.

To include the headers, place both directories (if different) on your compiler's search path for includes. Do *not* place the parent directories on the search path and then use `#include <pythonX.Y/Python.h>`; this will break on multi-platform builds since the platform independent headers under `prefix` include the platform specific headers from `exec_prefix`.

C++ users should note that though the API is defined entirely using C, the header files do properly declare the entry points to be `extern "C"`, so there is no need to do anything special to use the API from C++.

1.3 Useful macros

Several useful macros are defined in the Python header files. Many are defined closer to where they are useful (e.g. *Py_RETURN_NONE*). Others of a more general utility are defined here. This is not necessarily a complete listing.

`Py_UNREACHABLE`
: Use this when you have a code path that you do not expect to be reached. For example, in the `default:` clause in a `switch` statement for which all possible values are covered in `case` statements. Use this in places where you might be tempted to put an `assert(0)` or `abort()` call.

  New in version 3.7.

`Py_ABS`(x)
: Return the absolute value of `x`.

  New in version 3.3.

`Py_MIN`(x, y)
: Return the minimum value between `x` and `y`.

  New in version 3.3.

`Py_MAX`(x, y)
: Return the maximum value between `x` and `y`.

  New in version 3.3.

`Py_STRINGIFY`(x)
: Convert `x` to a C string. E.g. `Py_STRINGIFY(123)` returns `"123"`.

  New in version 3.4.

`Py_MEMBER_SIZE`(type, member)
: Return the size of a structure (`type`) `member` in bytes.

  New in version 3.6.

`Py_CHARMASK`(c)
: Argument must be a character or an integer in the range [-128, 127] or [0, 255]. This macro returns `c` cast to an `unsigned char`.

`Py_GETENV`(s)
: Like `getenv(s)`, but returns *NULL* if `-E` was passed on the command line (i.e. if `Py_IgnoreEnvironmentFlag` is set).

`Py_UNUSED`(arg)
: Use this for unused arguments in a function definition to silence compiler warnings, e.g. `PyObject* func(PyObject *Py_UNUSED(ignored))`.

  New in version 3.4.

1.4 Objects, Types and Reference Counts

Most Python/C API functions have one or more arguments as well as a return value of type *PyObject**. This type is a pointer to an opaque data type representing an arbitrary Python object. Since all Python object types are treated the same way by the Python language in most situations (e.g., assignments, scope rules, and argument passing), it is only fitting that they should be represented by a single C type. Almost all Python objects live on the heap: you never declare an automatic or static variable of type *PyObject*, only pointer variables of type *PyObject** can be declared. The sole exception are the type objects; since these must never be deallocated, they are typically static *PyTypeObject* objects.

All Python objects (even Python integers) have a *type* and a *reference count*. An object's type determines what kind of object it is (e.g., an integer, a list, or a user-defined function; there are many more as explained in types). For each of the well-known types there is a macro to check whether an object is of that type; for instance, `PyList_Check(a)` is true if (and only if) the object pointed to by *a* is a Python list.

1.4.1 Reference Counts

The reference count is important because today's computers have a finite (and often severely limited) memory size; it counts how many different places there are that have a reference to an object. Such a place could be another object, or a global (or static) C variable, or a local variable in some C function. When an object's reference count becomes zero, the object is deallocated. If it contains references to other objects, their reference count is decremented. Those other objects may be deallocated in turn, if this decrement makes their reference count become zero, and so on. (There's an obvious problem with objects that reference each other here; for now, the solution is "don't do that.")

Reference counts are always manipulated explicitly. The normal way is to use the macro *Py_INCREF()* to increment an object's reference count by one, and *Py_DECREF()* to decrement it by one. The *Py_DECREF()* macro is considerably more complex than the incref one, since it must check whether the reference count becomes zero and then cause the object's deallocator to be called. The deallocator is a function pointer contained in the object's type structure. The type-specific deallocator takes care of decrementing the reference counts for other objects contained in the object if this is a compound object type, such as a list, as well as performing any additional finalization that's needed. There's no chance that the reference count can overflow; at least as many bits are used to hold the reference count as there are distinct memory locations in virtual memory (assuming `sizeof(Py_ssize_t) >= sizeof(void*)`). Thus, the reference count increment is a simple operation.

It is not necessary to increment an object's reference count for every local variable that contains a pointer to an object. In theory, the object's reference count goes up by one when the variable is made to point to it and it goes down by one when the variable goes out of scope. However, these two cancel each other out, so at the end the reference count hasn't changed. The only real reason to use the reference count is to prevent the object from being deallocated as long as our variable is pointing to it. If we know that there is at least one other reference to the object that lives at least as long as our variable, there is no need to increment the reference count temporarily. An important situation where this arises is in objects that are passed as arguments to C functions in an extension module that are called from Python; the call mechanism guarantees to hold a reference to every argument for the duration of the call.

However, a common pitfall is to extract an object from a list and hold on to it for a while without incrementing its reference count. Some other operation might conceivably remove the object from the list, decrementing its reference count and possible deallocating it. The real danger is that innocent-looking operations may invoke arbitrary Python code which could do this; there is a code path which allows control to flow back to the user from a *Py_DECREF()*, so almost any operation is potentially dangerous.

A safe approach is to always use the generic operations (functions whose name begins with `PyObject_`, `PyNumber_`, `PySequence_` or `PyMapping_`). These operations always increment the reference count of the object they return. This leaves the caller with the responsibility to call *Py_DECREF()* when they are done with the result; this soon becomes second nature.

Reference Count Details

The reference count behavior of functions in the Python/C API is best explained in terms of *ownership of references*. Ownership pertains to references, never to objects (objects are not owned: they are always shared). "Owning a reference" means being responsible for calling Py_DECREF on it when the reference is no longer needed. Ownership can also be transferred, meaning that the code that receives ownership of the reference then becomes responsible for eventually decref'ing it by calling *Py_DECREF()* or *Py_XDECREF()* when it's no longer needed—or passing on this responsibility (usually to its caller). When a function passes ownership of a reference on to its caller, the caller is said to receive a *new* reference. When no ownership is transferred, the caller is said to *borrow* the reference. Nothing needs to be done for a borrowed reference.

Conversely, when a calling function passes in a reference to an object, there are two possibilities: the function *steals* a reference to the object, or it does not. *Stealing a reference* means that when you pass a reference to a function, that function assumes that it now owns that reference, and you are not responsible for it any longer.

Few functions steal references; the two notable exceptions are *PyList_SetItem()* and *PyTuple_SetItem()*, which steal a reference to the item (but not to the tuple or list into which the item is put!). These functions were designed to steal a reference because of a common idiom for populating a tuple or list with newly created objects; for example, the code to create the tuple `(1, 2, "three")` could look like this (forgetting about error handling for the moment; a better way to code this is shown below):

```
PyObject *t;

t = PyTuple_New(3);
PyTuple_SetItem(t, 0, PyLong_FromLong(1L));
PyTuple_SetItem(t, 1, PyLong_FromLong(2L));
PyTuple_SetItem(t, 2, PyUnicode_FromString("three"));
```

Here, *PyLong_FromLong()* returns a new reference which is immediately stolen by *PyTuple_SetItem()*. When you want to keep using an object although the reference to it will be stolen, use *Py_INCREF()* to grab another reference before calling the reference-stealing function.

Incidentally, *PyTuple_SetItem()* is the *only* way to set tuple items; *PySequence_SetItem()* and *PyObject_SetItem()* refuse to do this since tuples are an immutable data type. You should only use *PyTuple_SetItem()* for tuples that you are creating yourself.

Equivalent code for populating a list can be written using *PyList_New()* and *PyList_SetItem()*.

However, in practice, you will rarely use these ways of creating and populating a tuple or list. There's a generic function, *Py_BuildValue()*, that can create most common objects from C values, directed by a *format string*. For example, the above two blocks of code could be replaced by the following (which also takes care of the error checking):

```
PyObject *tuple, *list;
```

(continues on next page)

(continued from previous page)

```
tuple = Py_BuildValue("(iis)", 1, 2, "three");
list = Py_BuildValue("[iis]", 1, 2, "three");
```

It is much more common to use *PyObject_SetItem()* and friends with items whose references you are only borrowing, like arguments that were passed in to the function you are writing. In that case, their behaviour regarding reference counts is much saner, since you don't have to increment a reference count so you can give a reference away ("have it be stolen"). For example, this function sets all items of a list (actually, any mutable sequence) to a given item:

```
int
set_all(PyObject *target, PyObject *item)
{
    Py_ssize_t i, n;

    n = PyObject_Length(target);
    if (n < 0)
        return -1;
    for (i = 0; i < n; i++) {
        PyObject *index = PyLong_FromSsize_t(i);
        if (!index)
            return -1;
        if (PyObject_SetItem(target, index, item) < 0) {
            Py_DECREF(index);
            return -1;
        }
        Py_DECREF(index);
    }
    return 0;
}
```

The situation is slightly different for function return values. While passing a reference to most functions does not change your ownership responsibilities for that reference, many functions that return a reference to an object give you ownership of the reference. The reason is simple: in many cases, the returned object is created on the fly, and the reference you get is the only reference to the object. Therefore, the generic functions that return object references, like *PyObject_GetItem()* and *PySequence_GetItem()*, always return a new reference (the caller becomes the owner of the reference).

It is important to realize that whether you own a reference returned by a function depends on which function you call only — *the plumage* (the type of the object passed as an argument to the function) *doesn't enter into it!* Thus, if you extract an item from a list using *PyList_GetItem()*, you don't own the reference — but if you obtain the same item from the same list using *PySequence_GetItem()* (which happens to take exactly the same arguments), you do own a reference to the returned object.

Here is an example of how you could write a function that computes the sum of the items in a list of integers; once using *PyList_GetItem()*, and once using *PySequence_GetItem()*.

```
long
sum_list(PyObject *list)
{
    Py_ssize_t i, n;
    long total = 0, value;
    PyObject *item;

    n = PyList_Size(list);
    if (n < 0)
        return -1; /* Not a list */
```

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```
    for (i = 0; i < n; i++) {
        item = PyList_GetItem(list, i); /* Can't fail */
        if (!PyLong_Check(item)) continue; /* Skip non-integers */
        value = PyLong_AsLong(item);
        if (value == -1 && PyErr_Occurred())
            /* Integer too big to fit in a C long, bail out */
            return -1;
        total += value;
    }
    return total;
}
```

```
long
sum_sequence(PyObject *sequence)
{
    Py_ssize_t i, n;
    long total = 0, value;
    PyObject *item;
    n = PySequence_Length(sequence);
    if (n < 0)
        return -1; /* Has no length */
    for (i = 0; i < n; i++) {
        item = PySequence_GetItem(sequence, i);
        if (item == NULL)
            return -1; /* Not a sequence, or other failure */
        if (PyLong_Check(item)) {
            value = PyLong_AsLong(item);
            Py_DECREF(item);
            if (value == -1 && PyErr_Occurred())
                /* Integer too big to fit in a C long, bail out */
                return -1;
            total += value;
        }
        else {
            Py_DECREF(item); /* Discard reference ownership */
        }
    }
    return total;
}
```

1.4.2 Types

There are few other data types that play a significant role in the Python/C API; most are simple C types such as `int`, `long`, `double` and `char*`. A few structure types are used to describe static tables used to list the functions exported by a module or the data attributes of a new object type, and another is used to describe the value of a complex number. These will be discussed together with the functions that use them.

1.5 Exceptions

The Python programmer only needs to deal with exceptions if specific error handling is required; unhandled exceptions are automatically propagated to the caller, then to the caller's caller, and so on, until they reach the top-level interpreter, where they are reported to the user accompanied by a stack traceback.

For C programmers, however, error checking always has to be explicit. All functions in the Python/C API can raise exceptions, unless an explicit claim is made otherwise in a function's documentation. In general, when a function encounters an error, it sets an exception, discards any object references that it owns, and returns an error indicator. If not documented otherwise, this indicator is either *NULL* or `-1`, depending on the function's return type. A few functions return a Boolean true/false result, with false indicating an error. Very few functions return no explicit error indicator or have an ambiguous return value, and require explicit testing for errors with *PyErr_Occurred()*. These exceptions are always explicitly documented.

Exception state is maintained in per-thread storage (this is equivalent to using global storage in an unthreaded application). A thread can be in one of two states: an exception has occurred, or not. The function *PyErr_Occurred()* can be used to check for this: it returns a borrowed reference to the exception type object when an exception has occurred, and *NULL* otherwise. There are a number of functions to set the exception state: *PyErr_SetString()* is the most common (though not the most general) function to set the exception state, and *PyErr_Clear()* clears the exception state.

The full exception state consists of three objects (all of which can be *NULL*): the exception type, the corresponding exception value, and the traceback. These have the same meanings as the Python result of `sys.exc_info()`; however, they are not the same: the Python objects represent the last exception being handled by a Python `try` … `except` statement, while the C level exception state only exists while an exception is being passed on between C functions until it reaches the Python bytecode interpreter's main loop, which takes care of transferring it to `sys.exc_info()` and friends.

Note that starting with Python 1.5, the preferred, thread-safe way to access the exception state from Python code is to call the function `sys.exc_info()`, which returns the per-thread exception state for Python code. Also, the semantics of both ways to access the exception state have changed so that a function which catches an exception will save and restore its thread's exception state so as to preserve the exception state of its caller. This prevents common bugs in exception handling code caused by an innocent-looking function overwriting the exception being handled; it also reduces the often unwanted lifetime extension for objects that are referenced by the stack frames in the traceback.

As a general principle, a function that calls another function to perform some task should check whether the called function raised an exception, and if so, pass the exception state on to its caller. It should discard any object references that it owns, and return an error indicator, but it should *not* set another exception — that would overwrite the exception that was just raised, and lose important information about the exact cause of the error.

A simple example of detecting exceptions and passing them on is shown in the `sum_sequence()` example above. It so happens that this example doesn't need to clean up any owned references when it detects an error. The following example function shows some error cleanup. First, to remind you why you like Python, we show the equivalent Python code:

```
def incr_item(dict, key):
    try:
        item = dict[key]
    except KeyError:
        item = 0
    dict[key] = item + 1
```

Here is the corresponding C code, in all its glory:

```
int
incr_item(PyObject *dict, PyObject *key)
{
    /* Objects all initialized to NULL for Py_XDECREF */
    PyObject *item = NULL, *const_one = NULL, *incremented_item = NULL;
    int rv = -1; /* Return value initialized to -1 (failure) */

    item = PyObject_GetItem(dict, key);
```

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```
    if (item == NULL) {
        /* Handle KeyError only: */
        if (!PyErr_ExceptionMatches(PyExc_KeyError))
            goto error;

        /* Clear the error and use zero: */
        PyErr_Clear();
        item = PyLong_FromLong(0L);
        if (item == NULL)
            goto error;
    }
    const_one = PyLong_FromLong(1L);
    if (const_one == NULL)
        goto error;

    incremented_item = PyNumber_Add(item, const_one);
    if (incremented_item == NULL)
        goto error;

    if (PyObject_SetItem(dict, key, incremented_item) < 0)
        goto error;
    rv = 0; /* Success */
    /* Continue with cleanup code */

 error:
    /* Cleanup code, shared by success and failure path */

    /* Use Py_XDECREF() to ignore NULL references */
    Py_XDECREF(item);
    Py_XDECREF(const_one);
    Py_XDECREF(incremented_item);

    return rv; /* -1 for error, 0 for success */
}
```

This example represents an endorsed use of the `goto` statement in C! It illustrates the use of *PyErr_ExceptionMatches()* and *PyErr_Clear()* to handle specific exceptions, and the use of *Py_XDECREF()* to dispose of owned references that may be *NULL* (note the `'X'` in the name; *Py_DECREF()* would crash when confronted with a *NULL* reference). It is important that the variables used to hold owned references are initialized to *NULL* for this to work; likewise, the proposed return value is initialized to `-1` (failure) and only set to success after the final call made is successful.

1.6 Embedding Python

The one important task that only embedders (as opposed to extension writers) of the Python interpreter have to worry about is the initialization, and possibly the finalization, of the Python interpreter. Most functionality of the interpreter can only be used after the interpreter has been initialized.

The basic initialization function is *Py_Initialize()*. This initializes the table of loaded modules, and creates the fundamental modules `builtins`, `__main__`, and `sys`. It also initializes the module search path (`sys.path`).

Py_Initialize() does not set the "script argument list" (`sys.argv`). If this variable is needed by Python code that will be executed later, it must be set explicitly with a call to `PySys_SetArgvEx(argc, argv, updatepath)` after the call to *Py_Initialize()*.

On most systems (in particular, on Unix and Windows, although the details are slightly different), *Py_Initialize()* calculates the module search path based upon its best guess for the location of the standard Python interpreter executable, assuming that the Python library is found in a fixed location relative to the Python interpreter executable. In particular, it looks for a directory named `lib/python`*`X.Y`* relative to the parent directory where the executable named `python` is found on the shell command search path (the environment variable `PATH`).

For instance, if the Python executable is found in `/usr/local/bin/python`, it will assume that the libraries are in `/usr/local/lib/python`*`X.Y`*. (In fact, this particular path is also the "fallback" location, used when no executable file named `python` is found along `PATH`.) The user can override this behavior by setting the environment variable `PYTHONHOME`, or insert additional directories in front of the standard path by setting `PYTHONPATH`.

The embedding application can steer the search by calling `Py_SetProgramName(file)` *before* calling *Py_Initialize()*. Note that `PYTHONHOME` still overrides this and `PYTHONPATH` is still inserted in front of the standard path. An application that requires total control has to provide its own implementation of *Py_GetPath()*, *Py_GetPrefix()*, *Py_GetExecPrefix()*, and *Py_GetProgramFullPath()* (all defined in `Modules/getpath.c`).

Sometimes, it is desirable to "uninitialize" Python. For instance, the application may want to start over (make another call to *Py_Initialize()*) or the application is simply done with its use of Python and wants to free memory allocated by Python. This can be accomplished by calling *Py_FinalizeEx()*. The function *Py_IsInitialized()* returns true if Python is currently in the initialized state. More information about these functions is given in a later chapter. Notice that *Py_FinalizeEx()* does *not* free all memory allocated by the Python interpreter, e.g. memory allocated by extension modules currently cannot be released.

1.7 Debugging Builds

Python can be built with several macros to enable extra checks of the interpreter and extension modules. These checks tend to add a large amount of overhead to the runtime so they are not enabled by default.

A full list of the various types of debugging builds is in the file `Misc/SpecialBuilds.txt` in the Python source distribution. Builds are available that support tracing of reference counts, debugging the memory allocator, or low-level profiling of the main interpreter loop. Only the most frequently-used builds will be described in the remainder of this section.

Compiling the interpreter with the `Py_DEBUG` macro defined produces what is generally meant by "a debug build" of Python. `Py_DEBUG` is enabled in the Unix build by adding `--with-pydebug` to the `./configure` command. It is also implied by the presence of the not-Python-specific `_DEBUG` macro. When `Py_DEBUG` is enabled in the Unix build, compiler optimization is disabled.

In addition to the reference count debugging described below, the following extra checks are performed:

- Extra checks are added to the object allocator.
- Extra checks are added to the parser and compiler.
- Downcasts from wide types to narrow types are checked for loss of information.
- A number of assertions are added to the dictionary and set implementations. In addition, the set object acquires a `test_c_api()` method.
- Sanity checks of the input arguments are added to frame creation.
- The storage for ints is initialized with a known invalid pattern to catch reference to uninitialized digits.
- Low-level tracing and extra exception checking are added to the runtime virtual machine.
- Extra checks are added to the memory arena implementation.
- Extra debugging is added to the thread module.

There may be additional checks not mentioned here.

Defining `Py_TRACE_REFS` enables reference tracing. When defined, a circular doubly linked list of active objects is maintained by adding two extra fields to every *PyObject*. Total allocations are tracked as well. Upon exit, all existing references are printed. (In interactive mode this happens after every statement run by the interpreter.) Implied by `Py_DEBUG`.

Please refer to `Misc/SpecialBuilds.txt` in the Python source distribution for more detailed information.

CHAPTER

TWO

STABLE APPLICATION BINARY INTERFACE

Traditionally, the C API of Python will change with every release. Most changes will be source-compatible, typically by only adding API, rather than changing existing API or removing API (although some interfaces do get removed after being deprecated first).

Unfortunately, the API compatibility does not extend to binary compatibility (the ABI). The reason is primarily the evolution of struct definitions, where addition of a new field, or changing the type of a field, might not break the API, but can break the ABI. As a consequence, extension modules need to be recompiled for every Python release (although an exception is possible on Unix when none of the affected interfaces are used). In addition, on Windows, extension modules link with a specific pythonXY.dll and need to be recompiled to link with a newer one.

Since Python 3.2, a subset of the API has been declared to guarantee a stable ABI. Extension modules wishing to use this API (called "limited API") need to define `Py_LIMITED_API`. A number of interpreter details then become hidden from the extension module; in return, a module is built that works on any 3.x version (x>=2) without recompilation.

In some cases, the stable ABI needs to be extended with new functions. Extension modules wishing to use these new APIs need to set `Py_LIMITED_API` to the `PY_VERSION_HEX` value (see *API and ABI Versioning*) of the minimum Python version they want to support (e.g. `0x03030000` for Python 3.3). Such modules will work on all subsequent Python releases, but fail to load (because of missing symbols) on the older releases.

As of Python 3.2, the set of functions available to the limited API is documented in **PEP 384**. In the C API documentation, API elements that are not part of the limited API are marked as "Not part of the limited API."

CHAPTER

THREE

THE VERY HIGH LEVEL LAYER

The functions in this chapter will let you execute Python source code given in a file or a buffer, but they will not let you interact in a more detailed way with the interpreter.

Several of these functions accept a start symbol from the grammar as a parameter. The available start symbols are `Py_eval_input`, `Py_file_input`, and `Py_single_input`. These are described following the functions which accept them as parameters.

Note also that several of these functions take `FILE*` parameters. One particular issue which needs to be handled carefully is that the `FILE` structure for different C libraries can be different and incompatible. Under Windows (at least), it is possible for dynamically linked extensions to actually use different libraries, so care should be taken that `FILE*` parameters are only passed to these functions if it is certain that they were created by the same library that the Python runtime is using.

int **Py_Main**(int *argc*, wchar_t ***argv*)
: The main program for the standard interpreter. This is made available for programs which embed Python. The *argc* and *argv* parameters should be prepared exactly as those which are passed to a C program's `main()` function (converted to wchar_t according to the user's locale). It is important to note that the argument list may be modified (but the contents of the strings pointed to by the argument list are not). The return value will be `0` if the interpreter exits normally (i.e., without an exception), `1` if the interpreter exits due to an exception, or `2` if the parameter list does not represent a valid Python command line.

  Note that if an otherwise unhandled `SystemExit` is raised, this function will not return `1`, but exit the process, as long as `Py_InspectFlag` is not set.

int **PyRun_AnyFile**(FILE **fp*, const char **filename*)
: This is a simplified interface to *PyRun_AnyFileExFlags()* below, leaving *closeit* set to `0` and *flags* set to *NULL*.

int **PyRun_AnyFileFlags**(FILE **fp*, const char **filename*, *PyCompilerFlags* **flags*)
: This is a simplified interface to *PyRun_AnyFileExFlags()* below, leaving the *closeit* argument set to `0`.

int **PyRun_AnyFileEx**(FILE **fp*, const char **filename*, int *closeit*)
: This is a simplified interface to *PyRun_AnyFileExFlags()* below, leaving the *flags* argument set to *NULL*.

int **PyRun_AnyFileExFlags**(FILE **fp*, const char **filename*, int *closeit*, *PyCompilerFlags* **flags*)
: If *fp* refers to a file associated with an interactive device (console or terminal input or Unix pseudo-terminal), return the value of *PyRun_InteractiveLoop()*, otherwise return the result of *PyRun_SimpleFile()*. *filename* is decoded from the filesystem encoding (`sys.getfilesystemencoding()`). If *filename* is *NULL*, this function uses `"???"` as the filename.

int **PyRun_SimpleString**(const char **command*)
: This is a simplified interface to *PyRun_SimpleStringFlags()* below, leaving the *PyCompilerFlags** argument set to NULL.

int **PyRun_SimpleStringFlags**(const char **command*, *PyCompilerFlags *flags*)
Executes the Python source code from *command* in the `__main__` module according to the *flags* argument. If `__main__` does not already exist, it is created. Returns `0` on success or `-1` if an exception was raised. If there was an error, there is no way to get the exception information. For the meaning of *flags*, see below.

Note that if an otherwise unhandled `SystemExit` is raised, this function will not return `-1`, but exit the process, as long as `Py_InspectFlag` is not set.

int **PyRun_SimpleFile**(FILE **fp*, const char **filename*)
This is a simplified interface to *PyRun_SimpleFileExFlags()* below, leaving *closeit* set to `0` and *flags* set to *NULL*.

int **PyRun_SimpleFileEx**(FILE **fp*, const char **filename*, int *closeit*)
This is a simplified interface to *PyRun_SimpleFileExFlags()* below, leaving *flags* set to *NULL*.

int **PyRun_SimpleFileExFlags**(FILE **fp*, const char **filename*, int *closeit*, *PyCompilerFlags *flags*)
Similar to *PyRun_SimpleStringFlags()*, but the Python source code is read from *fp* instead of an in-memory string. *filename* should be the name of the file, it is decoded from the filesystem encoding (`sys.getfilesystemencoding()`). If *closeit* is true, the file is closed before PyRun_SimpleFileExFlags returns.

int **PyRun_InteractiveOne**(FILE **fp*, const char **filename*)
This is a simplified interface to *PyRun_InteractiveOneFlags()* below, leaving *flags* set to *NULL*.

int **PyRun_InteractiveOneFlags**(FILE **fp*, const char **filename*, *PyCompilerFlags *flags*)
Read and execute a single statement from a file associated with an interactive device according to the *flags* argument. The user will be prompted using `sys.ps1` and `sys.ps2`. *filename* is decoded from the filesystem encoding (`sys.getfilesystemencoding()`).

Returns `0` when the input was executed successfully, `-1` if there was an exception, or an error code from the `errcode.h` include file distributed as part of Python if there was a parse error. (Note that `errcode.h` is not included by `Python.h`, so must be included specifically if needed.)

int **PyRun_InteractiveLoop**(FILE **fp*, const char **filename*)
This is a simplified interface to *PyRun_InteractiveLoopFlags()* below, leaving *flags* set to *NULL*.

int **PyRun_InteractiveLoopFlags**(FILE **fp*, const char **filename*, *PyCompilerFlags *flags*)
Read and execute statements from a file associated with an interactive device until EOF is reached. The user will be prompted using `sys.ps1` and `sys.ps2`. *filename* is decoded from the filesystem encoding (`sys.getfilesystemencoding()`). Returns `0` at EOF or a negative number upon failure.

int **(*PyOS_InputHook)**(void)
Can be set to point to a function with the prototype `int func(void)`. The function will be called when Python's interpreter prompt is about to become idle and wait for user input from the terminal. The return value is ignored. Overriding this hook can be used to integrate the interpreter's prompt with other event loops, as done in the `Modules/_tkinter.c` in the Python source code.

char* **(*PyOS_ReadlineFunctionPointer)**(FILE ***, FILE ***, const char ***)
Can be set to point to a function with the prototype `char *func(FILE *stdin, FILE *stdout, char *prompt)`, overriding the default function used to read a single line of input at the interpreter's prompt. The function is expected to output the string *prompt* if it's not *NULL*, and then read a line of input from the provided standard input file, returning the resulting string. For example, The `readline` module sets this hook to provide line-editing and tab-completion features.

The result must be a string allocated by *PyMem_RawMalloc()* or *PyMem_RawRealloc()*, or *NULL* if an error occurred.

Changed in version 3.4: The result must be allocated by *PyMem_RawMalloc()* or *PyMem_RawRealloc()*, instead of being allocated by *PyMem_Malloc()* or *PyMem_Realloc()*.

struct _node* **PyParser_SimpleParseString**(const char **str*, int *start*)
This is a simplified interface to *PyParser_SimpleParseStringFlagsFilename()* below, leaving *filename* set to *NULL* and *flags* set to `0`.

struct _node* **PyParser_SimpleParseStringFlags**(const char **str*, int *start*, int *flags*)
This is a simplified interface to *PyParser_SimpleParseStringFlagsFilename()* below, leaving *filename* set to *NULL*.

struct _node* **PyParser_SimpleParseStringFlagsFilename**(const char **str*, const char **filename*, int *start*, int *flags*)
Parse Python source code from *str* using the start token *start* according to the *flags* argument. The result can be used to create a code object which can be evaluated efficiently. This is useful if a code fragment must be evaluated many times. *filename* is decoded from the filesystem encoding (`sys.getfilesystemencoding()`).

struct _node* **PyParser_SimpleParseFile**(FILE **fp*, const char **filename*, int *start*)
This is a simplified interface to *PyParser_SimpleParseFileFlags()* below, leaving *flags* set to `0`.

struct _node* **PyParser_SimpleParseFileFlags**(FILE **fp*, const char **filename*, int *start*, int *flags*)
Similar to *PyParser_SimpleParseStringFlagsFilename()*, but the Python source code is read from *fp* instead of an in-memory string.

*PyObject** **PyRun_String**(const char **str*, int *start*, *PyObject* **globals*, *PyObject* **locals*)
Return value: New reference. This is a simplified interface to *PyRun_StringFlags()* below, leaving *flags* set to *NULL*.

*PyObject** **PyRun_StringFlags**(const char **str*, int *start*, *PyObject* **globals*, *PyObject* **locals*, *PyCompilerFlags* **flags*)
Return value: New reference. Execute Python source code from *str* in the context specified by the objects *globals* and *locals* with the compiler flags specified by *flags*. *globals* must be a dictionary; *locals* can be any object that implements the mapping protocol. The parameter *start* specifies the start token that should be used to parse the source code.

Returns the result of executing the code as a Python object, or *NULL* if an exception was raised.

*PyObject** **PyRun_File**(FILE **fp*, const char **filename*, int *start*, *PyObject* **globals*, *PyObject* **locals*)
Return value: New reference. This is a simplified interface to *PyRun_FileExFlags()* below, leaving *closeit* set to `0` and *flags* set to *NULL*.

*PyObject** **PyRun_FileEx**(FILE **fp*, const char **filename*, int *start*, *PyObject* **globals*, *PyObject* **locals*, int *closeit*)
Return value: New reference. This is a simplified interface to *PyRun_FileExFlags()* below, leaving *flags* set to *NULL*.

*PyObject** **PyRun_FileFlags**(FILE **fp*, const char **filename*, int *start*, *PyObject* **globals*, *PyObject* **locals*, *PyCompilerFlags* **flags*)
Return value: New reference. This is a simplified interface to *PyRun_FileExFlags()* below, leaving *closeit* set to `0`.

*PyObject** **PyRun_FileExFlags**(FILE **fp*, const char **filename*, int *start*, *PyObject* **globals*, *PyObject* **locals*, int *closeit*, *PyCompilerFlags* **flags*)
Return value: New reference. Similar to *PyRun_StringFlags()*, but the Python source code is read from *fp* instead of an in-memory string. *filename* should be the name of the file, it is decoded from the filesystem encoding (`sys.getfilesystemencoding()`). If *closeit* is true, the file is closed before *PyRun_FileExFlags()* returns.

*PyObject** **Py_CompileString**(const char **str*, const char **filename*, int *start*)
Return value: New reference. This is a simplified interface to *Py_CompileStringFlags()* below, leaving *flags* set to *NULL*.

*PyObject** **Py_CompileStringFlags**(const char **str*, const char **filename*, int *start*, *PyCompilerFlags* **flags*)

Return value: New reference. This is a simplified interface to *Py_CompileStringExFlags()* below, with *optimize* set to `-1`.

*PyObject** **Py_CompileStringObject**(const char **str*, *PyObject *filename*, int *start*, *PyCompilerFlags *flags*, int *optimize*)

Parse and compile the Python source code in *str*, returning the resulting code object. The start token is given by *start*; this can be used to constrain the code which can be compiled and should be `Py_eval_input`, `Py_file_input`, or `Py_single_input`. The filename specified by *filename* is used to construct the code object and may appear in tracebacks or `SyntaxError` exception messages. This returns *NULL* if the code cannot be parsed or compiled.

The integer *optimize* specifies the optimization level of the compiler; a value of `-1` selects the optimization level of the interpreter as given by `-O` options. Explicit levels are `0` (no optimization; `__debug__` is true), `1` (asserts are removed, `__debug__` is false) or `2` (docstrings are removed too).

New in version 3.4.

*PyObject** **Py_CompileStringExFlags**(const char **str*, const char **filename*, int *start*, *PyCompilerFlags *flags*, int *optimize*)

Like *Py_CompileStringObject()*, but *filename* is a byte string decoded from the filesystem encoding (`os.fsdecode()`).

New in version 3.2.

*PyObject** **PyEval_EvalCode**(*PyObject *co*, *PyObject *globals*, *PyObject *locals*)

Return value: New reference. This is a simplified interface to *PyEval_EvalCodeEx()*, with just the code object, and global and local variables. The other arguments are set to *NULL*.

*PyObject** **PyEval_EvalCodeEx**(*PyObject *co*, *PyObject *globals*, *PyObject *locals*, *PyObject* *const **args*, int *argcount*, *PyObject* *const **kws*, int *kwcount*, *PyObject* *const **defs*, int *defcount*, *PyObject *kwdefs*, *PyObject *closure*)

Evaluate a precompiled code object, given a particular environment for its evaluation. This environment consists of a dictionary of global variables, a mapping object of local variables, arrays of arguments, keywords and defaults, a dictionary of default values for *keyword-only* arguments and a closure tuple of cells.

PyFrameObject

The C structure of the objects used to describe frame objects. The fields of this type are subject to change at any time.

*PyObject** **PyEval_EvalFrame**(*PyFrameObject *f*)

Evaluate an execution frame. This is a simplified interface to *PyEval_EvalFrameEx()*, for backward compatibility.

*PyObject** **PyEval_EvalFrameEx**(*PyFrameObject *f*, int *throwflag*)

This is the main, unvarnished function of Python interpretation. It is literally 2000 lines long. The code object associated with the execution frame *f* is executed, interpreting bytecode and executing calls as needed. The additional *throwflag* parameter can mostly be ignored - if true, then it causes an exception to immediately be thrown; this is used for the `throw()` methods of generator objects.

Changed in version 3.4: This function now includes a debug assertion to help ensure that it does not silently discard an active exception.

int **PyEval_MergeCompilerFlags**(*PyCompilerFlags *cf*)

This function changes the flags of the current evaluation frame, and returns true on success, false on failure.

int **Py_eval_input**

The start symbol from the Python grammar for isolated expressions; for use with *Py_CompileString()*.

int **Py_file_input**

The start symbol from the Python grammar for sequences of statements as read from a file or other

source; for use with *Py_CompileString()*. This is the symbol to use when compiling arbitrarily long Python source code.

int **Py_single_input**
The start symbol from the Python grammar for a single statement; for use with *Py_CompileString()*. This is the symbol used for the interactive interpreter loop.

struct **PyCompilerFlags**
This is the structure used to hold compiler flags. In cases where code is only being compiled, it is passed as `int flags`, and in cases where code is being executed, it is passed as `PyCompilerFlags *flags`. In this case, `from __future__ import` can modify *flags*.

Whenever `PyCompilerFlags *flags` is *NULL*, `cf_flags` is treated as equal to `0`, and any modification due to `from __future__ import` is discarded.

```
struct PyCompilerFlags {
    int cf_flags;
}
```

int **CO_FUTURE_DIVISION**
This bit can be set in *flags* to cause division operator `/` to be interpreted as "true division" according to **PEP 238**.

CHAPTER

FOUR

REFERENCE COUNTING

The macros in this section are used for managing reference counts of Python objects.

void **Py_INCREF**(*PyObject *o*)
Increment the reference count for object *o*. The object must not be *NULL*; if you aren't sure that it isn't *NULL*, use *Py_XINCREF()*.

void **Py_XINCREF**(*PyObject *o*)
Increment the reference count for object *o*. The object may be *NULL*, in which case the macro has no effect.

void **Py_DECREF**(*PyObject *o*)
Decrement the reference count for object *o*. The object must not be *NULL*; if you aren't sure that it isn't *NULL*, use *Py_XDECREF()*. If the reference count reaches zero, the object's type's deallocation function (which must not be *NULL*) is invoked.

> **Warning:** The deallocation function can cause arbitrary Python code to be invoked (e.g. when a class instance with a `__del__()` method is deallocated). While exceptions in such code are not propagated, the executed code has free access to all Python global variables. This means that any object that is reachable from a global variable should be in a consistent state before *Py_DECREF()* is invoked. For example, code to delete an object from a list should copy a reference to the deleted object in a temporary variable, update the list data structure, and then call *Py_DECREF()* for the temporary variable.

void **Py_XDECREF**(*PyObject *o*)
Decrement the reference count for object *o*. The object may be *NULL*, in which case the macro has no effect; otherwise the effect is the same as for *Py_DECREF()*, and the same warning applies.

void **Py_CLEAR**(*PyObject *o*)
Decrement the reference count for object *o*. The object may be *NULL*, in which case the macro has no effect; otherwise the effect is the same as for *Py_DECREF()*, except that the argument is also set to *NULL*. The warning for *Py_DECREF()* does not apply with respect to the object passed because the macro carefully uses a temporary variable and sets the argument to *NULL* before decrementing its reference count.

It is a good idea to use this macro whenever decrementing the value of a variable that might be traversed during garbage collection.

The following functions are for runtime dynamic embedding of Python: `Py_IncRef(PyObject *o)`, `Py_DecRef(PyObject *o)`. They are simply exported function versions of *Py_XINCREF()* and *Py_XDECREF()*, respectively.

The following functions or macros are only for use within the interpreter core: `_Py_Dealloc()`, `_Py_ForgetReference()`, `_Py_NewReference()`, as well as the global variable `_Py_RefTotal`.

CHAPTER

FIVE

EXCEPTION HANDLING

The functions described in this chapter will let you handle and raise Python exceptions. It is important to understand some of the basics of Python exception handling. It works somewhat like the POSIX `errno` variable: there is a global indicator (per thread) of the last error that occurred. Most C API functions don't clear this on success, but will set it to indicate the cause of the error on failure. Most C API functions also return an error indicator, usually *NULL* if they are supposed to return a pointer, or `-1` if they return an integer (exception: the `PyArg_*()` functions return `1` for success and `0` for failure).

Concretely, the error indicator consists of three object pointers: the exception's type, the exception's value, and the traceback object. Any of those pointers can be NULL if non-set (although some combinations are forbidden, for example you can't have a non-NULL traceback if the exception type is NULL).

When a function must fail because some function it called failed, it generally doesn't set the error indicator; the function it called already set it. It is responsible for either handling the error and clearing the exception or returning after cleaning up any resources it holds (such as object references or memory allocations); it should *not* continue normally if it is not prepared to handle the error. If returning due to an error, it is important to indicate to the caller that an error has been set. If the error is not handled or carefully propagated, additional calls into the Python/C API may not behave as intended and may fail in mysterious ways.

Note: The error indicator is **not** the result of `sys.exc_info()`. The former corresponds to an exception that is not yet caught (and is therefore still propagating), while the latter returns an exception after it is caught (and has therefore stopped propagating).

5.1 Printing and clearing

void **PyErr_Clear**()
Clear the error indicator. If the error indicator is not set, there is no effect.

void **PyErr_PrintEx**(int *set_sys_last_vars*)
Print a standard traceback to `sys.stderr` and clear the error indicator. Call this function only when the error indicator is set. (Otherwise it will cause a fatal error!)

If *set_sys_last_vars* is nonzero, the variables `sys.last_type`, `sys.last_value` and `sys.last_traceback` will be set to the type, value and traceback of the printed exception, respectively.

void **PyErr_Print**()
Alias for `PyErr_PrintEx(1)`.

void **PyErr_WriteUnraisable**(*PyObject* *obj)
This utility function prints a warning message to `sys.stderr` when an exception has been set but it is impossible for the interpreter to actually raise the exception. It is used, for example, when an exception occurs in an `__del__()` method.

The function is called with a single argument *obj* that identifies the context in which the unraisable exception occurred. If possible, the repr of *obj* will be printed in the warning message.

5.2 Raising exceptions

These functions help you set the current thread's error indicator. For convenience, some of these functions will always return a NULL pointer for use in a `return` statement.

void **PyErr_SetString**(*PyObject* *type, const char *message)
This is the most common way to set the error indicator. The first argument specifies the exception type; it is normally one of the standard exceptions, e.g. `PyExc_RuntimeError`. You need not increment its reference count. The second argument is an error message; it is decoded from `'utf-8'`.

void **PyErr_SetObject**(*PyObject* *type, *PyObject* *value)
This function is similar to *PyErr_SetString()* but lets you specify an arbitrary Python object for the "value" of the exception.

*PyObject** **PyErr_Format**(*PyObject* *exception, const char *format, ...)
Return value: Always NULL. This function sets the error indicator and returns *NULL*. *exception* should be a Python exception class. The *format* and subsequent parameters help format the error message; they have the same meaning and values as in *PyUnicode_FromFormat()*. *format* is an ASCII-encoded string.

*PyObject** **PyErr_FormatV**(*PyObject* *exception, const char *format, va_list *vargs*)
Return value: Always NULL. Same as *PyErr_Format()*, but taking a `va_list` argument rather than a variable number of arguments.

New in version 3.5.

void **PyErr_SetNone**(*PyObject* *type)
This is a shorthand for `PyErr_SetObject(type, Py_None)`.

int **PyErr_BadArgument**()
This is a shorthand for `PyErr_SetString(PyExc_TypeError, message)`, where *message* indicates that a built-in operation was invoked with an illegal argument. It is mostly for internal use.

*PyObject** **PyErr_NoMemory**()
Return value: Always NULL. This is a shorthand for `PyErr_SetNone(PyExc_MemoryError)`; it returns *NULL* so an object allocation function can write `return PyErr_NoMemory();` when it runs out of memory.

*PyObject** **PyErr_SetFromErrno**(*PyObject* *type)
Return value: Always NULL. This is a convenience function to raise an exception when a C library function has returned an error and set the C variable `errno`. It constructs a tuple object whose first item is the integer `errno` value and whose second item is the corresponding error message (gotten from `strerror()`), and then calls `PyErr_SetObject(type, object)`. On Unix, when the `errno` value is `EINTR`, indicating an interrupted system call, this calls *PyErr_CheckSignals()*, and if that set the error indicator, leaves it set to that. The function always returns *NULL*, so a wrapper function around a system call can write `return PyErr_SetFromErrno(type);` when the system call returns an error.

*PyObject** **PyErr_SetFromErrnoWithFilenameObject**(*PyObject* *type, *PyObject* *filenameObject)
Similar to *PyErr_SetFromErrno()*, with the additional behavior that if *filenameObject* is not *NULL*, it is passed to the constructor of *type* as a third parameter. In the case of `OSError` exception, this is used to define the `filename` attribute of the exception instance.

*PyObject** **PyErr_SetFromErrnoWithFilenameObjects**(*PyObject* *type, *PyObject* *filenameObject, *PyObject* *filenameObject2)
Similar to *PyErr_SetFromErrnoWithFilenameObject()*, but takes a second filename object, for raising errors when a function that takes two filenames fails.

New in version 3.4.

*PyObject** **PyErr_SetFromErrnoWithFilename**(*PyObject *type*, const char **filename*)
Return value: Always NULL. Similar to *PyErr_SetFromErrnoWithFilenameObject()*, but the filename is given as a C string. *filename* is decoded from the filesystem encoding (`os.fsdecode()`).

*PyObject** **PyErr_SetFromWindowsErr**(int *ierr*)
Return value: Always NULL. This is a convenience function to raise `WindowsError`. If called with *ierr* of `0`, the error code returned by a call to `GetLastError()` is used instead. It calls the Win32 function `FormatMessage()` to retrieve the Windows description of error code given by *ierr* or `GetLastError()`, then it constructs a tuple object whose first item is the *ierr* value and whose second item is the corresponding error message (gotten from `FormatMessage()`), and then calls `PyErr_SetObject(PyExc_WindowsError, object)`. This function always returns *NULL*. Availability: Windows.

*PyObject** **PyErr_SetExcFromWindowsErr**(*PyObject *type*, int *ierr*)
Return value: Always NULL. Similar to *PyErr_SetFromWindowsErr()*, with an additional parameter specifying the exception type to be raised. Availability: Windows.

*PyObject** **PyErr_SetFromWindowsErrWithFilename**(int *ierr*, const char **filename*)
Return value: Always NULL. Similar to `PyErr_SetFromWindowsErrWithFilenameObject()`, but the filename is given as a C string. *filename* is decoded from the filesystem encoding (`os.fsdecode()`). Availability: Windows.

*PyObject** **PyErr_SetExcFromWindowsErrWithFilenameObject**(*PyObject *type*, int *ierr*, *PyObject *filename*)
Similar to `PyErr_SetFromWindowsErrWithFilenameObject()`, with an additional parameter specifying the exception type to be raised. Availability: Windows.

*PyObject** **PyErr_SetExcFromWindowsErrWithFilenameObjects**(*PyObject *type*, int *ierr*, *PyObject *filename*, *PyObject *filename2*)
Similar to *PyErr_SetExcFromWindowsErrWithFilenameObject()*, but accepts a second filename object. Availability: Windows.

New in version 3.4.

*PyObject** **PyErr_SetExcFromWindowsErrWithFilename**(*PyObject *type*, int *ierr*, const char **filename*)
Return value: Always NULL. Similar to *PyErr_SetFromWindowsErrWithFilename()*, with an additional parameter specifying the exception type to be raised. Availability: Windows.

*PyObject** **PyErr_SetImportError**(*PyObject **msg*, *PyObject **name*, *PyObject **path*)
This is a convenience function to raise `ImportError`. *msg* will be set as the exception's message string. *name* and *path*, both of which can be `NULL`, will be set as the `ImportError`'s respective `name` and `path` attributes.

New in version 3.3.

void **PyErr_SyntaxLocationObject**(*PyObject **filename*, int *lineno*, int *col_offset*)
Set file, line, and offset information for the current exception. If the current exception is not a `SyntaxError`, then it sets additional attributes, which make the exception printing subsystem think the exception is a `SyntaxError`.

New in version 3.4.

void **PyErr_SyntaxLocationEx**(const char **filename*, int *lineno*, int *col_offset*)
Like *PyErr_SyntaxLocationObject()*, but *filename* is a byte string decoded from the filesystem encoding (`os.fsdecode()`).

New in version 3.2.

void **PyErr_SyntaxLocation**(const char **filename*, int *lineno*)
Like *PyErr_SyntaxLocationEx()*, but the col_offset parameter is omitted.

void **PyErr_BadInternalCall**()
This is a shorthand for `PyErr_SetString(PyExc_SystemError, message)`, where *message* indicates that an internal operation (e.g. a Python/C API function) was invoked with an illegal argument. It is mostly for internal use.

5.3 Issuing warnings

Use these functions to issue warnings from C code. They mirror similar functions exported by the Python `warnings` module. They normally print a warning message to *sys.stderr*; however, it is also possible that the user has specified that warnings are to be turned into errors, and in that case they will raise an exception. It is also possible that the functions raise an exception because of a problem with the warning machinery. The return value is `0` if no exception is raised, or `-1` if an exception is raised. (It is not possible to determine whether a warning message is actually printed, nor what the reason is for the exception; this is intentional.) If an exception is raised, the caller should do its normal exception handling (for example, *Py_DECREF()* owned references and return an error value).

int **PyErr_WarnEx**(*PyObject* **category*, const char **message*, Py_ssize_t *stack_level*)
Issue a warning message. The *category* argument is a warning category (see below) or *NULL*; the *message* argument is a UTF-8 encoded string. *stack_level* is a positive number giving a number of stack frames; the warning will be issued from the currently executing line of code in that stack frame. A *stack_level* of 1 is the function calling *PyErr_WarnEx()*, 2 is the function above that, and so forth.

Warning categories must be subclasses of `PyExc_Warning`; `PyExc_Warning` is a subclass of `PyExc_Exception`; the default warning category is `PyExc_RuntimeWarning`. The standard Python warning categories are available as global variables whose names are enumerated at *Standard Warning Categories*.

For information about warning control, see the documentation for the `warnings` module and the `-W` option in the command line documentation. There is no C API for warning control.

*PyObject** **PyErr_SetImportErrorSubclass**(*PyObject* **msg*, *PyObject* **name*, *PyObject* **path*)
Much like *PyErr_SetImportError()* but this function allows for specifying a subclass of `ImportError` to raise.

New in version 3.6.

int **PyErr_WarnExplicitObject**(*PyObject* **category*, *PyObject* **message*, *PyObject* **filename*, int *lineno*, *PyObject* **module*, *PyObject* **registry*)
Issue a warning message with explicit control over all warning attributes. This is a straightforward wrapper around the Python function `warnings.warn_explicit()`, see there for more information. The *module* and *registry* arguments may be set to *NULL* to get the default effect described there.

New in version 3.4.

int **PyErr_WarnExplicit**(*PyObject* **category*, const char **message*, const char **filename*, int *lineno*, const char **module*, *PyObject* **registry*)
Similar to *PyErr_WarnExplicitObject()* except that *message* and *module* are UTF-8 encoded strings, and *filename* is decoded from the filesystem encoding (`os.fsdecode()`).

int **PyErr_WarnFormat**(*PyObject* **category*, Py_ssize_t *stack_level*, const char **format*, ...)
Function similar to *PyErr_WarnEx()*, but use *PyUnicode_FromFormat()* to format the warning message. *format* is an ASCII-encoded string.

New in version 3.2.

int **PyErr_ResourceWarning**(*PyObject* *source*, Py_ssize_t *stack_level*, const char *format*, ...)
Function similar to *PyErr_WarnFormat()*, but *category* is `ResourceWarning` and pass *source* to `warnings.WarningMessage()`.

New in version 3.6.

5.4 Querying the error indicator

*PyObject** **PyErr_Occurred**()
Return value: Borrowed reference. Test whether the error indicator is set. If set, return the exception *type* (the first argument to the last call to one of the `PyErr_Set*()` functions or to *PyErr_Restore()*). If not set, return *NULL*. You do not own a reference to the return value, so you do not need to *Py_DECREF()* it.

Note: Do not compare the return value to a specific exception; use *PyErr_ExceptionMatches()* instead, shown below. (The comparison could easily fail since the exception may be an instance instead of a class, in the case of a class exception, or it may be a subclass of the expected exception.)

---

int **PyErr_ExceptionMatches**(*PyObject* *exc*)
Equivalent to `PyErr_GivenExceptionMatches(PyErr_Occurred(), exc)`. This should only be called when an exception is actually set; a memory access violation will occur if no exception has been raised.

int **PyErr_GivenExceptionMatches**(*PyObject* *given*, *PyObject* *exc*)
Return true if the *given* exception matches the exception type in *exc*. If *exc* is a class object, this also returns true when *given* is an instance of a subclass. If *exc* is a tuple, all exception types in the tuple (and recursively in subtuples) are searched for a match.

void **PyErr_Fetch**(*PyObject* **ptype*, *PyObject* **pvalue*, *PyObject* **ptraceback*)
Retrieve the error indicator into three variables whose addresses are passed. If the error indicator is not set, set all three variables to *NULL*. If it is set, it will be cleared and you own a reference to each object retrieved. The value and traceback object may be *NULL* even when the type object is not.

Note: This function is normally only used by code that needs to catch exceptions or by code that needs to save and restore the error indicator temporarily, e.g.:

```
{
   PyObject *type, *value, *traceback;
   PyErr_Fetch(&type, &value, &traceback);

   /* ... code that might produce other errors ... */

   PyErr_Restore(type, value, traceback);
}
```

---

void **PyErr_Restore**(*PyObject* *type*, *PyObject* *value*, *PyObject* *traceback*)
Set the error indicator from the three objects. If the error indicator is already set, it is cleared first. If the objects are *NULL*, the error indicator is cleared. Do not pass a *NULL* type and non-*NULL* value or traceback. The exception type should be a class. Do not pass an invalid exception type or value. (Violating these rules will cause subtle problems later.) This call takes away a reference to each object: you must own a reference to each object before the call and after the call you no longer own these references. (If you don't understand this, don't use this function. I warned you.)

Note: This function is normally only used by code that needs to save and restore the error indicator temporarily. Use *PyErr_Fetch()* to save the current error indicator.

void **PyErr_NormalizeException**(*PyObject***exc, *PyObject***val, *PyObject***tb)
Under certain circumstances, the values returned by *PyErr_Fetch()* below can be "unnormalized", meaning that `*exc` is a class object but `*val` is not an instance of the same class. This function can be used to instantiate the class in that case. If the values are already normalized, nothing happens. The delayed normalization is implemented to improve performance.

Note: This function *does not* implicitly set the `__traceback__` attribute on the exception value. If setting the traceback appropriately is desired, the following additional snippet is needed:

```
if (tb != NULL) {
  PyException_SetTraceback(val, tb);
}
```

void **PyErr_GetExcInfo**(*PyObject* ***ptype*, *PyObject* ***pvalue*, *PyObject* ***ptraceback*)
Retrieve the exception info, as known from `sys.exc_info()`. This refers to an exception that was *already caught*, not to an exception that was freshly raised. Returns new references for the three objects, any of which may be *NULL*. Does not modify the exception info state.

Note: This function is not normally used by code that wants to handle exceptions. Rather, it can be used when code needs to save and restore the exception state temporarily. Use *PyErr_SetExcInfo()* to restore or clear the exception state.

New in version 3.3.

void **PyErr_SetExcInfo**(*PyObject* **type*, *PyObject* **value*, *PyObject* **traceback*)
Set the exception info, as known from `sys.exc_info()`. This refers to an exception that was *already caught*, not to an exception that was freshly raised. This function steals the references of the arguments. To clear the exception state, pass *NULL* for all three arguments. For general rules about the three arguments, see *PyErr_Restore()*.

Note: This function is not normally used by code that wants to handle exceptions. Rather, it can be used when code needs to save and restore the exception state temporarily. Use *PyErr_GetExcInfo()* to read the exception state.

New in version 3.3.

5.5 Signal Handling

int **PyErr_CheckSignals**()
This function interacts with Python's signal handling. It checks whether a signal has been sent to the processes and if so, invokes the corresponding signal handler. If the `signal` module is supported, this can invoke a signal handler written in Python. In all cases, the default effect for `SIGINT` is to raise the `KeyboardInterrupt` exception. If an exception is raised the error indicator is set and the function returns `-1`; otherwise the function returns `0`. The error indicator may or may not be cleared if it was previously set.

void **PyErr_SetInterrupt**()
This function simulates the effect of a SIGINT signal arriving — the next time *PyErr_CheckSignals()* is called, KeyboardInterrupt will be raised. It may be called without holding the interpreter lock.

int **PySignal_SetWakeupFd**(int *fd*)
This utility function specifies a file descriptor to which the signal number is written as a single byte whenever a signal is received. *fd* must be non-blocking. It returns the previous such file descriptor.

The value -1 disables the feature; this is the initial state. This is equivalent to signal.set_wakeup_fd() in Python, but without any error checking. *fd* should be a valid file descriptor. The function should only be called from the main thread.

Changed in version 3.5: On Windows, the function now also supports socket handles.

5.6 Exception Classes

*PyObject** **PyErr_NewException**(const char **name*, *PyObject* **base*, *PyObject* **dict*)
Return value: New reference. This utility function creates and returns a new exception class. The *name* argument must be the name of the new exception, a C string of the form module.classname. The *base* and *dict* arguments are normally *NULL*. This creates a class object derived from Exception (accessible in C as PyExc_Exception).

The __module__ attribute of the new class is set to the first part (up to the last dot) of the *name* argument, and the class name is set to the last part (after the last dot). The *base* argument can be used to specify alternate base classes; it can either be only one class or a tuple of classes. The *dict* argument can be used to specify a dictionary of class variables and methods.

*PyObject** **PyErr_NewExceptionWithDoc**(const char **name*, const char **doc*, *PyObject* **base*, *PyObject* **dict*)
Return value: New reference. Same as *PyErr_NewException()*, except that the new exception class can easily be given a docstring: If *doc* is non-*NULL*, it will be used as the docstring for the exception class.

New in version 3.2.

5.7 Exception Objects

*PyObject** **PyException_GetTraceback**(*PyObject* **ex*)
Return value: New reference. Return the traceback associated with the exception as a new reference, as accessible from Python through __traceback__. If there is no traceback associated, this returns *NULL*.

int **PyException_SetTraceback**(*PyObject* **ex*, *PyObject* **tb*)
Set the traceback associated with the exception to *tb*. Use Py_None to clear it.

*PyObject** **PyException_GetContext**(*PyObject* **ex*)
Return the context (another exception instance during whose handling *ex* was raised) associated with the exception as a new reference, as accessible from Python through __context__. If there is no context associated, this returns *NULL*.

void **PyException_SetContext**(*PyObject* **ex*, *PyObject* **ctx*)
Set the context associated with the exception to *ctx*. Use *NULL* to clear it. There is no type check to make sure that *ctx* is an exception instance. This steals a reference to *ctx*.

*PyObject** **PyException_GetCause**(*PyObject* **ex*)
Return the cause (either an exception instance, or None, set by raise ... from ...) associated with the exception as a new reference, as accessible from Python through __cause__.

void **PyException_SetCause**(*PyObject* *ex, *PyObject* *cause)
Set the cause associated with the exception to *cause*. Use *NULL* to clear it. There is no type check to make sure that *cause* is either an exception instance or `None`. This steals a reference to *cause*.

`__suppress_context__` is implicitly set to `True` by this function.

5.8 Unicode Exception Objects

The following functions are used to create and modify Unicode exceptions from C.

*PyObject** **PyUnicodeDecodeError_Create**(const char *encoding, const char *object, Py_ssize_t *length*, Py_ssize_t *start*, Py_ssize_t *end*, const char *reason*)
Create a `UnicodeDecodeError` object with the attributes *encoding*, *object*, *length*, *start*, *end* and *reason*. *encoding* and *reason* are UTF-8 encoded strings.

*PyObject** **PyUnicodeEncodeError_Create**(const char *encoding, const *Py_UNICODE* *object, Py_ssize_t *length*, Py_ssize_t *start*, Py_ssize_t *end*, const char *reason*)
Create a `UnicodeEncodeError` object with the attributes *encoding*, *object*, *length*, *start*, *end* and *reason*. *encoding* and *reason* are UTF-8 encoded strings.

*PyObject** **PyUnicodeTranslateError_Create**(const *Py_UNICODE* *object, Py_ssize_t *length*, Py_ssize_t *start*, Py_ssize_t *end*, const char *reason*)
Create a `UnicodeTranslateError` object with the attributes *object*, *length*, *start*, *end* and *reason*. *reason* is a UTF-8 encoded string.

*PyObject** **PyUnicodeDecodeError_GetEncoding**(*PyObject* *exc)
*PyObject** **PyUnicodeEncodeError_GetEncoding**(*PyObject* *exc)
Return the *encoding* attribute of the given exception object.

*PyObject** **PyUnicodeDecodeError_GetObject**(*PyObject* *exc)
*PyObject** **PyUnicodeEncodeError_GetObject**(*PyObject* *exc)
*PyObject** **PyUnicodeTranslateError_GetObject**(*PyObject* *exc)
Return the *object* attribute of the given exception object.

int **PyUnicodeDecodeError_GetStart**(*PyObject* *exc, Py_ssize_t *start)
int **PyUnicodeEncodeError_GetStart**(*PyObject* *exc, Py_ssize_t *start)
int **PyUnicodeTranslateError_GetStart**(*PyObject* *exc, Py_ssize_t *start)
Get the *start* attribute of the given exception object and place it into *start. *start* must not be *NULL*. Return `0` on success, `-1` on failure.

int **PyUnicodeDecodeError_SetStart**(*PyObject* *exc, Py_ssize_t *start*)
int **PyUnicodeEncodeError_SetStart**(*PyObject* *exc, Py_ssize_t *start*)
int **PyUnicodeTranslateError_SetStart**(*PyObject* *exc, Py_ssize_t *start*)
Set the *start* attribute of the given exception object to *start*. Return `0` on success, `-1` on failure.

int **PyUnicodeDecodeError_GetEnd**(*PyObject* *exc, Py_ssize_t *end)
int **PyUnicodeEncodeError_GetEnd**(*PyObject* *exc, Py_ssize_t *end)
int **PyUnicodeTranslateError_GetEnd**(*PyObject* *exc, Py_ssize_t *end)
Get the *end* attribute of the given exception object and place it into *end. *end* must not be *NULL*. Return `0` on success, `-1` on failure.

int **PyUnicodeDecodeError_SetEnd**(*PyObject* *exc, Py_ssize_t *end*)
int **PyUnicodeEncodeError_SetEnd**(*PyObject* *exc, Py_ssize_t *end*)
int **PyUnicodeTranslateError_SetEnd**(*PyObject* *exc, Py_ssize_t *end*)
Set the *end* attribute of the given exception object to *end*. Return `0` on success, `-1` on failure.

*PyObject** **PyUnicodeDecodeError_GetReason**(*PyObject* *exc)

*PyObject** **PyUnicodeEncodeError_GetReason**(*PyObject* *exc)
*PyObject** **PyUnicodeTranslateError_GetReason**(*PyObject* *exc)
Return the *reason* attribute of the given exception object.

int **PyUnicodeDecodeError_SetReason**(*PyObject* *exc, const char *reason)
int **PyUnicodeEncodeError_SetReason**(*PyObject* *exc, const char *reason)
int **PyUnicodeTranslateError_SetReason**(*PyObject* *exc, const char *reason)
Set the *reason* attribute of the given exception object to *reason*. Return `0` on success, `-1` on failure.

5.9 Recursion Control

These two functions provide a way to perform safe recursive calls at the C level, both in the core and in extension modules. They are needed if the recursive code does not necessarily invoke Python code (which tracks its recursion depth automatically).

int **Py_EnterRecursiveCall**(const char *where)
Marks a point where a recursive C-level call is about to be performed.

If `USE_STACKCHECK` is defined, this function checks if the OS stack overflowed using *PyOS_CheckStack()*. In this is the case, it sets a `MemoryError` and returns a nonzero value.

The function then checks if the recursion limit is reached. If this is the case, a `RecursionError` is set and a nonzero value is returned. Otherwise, zero is returned.

where should be a string such as `" in instance check"` to be concatenated to the `RecursionError` message caused by the recursion depth limit.

void **Py_LeaveRecursiveCall**()
Ends a *Py_EnterRecursiveCall()*. Must be called once for each *successful* invocation of *Py_EnterRecursiveCall()*.

Properly implementing *tp_repr* for container types requires special recursion handling. In addition to protecting the stack, *tp_repr* also needs to track objects to prevent cycles. The following two functions facilitate this functionality. Effectively, these are the C equivalent to `reprlib.recursive_repr()`.

int **Py_ReprEnter**(*PyObject* *object)
Called at the beginning of the *tp_repr* implementation to detect cycles.

If the object has already been processed, the function returns a positive integer. In that case the *tp_repr* implementation should return a string object indicating a cycle. As examples, `dict` objects return `{...}` and `list` objects return `[...]`.

The function will return a negative integer if the recursion limit is reached. In that case the *tp_repr* implementation should typically return `NULL`.

Otherwise, the function returns zero and the *tp_repr* implementation can continue normally.

void **Py_ReprLeave**(*PyObject* *object)
Ends a *Py_ReprEnter()*. Must be called once for each invocation of *Py_ReprEnter()* that returns zero.

5.10 Standard Exceptions

All standard Python exceptions are available as global variables whose names are `PyExc_` followed by the Python exception name. These have the type *PyObject**; they are all class objects. For completeness, here are all the variables:

C Name	Python Name	Notes
PyExc_BaseException	BaseException	(1)
PyExc_Exception	Exception	(1)
PyExc_ArithmeticError	ArithmeticError	(1)
PyExc_AssertionError	AssertionError	
PyExc_AttributeError	AttributeError	
PyExc_BlockingIOError	BlockingIOError	
PyExc_BrokenPipeError	BrokenPipeError	
PyExc_BufferError	BufferError	
PyExc_ChildProcessError	ChildProcessError	
PyExc_ConnectionAbortedError	ConnectionAbortedError	
PyExc_ConnectionError	ConnectionError	
PyExc_ConnectionRefusedError	ConnectionRefusedError	
PyExc_ConnectionResetError	ConnectionResetError	
PyExc_EOFError	EOFError	
PyExc_FileExistsError	FileExistsError	
PyExc_FileNotFoundError	FileNotFoundError	
PyExc_FloatingPointError	FloatingPointError	
PyExc_GeneratorExit	GeneratorExit	
PyExc_ImportError	ImportError	
PyExc_IndentationError	IndentationError	
PyExc_IndexError	IndexError	
PyExc_InterruptedError	InterruptedError	
PyExc_IsADirectoryError	IsADirectoryError	
PyExc_KeyError	KeyError	
PyExc_KeyboardInterrupt	KeyboardInterrupt	
PyExc_LookupError	LookupError	(1)
PyExc_MemoryError	MemoryError	
PyExc_ModuleNotFoundError	ModuleNotFoundError	
PyExc_NameError	NameError	
PyExc_NotADirectoryError	NotADirectoryError	
PyExc_NotImplementedError	NotImplementedError	
PyExc_OSError	OSError	(1)
PyExc_OverflowError	OverflowError	
PyExc_PermissionError	PermissionError	
PyExc_ProcessLookupError	ProcessLookupError	
PyExc_RecursionError	RecursionError	
PyExc_ReferenceError	ReferenceError	(2)
PyExc_RuntimeError	RuntimeError	
PyExc_StopAsyncIteration	StopAsyncIteration	
PyExc_StopIteration	StopIteration	
PyExc_SyntaxError	SyntaxError	
PyExc_SystemError	SystemError	
PyExc_SystemExit	SystemExit	
PyExc_TabError	TabError	
PyExc_TimeoutError	TimeoutError	
PyExc_TypeError	TypeError	
PyExc_UnboundLocalError	UnboundLocalError	
PyExc_UnicodeDecodeError	UnicodeDecodeError	
PyExc_UnicodeEncodeError	UnicodeEncodeError	
PyExc_UnicodeError	UnicodeError	

Continued on next page

Table 1 – continued from previous page

C Name	Python Name	Notes
PyExc_UnicodeTranslateError	UnicodeTranslateError	
PyExc_ValueError	ValueError	
PyExc_ZeroDivisionError	ZeroDivisionError	

New in version 3.3: PyExc_BlockingIOError, PyExc_BrokenPipeError, PyExc_ChildProcessError, PyExc_ConnectionError, PyExc_ConnectionAbortedError, PyExc_ConnectionRefusedError, PyExc_ConnectionResetError, PyExc_FileExistsError, PyExc_FileNotFoundError, PyExc_InterruptedError, PyExc_IsADirectoryError, PyExc_NotADirectoryError, PyExc_PermissionError, PyExc_ProcessLookupError and PyExc_TimeoutError were introduced following **PEP 3151**.

New in version 3.5: PyExc_StopAsyncIteration and PyExc_RecursionError.

New in version 3.6: PyExc_ModuleNotFoundError.

These are compatibility aliases to PyExc_OSError:

C Name	Notes
PyExc_EnvironmentError	
PyExc_IOError	
PyExc_WindowsError	(3)

Changed in version 3.3: These aliases used to be separate exception types.

Notes:

1. This is a base class for other standard exceptions.
2. This is the same as weakref.ReferenceError.
3. Only defined on Windows; protect code that uses this by testing that the preprocessor macro MS_WINDOWS is defined.

5.11 Standard Warning Categories

All standard Python warning categories are available as global variables whose names are PyExc_ followed by the Python exception name. These have the type *PyObject**; they are all class objects. For completeness, here are all the variables:

C Name	Python Name	Notes
PyExc_Warning	Warning	(1)
PyExc_BytesWarning	BytesWarning	
PyExc_DeprecationWarning	DeprecationWarning	
PyExc_FutureWarning	FutureWarning	
PyExc_ImportWarning	ImportWarning	
PyExc_PendingDeprecationWarning	PendingDeprecationWarning	
PyExc_ResourceWarning	ResourceWarning	
PyExc_RuntimeWarning	RuntimeWarning	
PyExc_SyntaxWarning	SyntaxWarning	
PyExc_UnicodeWarning	UnicodeWarning	
PyExc_UserWarning	UserWarning	

New in version 3.2: PyExc_ResourceWarning.

Notes:

1. This is a base class for other standard warning categories.

CHAPTER

SIX

UTILITIES

The functions in this chapter perform various utility tasks, ranging from helping C code be more portable across platforms, using Python modules from C, and parsing function arguments and constructing Python values from C values.

6.1 Operating System Utilities

*PyObject** **PyOS_FSPath**(*PyObject* *path)
Return value: New reference. Return the file system representation for *path*. If the object is a `str` or `bytes` object, then its reference count is incremented. If the object implements the `os.PathLike` interface, then `__fspath__()` is returned as long as it is a `str` or `bytes` object. Otherwise `TypeError` is raised and `NULL` is returned.

New in version 3.6.

int **Py_FdIsInteractive**(FILE *fp, const char *filename)
Return true (nonzero) if the standard I/O file *fp* with name *filename* is deemed interactive. This is the case for files for which `isatty(fileno(fp))` is true. If the global flag *Py_InteractiveFlag* is true, this function also returns true if the *filename* pointer is *NULL* or if the name is equal to one of the strings `'<stdin>'` or `'???'`.

void **PyOS_BeforeFork**()
Function to prepare some internal state before a process fork. This should be called before calling `fork()` or any similar function that clones the current process. Only available on systems where `fork()` is defined.

New in version 3.7.

void **PyOS_AfterFork_Parent**()
Function to update some internal state after a process fork. This should be called from the parent process after calling `fork()` or any similar function that clones the current process, regardless of whether process cloning was successful. Only available on systems where `fork()` is defined.

New in version 3.7.

void **PyOS_AfterFork_Child**()
Function to update internal interpreter state after a process fork. This must be called from the child process after calling `fork()`, or any similar function that clones the current process, if there is any chance the process will call back into the Python interpreter. Only available on systems where `fork()` is defined.

New in version 3.7.

See also:

`os.register_at_fork()` allows registering custom Python functions to be called by *PyOS_BeforeFork()*, *PyOS_AfterFork_Parent()* and *PyOS_AfterFork_Child()*.

void **PyOS_AfterFork()**
Function to update some internal state after a process fork; this should be called in the new process if the Python interpreter will continue to be used. If a new executable is loaded into the new process, this function does not need to be called.

Deprecated since version 3.7: This function is superseded by *PyOS_AfterFork_Child()*.

int **PyOS_CheckStack()**
Return true when the interpreter runs out of stack space. This is a reliable check, but is only available when `USE_STACKCHECK` is defined (currently on Windows using the Microsoft Visual C++ compiler). `USE_STACKCHECK` will be defined automatically; you should never change the definition in your own code.

PyOS_sighandler_t **PyOS_getsig**(int *i*)
Return the current signal handler for signal *i*. This is a thin wrapper around either `sigaction()` or `signal()`. Do not call those functions directly! `PyOS_sighandler_t` is a typedef alias for `void (*)(int)`.

PyOS_sighandler_t **PyOS_setsig**(int *i*, PyOS_sighandler_t *h*)
Set the signal handler for signal *i* to be *h*; return the old signal handler. This is a thin wrapper around either `sigaction()` or `signal()`. Do not call those functions directly! `PyOS_sighandler_t` is a typedef alias for `void (*)(int)`.

wchar_t* **Py_DecodeLocale**(const char* *arg*, size_t **size*)
Decode a byte string from the locale encoding with the surrogateescape error handler: undecodable bytes are decoded as characters in range U+DC80..U+DCFF. If a byte sequence can be decoded as a surrogate character, escape the bytes using the surrogateescape error handler instead of decoding them.

Encoding, highest priority to lowest priority:

- `UTF-8` on macOS and Android;
- `UTF-8` if the Python UTF-8 mode is enabled;
- `ASCII` if the `LC_CTYPE` locale is `"C"`, `nl_langinfo(CODESET)` returns the `ASCII` encoding (or an alias), and `mbstowcs()` and `wcstombs()` functions uses the `ISO-8859-1` encoding.
- the current locale encoding.

Return a pointer to a newly allocated wide character string, use *PyMem_RawFree()* to free the memory. If size is not `NULL`, write the number of wide characters excluding the null character into `*size`

Return `NULL` on decoding error or memory allocation error. If *size* is not `NULL`, `*size` is set to `(size_t)-1` on memory error or set to `(size_t)-2` on decoding error.

Decoding errors should never happen, unless there is a bug in the C library.

Use the *Py_EncodeLocale()* function to encode the character string back to a byte string.

See also:

The *PyUnicode_DecodeFSDefaultAndSize()* and *PyUnicode_DecodeLocaleAndSize()* functions.

New in version 3.5.

Changed in version 3.7: The function now uses the UTF-8 encoding in the UTF-8 mode.

char* **Py_EncodeLocale**(const wchar_t **text*, size_t **error_pos*)
Encode a wide character string to the locale encoding with the surrogateescape error handler: surrogate characters in the range U+DC80..U+DCFF are converted to bytes 0x80..0xFF.

Encoding, highest priority to lowest priority:

- `UTF-8` on macOS and Android;
- `UTF-8` if the Python UTF-8 mode is enabled;

- `ASCII` if the `LC_CTYPE` locale is `"C"`, `nl_langinfo(CODESET)` returns the `ASCII` encoding (or an alias), and `mbstowcs()` and `wcstombs()` functions uses the `ISO-8859-1` encoding.
- the current locale encoding.

The function uses the UTF-8 encoding in the Python UTF-8 mode.

Return a pointer to a newly allocated byte string, use *PyMem_Free()* to free the memory. Return `NULL` on encoding error or memory allocation error

If error_pos is not `NULL`, `*error_pos` is set to `(size_t)-1` on success, or set to the index of the invalid character on encoding error.

Use the *Py_DecodeLocale()* function to decode the bytes string back to a wide character string.

Changed in version 3.7: The function now uses the UTF-8 encoding in the UTF-8 mode.

See also:

The *PyUnicode_EncodeFSDefault()* and *PyUnicode_EncodeLocale()* functions.

New in version 3.5.

Changed in version 3.7: The function now supports the UTF-8 mode.

6.2 System Functions

These are utility functions that make functionality from the `sys` module accessible to C code. They all work with the current interpreter thread's `sys` module's dict, which is contained in the internal thread state structure.

PyObject ***PySys_GetObject**(const char **name*)
Return value: Borrowed reference. Return the object *name* from the `sys` module or *NULL* if it does not exist, without setting an exception.

int **PySys_SetObject**(const char **name*, *PyObject* **v*)
Set *name* in the `sys` module to *v* unless *v* is *NULL*, in which case *name* is deleted from the sys module. Returns `0` on success, `-1` on error.

void **PySys_ResetWarnOptions**()
Reset `sys.warnoptions` to an empty list. This function may be called prior to *Py_Initialize()*.

void **PySys_AddWarnOption**(const wchar_t **s*)
Append *s* to `sys.warnoptions`. This function must be called prior to *Py_Initialize()* in order to affect the warnings filter list.

void **PySys_AddWarnOptionUnicode**(*PyObject* **unicode*)
Append *unicode* to `sys.warnoptions`.

Note: this function is not currently usable from outside the CPython implementation, as it must be called prior to the implicit import of `warnings` in *Py_Initialize()* to be effective, but can't be called until enough of the runtime has been initialized to permit the creation of Unicode objects.

void **PySys_SetPath**(const wchar_t **path*)
Set `sys.path` to a list object of paths found in *path* which should be a list of paths separated with the platform's search path delimiter (`:` on Unix, `;` on Windows).

void **PySys_WriteStdout**(const char **format*, ...)
Write the output string described by *format* to `sys.stdout`. No exceptions are raised, even if truncation occurs (see below).

format should limit the total size of the formatted output string to 1000 bytes or less – after 1000 bytes, the output string is truncated. In particular, this means that no unrestricted "%s" formats

should occur; these should be limited using "%.<N>s" where <N> is a decimal number calculated so that <N> plus the maximum size of other formatted text does not exceed 1000 bytes. Also watch out for "%f", which can print hundreds of digits for very large numbers.

If a problem occurs, or `sys.stdout` is unset, the formatted message is written to the real (C level) *stdout*.

void **PySys_WriteStderr**(const char **format*, ...)
As *PySys_WriteStdout()*, but write to `sys.stderr` or *stderr* instead.

void **PySys_FormatStdout**(const char **format*, ...)
Function similar to PySys_WriteStdout() but format the message using *PyUnicode_FromFormatV()* and don't truncate the message to an arbitrary length.

New in version 3.2.

void **PySys_FormatStderr**(const char **format*, ...)
As *PySys_FormatStdout()*, but write to `sys.stderr` or *stderr* instead.

New in version 3.2.

void **PySys_AddXOption**(const wchar_t **s*)
Parse *s* as a set of `-X` options and add them to the current options mapping as returned by *PySys_GetXOptions()*. This function may be called prior to *Py_Initialize()*.

New in version 3.2.

PyObject ***PySys_GetXOptions**()
Return value: Borrowed reference. Return the current dictionary of `-X` options, similarly to `sys._xoptions`. On error, *NULL* is returned and an exception is set.

New in version 3.2.

6.3 Process Control

void **Py_FatalError**(const char **message*)
Print a fatal error message and kill the process. No cleanup is performed. This function should only be invoked when a condition is detected that would make it dangerous to continue using the Python interpreter; e.g., when the object administration appears to be corrupted. On Unix, the standard C library function `abort()` is called which will attempt to produce a `core` file.

void **Py_Exit**(int *status*)
Exit the current process. This calls *Py_FinalizeEx()* and then calls the standard C library function `exit(status)`. If *Py_FinalizeEx()* indicates an error, the exit status is set to 120.

Changed in version 3.6: Errors from finalization no longer ignored.

int **Py_AtExit**(void (**func*)())
Register a cleanup function to be called by *Py_FinalizeEx()*. The cleanup function will be called with no arguments and should return no value. At most 32 cleanup functions can be registered. When the registration is successful, *Py_AtExit()* returns `0`; on failure, it returns `-1`. The cleanup function registered last is called first. Each cleanup function will be called at most once. Since Python's internal finalization will have completed before the cleanup function, no Python APIs should be called by *func*.

6.4 Importing Modules

*PyObject** **PyImport_ImportModule**(const char **name*)
Return value: New reference. This is a simplified interface to *PyImport_ImportModuleEx()* below,

leaving the *globals* and *locals* arguments set to *NULL* and *level* set to 0. When the *name* argument contains a dot (when it specifies a submodule of a package), the *fromlist* argument is set to the list `['*']` so that the return value is the named module rather than the top-level package containing it as would otherwise be the case. (Unfortunately, this has an additional side effect when *name* in fact specifies a subpackage instead of a submodule: the submodules specified in the package's `__all__` variable are loaded.) Return a new reference to the imported module, or *NULL* with an exception set on failure. A failing import of a module doesn't leave the module in `sys.modules`.

This function always uses absolute imports.

*PyObject** **PyImport_ImportModuleNoBlock**(const char **name*)
This function is a deprecated alias of *PyImport_ImportModule()*.

Changed in version 3.3: This function used to fail immediately when the import lock was held by another thread. In Python 3.3 though, the locking scheme switched to per-module locks for most purposes, so this function's special behaviour isn't needed anymore.

*PyObject** **PyImport_ImportModuleEx**(const char **name*, *PyObject* **globals*, *PyObject* **locals*, *PyObject* **fromlist*)
Return value: New reference. Import a module. This is best described by referring to the built-in Python function `__import__()`.

The return value is a new reference to the imported module or top-level package, or *NULL* with an exception set on failure. Like for `__import__()`, the return value when a submodule of a package was requested is normally the top-level package, unless a non-empty *fromlist* was given.

Failing imports remove incomplete module objects, like with *PyImport_ImportModule()*.

*PyObject** **PyImport_ImportModuleLevelObject**(*PyObject* **name*, *PyObject* **globals*, *PyObject* **locals*, *PyObject* **fromlist*, int *level*)
Import a module. This is best described by referring to the built-in Python function `__import__()`, as the standard `__import__()` function calls this function directly.

The return value is a new reference to the imported module or top-level package, or *NULL* with an exception set on failure. Like for `__import__()`, the return value when a submodule of a package was requested is normally the top-level package, unless a non-empty *fromlist* was given.

New in version 3.3.

*PyObject** **PyImport_ImportModuleLevel**(const char **name*, *PyObject* **globals*, *PyObject* **locals*, *PyObject* **fromlist*, int *level*)
Return value: New reference. Similar to *PyImport_ImportModuleLevelObject()*, but the name is a UTF-8 encoded string instead of a Unicode object.

Changed in version 3.3: Negative values for *level* are no longer accepted.

*PyObject** **PyImport_Import**(*PyObject* **name*)
Return value: New reference. This is a higher-level interface that calls the current "import hook function" (with an explicit *level* of 0, meaning absolute import). It invokes the `__import__()` function from the `__builtins__` of the current globals. This means that the import is done using whatever import hooks are installed in the current environment.

This function always uses absolute imports.

*PyObject** **PyImport_ReloadModule**(*PyObject* **m*)
Return value: New reference. Reload a module. Return a new reference to the reloaded module, or *NULL* with an exception set on failure (the module still exists in this case).

*PyObject** **PyImport_AddModuleObject**(*PyObject* **name*)
Return the module object corresponding to a module name. The *name* argument may be of the form `package.module`. First check the modules dictionary if there's one there, and if not, create a new one and insert it in the modules dictionary. Return *NULL* with an exception set on failure.

Note: This function does not load or import the module; if the module wasn't already loaded, you will get an empty module object. Use *PyImport_ImportModule()* or one of its variants to import a module. Package structures implied by a dotted name for *name* are not created if not already present.

New in version 3.3.

*PyObject** **PyImport_AddModule**(const char **name*)
Return value: Borrowed reference. Similar to *PyImport_AddModuleObject()*, but the name is a UTF-8 encoded string instead of a Unicode object.

*PyObject** **PyImport_ExecCodeModule**(const char **name*, *PyObject* **co*)
Return value: New reference. Given a module name (possibly of the form `package.module`) and a code object read from a Python bytecode file or obtained from the built-in function `compile()`, load the module. Return a new reference to the module object, or *NULL* with an exception set if an error occurred. *name* is removed from `sys.modules` in error cases, even if *name* was already in `sys.modules` on entry to *PyImport_ExecCodeModule()*. Leaving incompletely initialized modules in `sys.modules` is dangerous, as imports of such modules have no way to know that the module object is an unknown (and probably damaged with respect to the module author's intents) state.

The module's `__spec__` and `__loader__` will be set, if not set already, with the appropriate values. The spec's loader will be set to the module's `__loader__` (if set) and to an instance of `SourceFileLoader` otherwise.

The module's `__file__` attribute will be set to the code object's `co_filename`. If applicable, `__cached__` will also be set.

This function will reload the module if it was already imported. See *PyImport_ReloadModule()* for the intended way to reload a module.

If *name* points to a dotted name of the form `package.module`, any package structures not already created will still not be created.

See also *PyImport_ExecCodeModuleEx()* and *PyImport_ExecCodeModuleWithPathnames()*.

*PyObject** **PyImport_ExecCodeModuleEx**(const char **name*, *PyObject* **co*, const char **pathname*)
Return value: New reference. Like *PyImport_ExecCodeModule()*, but the `__file__` attribute of the module object is set to *pathname* if it is non-`NULL`.

See also *PyImport_ExecCodeModuleWithPathnames()*.

*PyObject** **PyImport_ExecCodeModuleObject**(*PyObject* **name*, *PyObject* **co*, *PyObject* **pathname*, *PyObject* **cpathname*)
Like *PyImport_ExecCodeModuleEx()*, but the `__cached__` attribute of the module object is set to *cpathname* if it is non-`NULL`. Of the three functions, this is the preferred one to use.

New in version 3.3.

*PyObject** **PyImport_ExecCodeModuleWithPathnames**(const char **name*, *PyObject* **co*, const char **pathname*, const char **cpathname*)
Like *PyImport_ExecCodeModuleObject()*, but *name*, *pathname* and *cpathname* are UTF-8 encoded strings. Attempts are also made to figure out what the value for *pathname* should be from *cpathname* if the former is set to `NULL`.

New in version 3.2.

Changed in version 3.3: Uses `imp.source_from_cache()` in calculating the source path if only the bytecode path is provided.

long **PyImport_GetMagicNumber**()
Return the magic number for Python bytecode files (a.k.a. `.pyc` file). The magic number should be present in the first four bytes of the bytecode file, in little-endian byte order. Returns `-1` on error.

Changed in version 3.3: Return value of `-1` upon failure.

const char * **PyImport_GetMagicTag**()
Return the magic tag string for **PEP 3147** format Python bytecode file names. Keep in mind that the value at `sys.implementation.cache_tag` is authoritative and should be used instead of this function.

New in version 3.2.

*PyObject** **PyImport_GetModuleDict**()
Return value: Borrowed reference. Return the dictionary used for the module administration (a.k.a. `sys.modules`). Note that this is a per-interpreter variable.

*PyObject** **PyImport_GetModule**(*PyObject *name*)
Return value: New reference. Return the already imported module with the given name. If the module has not been imported yet then returns NULL but does not set an error. Returns NULL and sets an error if the lookup failed.

New in version 3.7.

*PyObject** **PyImport_GetImporter**(*PyObject *path*)
Return a finder object for a `sys.path`/`pkg.__path__` item *path*, possibly by fetching it from the `sys.path_importer_cache` dict. If it wasn't yet cached, traverse `sys.path_hooks` until a hook is found that can handle the path item. Return `None` if no hook could; this tells our caller that the *path based finder* could not find a finder for this path item. Cache the result in `sys.path_importer_cache`. Return a new reference to the finder object.

void **_PyImport_Init**()
Initialize the import mechanism. For internal use only.

void **PyImport_Cleanup**()
Empty the module table. For internal use only.

void **_PyImport_Fini**()
Finalize the import mechanism. For internal use only.

int **PyImport_ImportFrozenModuleObject**(*PyObject *name*)
Load a frozen module named *name*. Return `1` for success, `0` if the module is not found, and `-1` with an exception set if the initialization failed. To access the imported module on a successful load, use *PyImport_ImportModule()*. (Note the misnomer — this function would reload the module if it was already imported.)

New in version 3.3.

Changed in version 3.4: The `__file__` attribute is no longer set on the module.

int **PyImport_ImportFrozenModule**(const char *name*)
Similar to *PyImport_ImportFrozenModuleObject()*, but the name is a UTF-8 encoded string instead of a Unicode object.

struct **_frozen**
This is the structure type definition for frozen module descriptors, as generated by the **freeze** utility (see `Tools/freeze/` in the Python source distribution). Its definition, found in `Include/import.h`, is:

```
struct _frozen {
    const char *name;
    const unsigned char *code;
    int size;
};
```

const struct *_frozen** **PyImport_FrozenModules**
This pointer is initialized to point to an array of `struct _frozen` records, terminated by one whose

members are all *NULL* or zero. When a frozen module is imported, it is searched in this table. Third-party code could play tricks with this to provide a dynamically created collection of frozen modules.

int **PyImport_AppendInittab**(const char **name*, *PyObject** (**initfunc*)(void))
Add a single module to the existing table of built-in modules. This is a convenience wrapper around *PyImport_ExtendInittab()*, returning `-1` if the table could not be extended. The new module can be imported by the name *name*, and uses the function *initfunc* as the initialization function called on the first attempted import. This should be called before *Py_Initialize()*.

struct **_inittab**
Structure describing a single entry in the list of built-in modules. Each of these structures gives the name and initialization function for a module built into the interpreter. The name is an ASCII encoded string. Programs which embed Python may use an array of these structures in conjunction with *PyImport_ExtendInittab()* to provide additional built-in modules. The structure is defined in `Include/import.h` as:

```
struct _inittab {
    const char *name;           /* ASCII encoded string */
    PyObject* (*initfunc)(void);
};
```

int **PyImport_ExtendInittab**(struct *_inittab* **newtab*)
Add a collection of modules to the table of built-in modules. The *newtab* array must end with a sentinel entry which contains *NULL* for the `name` field; failure to provide the sentinel value can result in a memory fault. Returns `0` on success or `-1` if insufficient memory could be allocated to extend the internal table. In the event of failure, no modules are added to the internal table. This should be called before *Py_Initialize()*.

6.5 Data marshalling support

These routines allow C code to work with serialized objects using the same data format as the `marshal` module. There are functions to write data into the serialization format, and additional functions that can be used to read the data back. Files used to store marshalled data must be opened in binary mode.

Numeric values are stored with the least significant byte first.

The module supports two versions of the data format: version 0 is the historical version, version 1 shares interned strings in the file, and upon unmarshalling. Version 2 uses a binary format for floating point numbers. *Py_MARSHAL_VERSION* indicates the current file format (currently 2).

void **PyMarshal_WriteLongToFile**(long *value*, FILE **file*, int *version*)
Marshal a `long` integer, *value*, to *file*. This will only write the least-significant 32 bits of *value*; regardless of the size of the native `long` type. *version* indicates the file format.

void **PyMarshal_WriteObjectToFile**(*PyObject* **value*, FILE **file*, int *version*)
Marshal a Python object, *value*, to *file*. *version* indicates the file format.

*PyObject** **PyMarshal_WriteObjectToString**(*PyObject* **value*, int *version*)
Return value: New reference. Return a bytes object containing the marshalled representation of *value*. *version* indicates the file format.

The following functions allow marshalled values to be read back in.

XXX What about error detection? It appears that reading past the end of the file will always result in a negative numeric value (where that's relevant), but it's not clear that negative values won't be handled properly when there's no error. What's the right way to tell? Should only non-negative values be written using these routines?

long **PyMarshal_ReadLongFromFile**(FILE **file*)
Return a C `long` from the data stream in a `FILE*` opened for reading. Only a 32-bit value can be read in using this function, regardless of the native size of `long`.

On error, raise an exception and return `-1`.

int **PyMarshal_ReadShortFromFile**(FILE **file*)
Return a C `short` from the data stream in a `FILE*` opened for reading. Only a 16-bit value can be read in using this function, regardless of the native size of `short`.

On error, raise an exception and return `-1`.

*PyObject** **PyMarshal_ReadObjectFromFile**(FILE **file*)
Return value: New reference. Return a Python object from the data stream in a `FILE*` opened for reading.

On error, sets the appropriate exception (`EOFError` or `TypeError`) and returns *NULL*.

*PyObject** **PyMarshal_ReadLastObjectFromFile**(FILE **file*)
Return value: New reference. Return a Python object from the data stream in a `FILE*` opened for reading. Unlike *PyMarshal_ReadObjectFromFile()*, this function assumes that no further objects will be read from the file, allowing it to aggressively load file data into memory so that the de-serialization can operate from data in memory rather than reading a byte at a time from the file. Only use these variant if you are certain that you won't be reading anything else from the file.

On error, sets the appropriate exception (`EOFError` or `TypeError`) and returns *NULL*.

*PyObject** **PyMarshal_ReadObjectFromString**(const char **data*, Py_ssize_t *len*)
Return value: New reference. Return a Python object from the data stream in a byte buffer containing *len* bytes pointed to by *data*.

On error, sets the appropriate exception (`EOFError` or `TypeError`) and returns *NULL*.

6.6 Parsing arguments and building values

These functions are useful when creating your own extensions functions and methods. Additional information and examples are available in extending-index.

The first three of these functions described, *PyArg_ParseTuple()*, *PyArg_ParseTupleAndKeywords()*, and *PyArg_Parse()*, all use *format strings* which are used to tell the function about the expected arguments. The format strings use the same syntax for each of these functions.

6.6.1 Parsing arguments

A format string consists of zero or more "format units." A format unit describes one Python object; it is usually a single character or a parenthesized sequence of format units. With a few exceptions, a format unit that is not a parenthesized sequence normally corresponds to a single address argument to these functions. In the following description, the quoted form is the format unit; the entry in (round) parentheses is the Python object type that matches the format unit; and the entry in [square] brackets is the type of the C variable(s) whose address should be passed.

Strings and buffers

These formats allow accessing an object as a contiguous chunk of memory. You don't have to provide raw storage for the returned unicode or bytes area.

In general, when a format sets a pointer to a buffer, the buffer is managed by the corresponding Python object, and the buffer shares the lifetime of this object. You won't have to release any memory yourself. The only exceptions are `es`, `es#`, `et` and `et#`.

However, when a *Py_buffer* structure gets filled, the underlying buffer is locked so that the caller can subsequently use the buffer even inside a *Py_BEGIN_ALLOW_THREADS* block without the risk of mutable data being resized or destroyed. As a result, **you have to call** *PyBuffer_Release()* after you have finished processing the data (or in any early abort case).

Unless otherwise stated, buffers are not NUL-terminated.

Some formats require a read-only *bytes-like object*, and set a pointer instead of a buffer structure. They work by checking that the object's *PyBufferProcs.bf_releasebuffer* field is *NULL*, which disallows mutable objects such as `bytearray`.

Note: For all `#` variants of formats (`s#`, `y#`, etc.), the type of the length argument (int or `Py_ssize_t`) is controlled by defining the macro `PY_SSIZE_T_CLEAN` before including `Python.h`. If the macro was defined, length is a `Py_ssize_t` rather than an `int`. This behavior will change in a future Python version to only support `Py_ssize_t` and drop `int` support. It is best to always define `PY_SSIZE_T_CLEAN`.

`s` (`str`) [**const char ***] Convert a Unicode object to a C pointer to a character string. A pointer to an existing string is stored in the character pointer variable whose address you pass. The C string is NUL-terminated. The Python string must not contain embedded null code points; if it does, a `ValueError` exception is raised. Unicode objects are converted to C strings using `'utf-8'` encoding. If this conversion fails, a `UnicodeError` is raised.

> **Note:** This format does not accept *bytes-like objects*. If you want to accept filesystem paths and convert them to C character strings, it is preferable to use the `O&` format with *PyUnicode_FSConverter()* as *converter*.

Changed in version 3.5: Previously, `TypeError` was raised when embedded null code points were encountered in the Python string.

`s*` (`str` or *bytes-like object*) [**Py_buffer**] This format accepts Unicode objects as well as bytes-like objects. It fills a *Py_buffer* structure provided by the caller. In this case the resulting C string may contain embedded NUL bytes. Unicode objects are converted to C strings using `'utf-8'` encoding.

`s#` (`str`, read-only *bytes-like object*) [**const char ***, **int** or `Py_ssize_t`] Like `s*`, except that it doesn't accept mutable objects. The result is stored into two C variables, the first one a pointer to a C string, the second one its length. The string may contain embedded null bytes. Unicode objects are converted to C strings using `'utf-8'` encoding.

`z` (`str` or `None`) [**const char ***] Like `s`, but the Python object may also be `None`, in which case the C pointer is set to *NULL*.

`z*` (`str`, *bytes-like object* or `None`) [**Py_buffer**] Like `s*`, but the Python object may also be `None`, in which case the `buf` member of the *Py_buffer* structure is set to *NULL*.

`z#` (`str`, read-only *bytes-like object* or `None`) [**const char ***, **int**] Like `s#`, but the Python object may also be `None`, in which case the C pointer is set to *NULL*.

`y` (read-only *bytes-like object*) [**const char ***] This format converts a bytes-like object to a C pointer to a character string; it does not accept Unicode objects. The bytes buffer must not contain embedded null bytes; if it does, a `ValueError` exception is raised.

Changed in version 3.5: Previously, `TypeError` was raised when embedded null bytes were encountered in the bytes buffer.

`y*` (*bytes-like object*) [**Py_buffer**] This variant on `s*` doesn't accept Unicode objects, only bytes-like objects. **This is the recommended way to accept binary data.**

`y#` (**read-only** *bytes-like object*) [**const char ***, **int**] This variant on `s#` doesn't accept Unicode objects, only bytes-like objects.

`S` (`bytes`) [**PyBytesObject ***] Requires that the Python object is a `bytes` object, without attempting any conversion. Raises `TypeError` if the object is not a bytes object. The C variable may also be declared as *PyObject**.

`Y` (`bytearray`) [**PyByteArrayObject ***] Requires that the Python object is a `bytearray` object, without attempting any conversion. Raises `TypeError` if the object is not a `bytearray` object. The C variable may also be declared as *PyObject**.

`u` (`str`) [**const Py_UNICODE ***] Convert a Python Unicode object to a C pointer to a NUL-terminated buffer of Unicode characters. You must pass the address of a *Py_UNICODE* pointer variable, which will be filled with the pointer to an existing Unicode buffer. Please note that the width of a *Py_UNICODE* character depends on compilation options (it is either 16 or 32 bits). The Python string must not contain embedded null code points; if it does, a `ValueError` exception is raised.

Changed in version 3.5: Previously, `TypeError` was raised when embedded null code points were encountered in the Python string.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsWideCharString()*.

`u#` (`str`) [**const Py_UNICODE ***, **int**] This variant on `u` stores into two C variables, the first one a pointer to a Unicode data buffer, the second one its length. This variant allows null code points.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsWideCharString()*.

`Z` (`str` or `None`) [**const Py_UNICODE ***] Like `u`, but the Python object may also be `None`, in which case the *Py_UNICODE* pointer is set to *NULL*.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsWideCharString()*.

`Z#` (`str` or `None`) [**const Py_UNICODE ***, **int**] Like `u#`, but the Python object may also be `None`, in which case the *Py_UNICODE* pointer is set to *NULL*.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsWideCharString()*.

`U` (`str`) [**PyObject ***] Requires that the Python object is a Unicode object, without attempting any conversion. Raises `TypeError` if the object is not a Unicode object. The C variable may also be declared as *PyObject**.

`w*` (**read-write** *bytes-like object*) [**Py_buffer**] This format accepts any object which implements the read-write buffer interface. It fills a *Py_buffer* structure provided by the caller. The buffer may contain embedded null bytes. The caller have to call *PyBuffer_Release()* when it is done with the buffer.

`es` (`str`) [**const char *encoding, char **buffer**] This variant on `s` is used for encoding Unicode into a character buffer. It only works for encoded data without embedded NUL bytes.

This format requires two arguments. The first is only used as input, and must be a `const char*` which points to the name of an encoding as a NUL-terminated string, or *NULL*, in which case `'utf-8'` encoding is used. An exception is raised if the named encoding is not known to Python. The second argument must be a `char**`; the value of the pointer it references will be set to a buffer with the contents of the argument text. The text will be encoded in the encoding specified by the first argument.

PyArg_ParseTuple() will allocate a buffer of the needed size, copy the encoded data into this buffer and adjust **buffer* to reference the newly allocated storage. The caller is responsible for calling *PyMem_Free()* to free the allocated buffer after use.

et (str, bytes or bytearray) [const char *encoding, char **buffer] Same as `es` except that byte string objects are passed through without recoding them. Instead, the implementation assumes that the byte string object uses the encoding passed in as parameter.

es# (str) [const char *encoding, char **buffer, int *buffer_length] This variant on `s#` is used for encoding Unicode into a character buffer. Unlike the `es` format, this variant allows input data which contains NUL characters.

It requires three arguments. The first is only used as input, and must be a `const char*` which points to the name of an encoding as a NUL-terminated string, or *NULL*, in which case `'utf-8'` encoding is used. An exception is raised if the named encoding is not known to Python. The second argument must be a `char**`; the value of the pointer it references will be set to a buffer with the contents of the argument text. The text will be encoded in the encoding specified by the first argument. The third argument must be a pointer to an integer; the referenced integer will be set to the number of bytes in the output buffer.

There are two modes of operation:

If **buffer* points a *NULL* pointer, the function will allocate a buffer of the needed size, copy the encoded data into this buffer and set **buffer* to reference the newly allocated storage. The caller is responsible for calling *PyMem_Free()* to free the allocated buffer after usage.

If **buffer* points to a non-*NULL* pointer (an already allocated buffer), *PyArg_ParseTuple()* will use this location as the buffer and interpret the initial value of **buffer_length* as the buffer size. It will then copy the encoded data into the buffer and NUL-terminate it. If the buffer is not large enough, a `ValueError` will be set.

In both cases, **buffer_length* is set to the length of the encoded data without the trailing NUL byte.

et# (str, bytes or bytearray) [const char *encoding, char **buffer, int *buffer_length] Same as `es#` except that byte string objects are passed through without recoding them. Instead, the implementation assumes that the byte string object uses the encoding passed in as parameter.

Numbers

b (int) [unsigned char] Convert a nonnegative Python integer to an unsigned tiny int, stored in a C `unsigned char`.

B (int) [unsigned char] Convert a Python integer to a tiny int without overflow checking, stored in a C `unsigned char`.

h (int) [short int] Convert a Python integer to a C `short int`.

H (int) [unsigned short int] Convert a Python integer to a C `unsigned short int`, without overflow checking.

i (int) [int] Convert a Python integer to a plain C `int`.

I (int) [unsigned int] Convert a Python integer to a C `unsigned int`, without overflow checking.

l (int) [long int] Convert a Python integer to a C `long int`.

k (int) [unsigned long] Convert a Python integer to a C `unsigned long` without overflow checking.

L (int) [long long] Convert a Python integer to a C `long long`.

K (int) [unsigned long long] Convert a Python integer to a C `unsigned long long` without overflow checking.

n (int) [Py_ssize_t] Convert a Python integer to a C `Py_ssize_t`.

`c` (`bytes` or `bytearray` of length 1) [**char**] Convert a Python byte, represented as a `bytes` or `bytearray` object of length 1, to a C `char`.

Changed in version 3.3: Allow `bytearray` objects.

`C` (`str` of length 1) [**int**] Convert a Python character, represented as a `str` object of length 1, to a C `int`.

`f` (`float`) [**float**] Convert a Python floating point number to a C `float`.

`d` (`float`) [**double**] Convert a Python floating point number to a C `double`.

`D` (`complex`) [**Py_complex**] Convert a Python complex number to a C *Py_complex* structure.

Other objects

`O` (object) [**PyObject ***] Store a Python object (without any conversion) in a C object pointer. The C program thus receives the actual object that was passed. The object's reference count is not increased. The pointer stored is not *NULL*.

`O!` (object) [***typeobject***, **PyObject ***] Store a Python object in a C object pointer. This is similar to `O`, but takes two C arguments: the first is the address of a Python type object, the second is the address of the C variable (of type *PyObject**) into which the object pointer is stored. If the Python object does not have the required type, `TypeError` is raised.

`O&` (object) [***converter***, ***anything***] Convert a Python object to a C variable through a *converter* function. This takes two arguments: the first is a function, the second is the address of a C variable (of arbitrary type), converted to `void *`. The *converter* function in turn is called as follows:

```
status = converter(object, address);
```

where *object* is the Python object to be converted and *address* is the `void*` argument that was passed to the *PyArg_Parse*()* function. The returned *status* should be `1` for a successful conversion and `0` if the conversion has failed. When the conversion fails, the *converter* function should raise an exception and leave the content of *address* unmodified.

If the *converter* returns `Py_CLEANUP_SUPPORTED`, it may get called a second time if the argument parsing eventually fails, giving the converter a chance to release any memory that it had already allocated. In this second call, the *object* parameter will be NULL; *address* will have the same value as in the original call.

Changed in version 3.1: `Py_CLEANUP_SUPPORTED` was added.

`p` (`bool`) [**int**] Tests the value passed in for truth (a boolean **p**redicate) and converts the result to its equivalent C true/false integer value. Sets the int to `1` if the expression was true and `0` if it was false. This accepts any valid Python value. See truth for more information about how Python tests values for truth.

New in version 3.3.

`(items)` (`tuple`) [***matching-items***] The object must be a Python sequence whose length is the number of format units in *items*. The C arguments must correspond to the individual format units in *items*. Format units for sequences may be nested.

It is possible to pass "long" integers (integers whose value exceeds the platform's `LONG_MAX`) however no proper range checking is done — the most significant bits are silently truncated when the receiving field is too small to receive the value (actually, the semantics are inherited from downcasts in C — your mileage may vary).

A few other characters have a meaning in a format string. These may not occur inside nested parentheses. They are:

`|` Indicates that the remaining arguments in the Python argument list are optional. The C variables corresponding to optional arguments should be initialized to their default value — when an optional argument is not specified, *PyArg_ParseTuple()* does not touch the contents of the corresponding C variable(s).

`$` *PyArg_ParseTupleAndKeywords()* only: Indicates that the remaining arguments in the Python argument list are keyword-only. Currently, all keyword-only arguments must also be optional arguments, so `|` must always be specified before `$` in the format string.

New in version 3.3.

`:` The list of format units ends here; the string after the colon is used as the function name in error messages (the "associated value" of the exception that *PyArg_ParseTuple()* raises).

`;` The list of format units ends here; the string after the semicolon is used as the error message *instead* of the default error message. `:` and `;` mutually exclude each other.

Note that any Python object references which are provided to the caller are *borrowed* references; do not decrement their reference count!

Additional arguments passed to these functions must be addresses of variables whose type is determined by the format string; these are used to store values from the input tuple. There are a few cases, as described in the list of format units above, where these parameters are used as input values; they should match what is specified for the corresponding format unit in that case.

For the conversion to succeed, the *arg* object must match the format and the format must be exhausted. On success, the *PyArg_Parse*()* functions return true, otherwise they return false and raise an appropriate exception. When the *PyArg_Parse*()* functions fail due to conversion failure in one of the format units, the variables at the addresses corresponding to that and the following format units are left untouched.

API Functions

int **PyArg_ParseTuple**(*PyObject* **args*, const char **format*, ...)
Parse the parameters of a function that takes only positional parameters into local variables. Returns true on success; on failure, it returns false and raises the appropriate exception.

int **PyArg_VaParse**(*PyObject* **args*, const char **format*, va_list *vargs*)
Identical to *PyArg_ParseTuple()*, except that it accepts a va_list rather than a variable number of arguments.

int **PyArg_ParseTupleAndKeywords**(*PyObject* **args*, *PyObject* **kw*, const char **format*, char **keywords[]*, ...)
Parse the parameters of a function that takes both positional and keyword parameters into local variables. The *keywords* argument is a *NULL*-terminated array of keyword parameter names. Empty names denote *positional-only parameters*. Returns true on success; on failure, it returns false and raises the appropriate exception.

Changed in version 3.6: Added support for *positional-only parameters*.

int **PyArg_VaParseTupleAndKeywords**(*PyObject* **args*, *PyObject* **kw*, const char **format*, char **keywords[]*, va_list *vargs*)
Identical to *PyArg_ParseTupleAndKeywords()*, except that it accepts a va_list rather than a variable number of arguments.

int **PyArg_ValidateKeywordArguments**(*PyObject* *)
Ensure that the keys in the keywords argument dictionary are strings. This is only needed if *PyArg_ParseTupleAndKeywords()* is not used, since the latter already does this check.

New in version 3.2.

int **PyArg_Parse**(*PyObject* **args*, const char **format*, ...)
Function used to deconstruct the argument lists of "old-style" functions — these are functions which

use the METH_OLDARGS parameter parsing method, which has been removed in Python 3. This is not recommended for use in parameter parsing in new code, and most code in the standard interpreter has been modified to no longer use this for that purpose. It does remain a convenient way to decompose other tuples, however, and may continue to be used for that purpose.

int **PyArg_UnpackTuple**(*PyObject* **args*, const char **name*, Py_ssize_t *min*, Py_ssize_t *max*, ...)

A simpler form of parameter retrieval which does not use a format string to specify the types of the arguments. Functions which use this method to retrieve their parameters should be declared as *METH_VARARGS* in function or method tables. The tuple containing the actual parameters should be passed as *args*; it must actually be a tuple. The length of the tuple must be at least *min* and no more than *max*; *min* and *max* may be equal. Additional arguments must be passed to the function, each of which should be a pointer to a *PyObject** variable; these will be filled in with the values from *args*; they will contain borrowed references. The variables which correspond to optional parameters not given by *args* will not be filled in; these should be initialized by the caller. This function returns true on success and false if *args* is not a tuple or contains the wrong number of elements; an exception will be set if there was a failure.

This is an example of the use of this function, taken from the sources for the `_weakref` helper module for weak references:

```
static PyObject *
weakref_ref(PyObject *self, PyObject *args)
{
    PyObject *object;
    PyObject *callback = NULL;
    PyObject *result = NULL;

    if (PyArg_UnpackTuple(args, "ref", 1, 2, &object, &callback)) {
        result = PyWeakref_NewRef(object, callback);
    }
    return result;
}
```

The call to *PyArg_UnpackTuple()* in this example is entirely equivalent to this call to *PyArg_ParseTuple()*:

```
PyArg_ParseTuple(args, "O|O:ref", &object, &callback)
```

6.6.2 Building values

*PyObject** **Py_BuildValue**(const char **format*, ...)

Return value: New reference. Create a new value based on a format string similar to those accepted by the *PyArg_Parse*()* family of functions and a sequence of values. Returns the value or *NULL* in the case of an error; an exception will be raised if *NULL* is returned.

Py_BuildValue() does not always build a tuple. It builds a tuple only if its format string contains two or more format units. If the format string is empty, it returns `None`; if it contains exactly one format unit, it returns whatever object is described by that format unit. To force it to return a tuple of size 0 or one, parenthesize the format string.

When memory buffers are passed as parameters to supply data to build objects, as for the `s` and `s#` formats, the required data is copied. Buffers provided by the caller are never referenced by the objects created by *Py_BuildValue()*. In other words, if your code invokes `malloc()` and passes the allocated memory to *Py_BuildValue()*, your code is responsible for calling `free()` for that memory once *Py_BuildValue()* returns.

In the following description, the quoted form is the format unit; the entry in (round) parentheses is the Python object type that the format unit will return; and the entry in [square] brackets is the type of the C value(s) to be passed.

The characters space, tab, colon and comma are ignored in format strings (but not within format units such as `s#`). This can be used to make long format strings a tad more readable.

`s` (`str` or `None`) [const char *] Convert a null-terminated C string to a Python `str` object using `'utf-8'` encoding. If the C string pointer is *NULL*, `None` is used.

`s#` (`str` or `None`) [const char *, int] Convert a C string and its length to a Python `str` object using `'utf-8'` encoding. If the C string pointer is *NULL*, the length is ignored and `None` is returned.

`y` (`bytes`) [const char *] This converts a C string to a Python `bytes` object. If the C string pointer is *NULL*, `None` is returned.

`y#` (`bytes`) [const char *, int] This converts a C string and its lengths to a Python object. If the C string pointer is *NULL*, `None` is returned.

`z` (`str` or `None`) [const char *] Same as `s`.

`z#` (`str` or `None`) [const char *, int] Same as `s#`.

`u` (`str`) [const wchar_t *] Convert a null-terminated `wchar_t` buffer of Unicode (UTF-16 or UCS-4) data to a Python Unicode object. If the Unicode buffer pointer is *NULL*, `None` is returned.

`u#` (`str`) [const wchar_t *, int] Convert a Unicode (UTF-16 or UCS-4) data buffer and its length to a Python Unicode object. If the Unicode buffer pointer is *NULL*, the length is ignored and `None` is returned.

`U` (`str` or `None`) [const char *] Same as `s`.

`U#` (`str` or `None`) [const char *, int] Same as `s#`.

`i` (`int`) [int] Convert a plain C `int` to a Python integer object.

`b` (`int`) [char] Convert a plain C `char` to a Python integer object.

`h` (`int`) [short int] Convert a plain C `short int` to a Python integer object.

`l` (`int`) [long int] Convert a C `long int` to a Python integer object.

`B` (`int`) [unsigned char] Convert a C `unsigned char` to a Python integer object.

`H` (`int`) [unsigned short int] Convert a C `unsigned short int` to a Python integer object.

`I` (`int`) [unsigned int] Convert a C `unsigned int` to a Python integer object.

`k` (`int`) [unsigned long] Convert a C `unsigned long` to a Python integer object.

`L` (`int`) [long long] Convert a C `long long` to a Python integer object.

`K` (`int`) [unsigned long long] Convert a C `unsigned long long` to a Python integer object.

`n` (`int`) [Py_ssize_t] Convert a C `Py_ssize_t` to a Python integer.

`c` (`bytes` of length 1) [char] Convert a C `int` representing a byte to a Python `bytes` object of length 1.

`C` (`str` of length 1) [int] Convert a C `int` representing a character to Python `str` object of length 1.

`d` (`float`) [double] Convert a C `double` to a Python floating point number.

`f` (`float`) [float] Convert a C `float` to a Python floating point number.

`D` (`complex`) [Py_complex *] Convert a C *`Py_complex`* structure to a Python complex number.

`O` (**object**) [**PyObject ***] Pass a Python object untouched (except for its reference count, which is incremented by one). If the object passed in is a *NULL* pointer, it is assumed that this was caused because the call producing the argument found an error and set an exception. Therefore, *Py_BuildValue()* will return *NULL* but won't raise an exception. If no exception has been raised yet, `SystemError` is set.

`S` (**object**) [**PyObject ***] Same as `O`.

`N` (**object**) [**PyObject ***] Same as `O`, except it doesn't increment the reference count on the object. Useful when the object is created by a call to an object constructor in the argument list.

`O&` (**object**) [***converter***, ***anything***] Convert *anything* to a Python object through a *converter* function. The function is called with *anything* (which should be compatible with `void *`) as its argument and should return a "new" Python object, or *NULL* if an error occurred.

`(items)` (**tuple**) [***matching-items***] Convert a sequence of C values to a Python tuple with the same number of items.

`[items]` (**list**) [***matching-items***] Convert a sequence of C values to a Python list with the same number of items.

`{items}` (**dict**) [***matching-items***] Convert a sequence of C values to a Python dictionary. Each pair of consecutive C values adds one item to the dictionary, serving as key and value, respectively.

If there is an error in the format string, the `SystemError` exception is set and *NULL* returned.

*PyObject** `Py_VaBuildValue`(const char **format*, va_list *vargs*)
Identical to *Py_BuildValue()*, except that it accepts a va_list rather than a variable number of arguments.

6.7 String conversion and formatting

Functions for number conversion and formatted string output.

int `PyOS_snprintf`(char **str*, size_t *size*, const char **format*, ...)
Output not more than *size* bytes to *str* according to the format string *format* and the extra arguments. See the Unix man page *snprintf(2)*.

int `PyOS_vsnprintf`(char **str*, size_t *size*, const char **format*, va_list *va*)
Output not more than *size* bytes to *str* according to the format string *format* and the variable argument list *va*. Unix man page *vsnprintf(2)*.

PyOS_snprintf() and *PyOS_vsnprintf()* wrap the Standard C library functions `snprintf()` and `vsnprintf()`. Their purpose is to guarantee consistent behavior in corner cases, which the Standard C functions do not.

The wrappers ensure that *str*[*size*-1] is always `'\0'` upon return. They never write more than *size* bytes (including the trailing `'\0'`) into str. Both functions require that `str != NULL`, `size > 0` and `format != NULL`.

If the platform doesn't have `vsnprintf()` and the buffer size needed to avoid truncation exceeds *size* by more than 512 bytes, Python aborts with a *Py_FatalError*.

The return value (*rv*) for these functions should be interpreted as follows:

- When `0 <= rv < size`, the output conversion was successful and *rv* characters were written to *str* (excluding the trailing `'\0'` byte at *str*[*rv*]).
- When `rv >= size`, the output conversion was truncated and a buffer with `rv + 1` bytes would have been needed to succeed. *str*[*size*-1] is `'\0'` in this case.

- When `rv < 0`, "something bad happened." *str*[*size*-1] is `'\0'` in this case too, but the rest of *str* is undefined. The exact cause of the error depends on the underlying platform.

The following functions provide locale-independent string to number conversions.

double **PyOS_string_to_double**(const char **s*, char ***endptr*, *PyObject* **overflow_exception*)
Convert a string `s` to a `double`, raising a Python exception on failure. The set of accepted strings corresponds to the set of strings accepted by Python's `float()` constructor, except that `s` must not have leading or trailing whitespace. The conversion is independent of the current locale.

If `endptr` is `NULL`, convert the whole string. Raise ValueError and return `-1.0` if the string is not a valid representation of a floating-point number.

If endptr is not `NULL`, convert as much of the string as possible and set `*endptr` to point to the first unconverted character. If no initial segment of the string is the valid representation of a floating-point number, set `*endptr` to point to the beginning of the string, raise ValueError, and return `-1.0`.

If `s` represents a value that is too large to store in a float (for example, `"1e500"` is such a string on many platforms) then if `overflow_exception` is `NULL` return `Py_HUGE_VAL` (with an appropriate sign) and don't set any exception. Otherwise, `overflow_exception` must point to a Python exception object; raise that exception and return `-1.0`. In both cases, set `*endptr` to point to the first character after the converted value.

If any other error occurs during the conversion (for example an out-of-memory error), set the appropriate Python exception and return `-1.0`.

New in version 3.1.

char* **PyOS_double_to_string**(double *val*, char *format_code*, int *precision*, int *flags*, int **ptype*)
Convert a `double` *val* to a string using supplied *format_code*, *precision*, and *flags*.

format_code must be one of `'e'`, `'E'`, `'f'`, `'F'`, `'g'`, `'G'` or `'r'`. For `'r'`, the supplied *precision* must be 0 and is ignored. The `'r'` format code specifies the standard `repr()` format.

flags can be zero or more of the values *Py_DTSF_SIGN*, *Py_DTSF_ADD_DOT_0*, or *Py_DTSF_ALT*, or-ed together:

- *Py_DTSF_SIGN* means to always precede the returned string with a sign character, even if *val* is non-negative.
- *Py_DTSF_ADD_DOT_0* means to ensure that the returned string will not look like an integer.
- *Py_DTSF_ALT* means to apply "alternate" formatting rules. See the documentation for the *PyOS_snprintf()* `'#'` specifier for details.

If *ptype* is non-NULL, then the value it points to will be set to one of *Py_DTST_FINITE*, *Py_DTST_INFINITE*, or *Py_DTST_NAN*, signifying that *val* is a finite number, an infinite number, or not a number, respectively.

The return value is a pointer to *buffer* with the converted string or *NULL* if the conversion failed. The caller is responsible for freeing the returned string by calling *PyMem_Free()*.

New in version 3.1.

int **PyOS_stricmp**(const char **s1*, const char **s2*)
Case insensitive comparison of strings. The function works almost identically to `strcmp()` except that it ignores the case.

int **PyOS_strnicmp**(const char **s1*, const char **s2*, Py_ssize_t *size*)
Case insensitive comparison of strings. The function works almost identically to `strncmp()` except that it ignores the case.

6.8 Reflection

*PyObject** **PyEval_GetBuiltins**()
Return value: Borrowed reference. Return a dictionary of the builtins in the current execution frame, or the interpreter of the thread state if no frame is currently executing.

*PyObject** **PyEval_GetLocals**()
Return value: Borrowed reference. Return a dictionary of the local variables in the current execution frame, or *NULL* if no frame is currently executing.

*PyObject** **PyEval_GetGlobals**()
Return value: Borrowed reference. Return a dictionary of the global variables in the current execution frame, or *NULL* if no frame is currently executing.

*PyFrameObject** **PyEval_GetFrame**()
Return value: Borrowed reference. Return the current thread state's frame, which is *NULL* if no frame is currently executing.

int **PyFrame_GetLineNumber**(*PyFrameObject *frame*)
Return the line number that *frame* is currently executing.

const char* **PyEval_GetFuncName**(*PyObject *func*)
Return the name of *func* if it is a function, class or instance object, else the name of *func*s type.

const char* **PyEval_GetFuncDesc**(*PyObject *func*)
Return a description string, depending on the type of *func*. Return values include "()" for functions and methods, " constructor", " instance", and " object". Concatenated with the result of *PyEval_GetFuncName()*, the result will be a description of *func*.

6.9 Codec registry and support functions

int **PyCodec_Register**(*PyObject *search_function*)
Register a new codec search function.

As side effect, this tries to load the `encodings` package, if not yet done, to make sure that it is always first in the list of search functions.

int **PyCodec_KnownEncoding**(const char *encoding*)
Return `1` or `0` depending on whether there is a registered codec for the given *encoding*.

*PyObject** **PyCodec_Encode**(*PyObject *object*, const char *encoding*, const char *errors*)
Generic codec based encoding API.

object is passed through the encoder function found for the given *encoding* using the error handling method defined by *errors*. *errors* may be *NULL* to use the default method defined for the codec. Raises a `LookupError` if no encoder can be found.

*PyObject** **PyCodec_Decode**(*PyObject *object*, const char *encoding*, const char *errors*)
Generic codec based decoding API.

object is passed through the decoder function found for the given *encoding* using the error handling method defined by *errors*. *errors* may be *NULL* to use the default method defined for the codec. Raises a `LookupError` if no encoder can be found.

6.9.1 Codec lookup API

In the following functions, the *encoding* string is looked up converted to all lower-case characters, which makes encodings looked up through this mechanism effectively case-insensitive. If no codec is found, a

`KeyError` is set and *NULL* returned.

*PyObject** **PyCodec_Encoder**(const char **encoding*)
Get an encoder function for the given *encoding*.

*PyObject** **PyCodec_Decoder**(const char **encoding*)
Get a decoder function for the given *encoding*.

*PyObject** **PyCodec_IncrementalEncoder**(const char **encoding*, const char **errors*)
Get an `IncrementalEncoder` object for the given *encoding*.

*PyObject** **PyCodec_IncrementalDecoder**(const char **encoding*, const char **errors*)
Get an `IncrementalDecoder` object for the given *encoding*.

*PyObject** **PyCodec_StreamReader**(const char **encoding*, *PyObject* **stream*, const char **errors*)
Get a `StreamReader` factory function for the given *encoding*.

*PyObject** **PyCodec_StreamWriter**(const char **encoding*, *PyObject* **stream*, const char **errors*)
Get a `StreamWriter` factory function for the given *encoding*.

6.9.2 Registry API for Unicode encoding error handlers

int **PyCodec_RegisterError**(const char **name*, *PyObject* **error*)
Register the error handling callback function *error* under the given *name*. This callback function will be called by a codec when it encounters unencodable characters/undecodable bytes and *name* is specified as the error parameter in the call to the encode/decode function.

The callback gets a single argument, an instance of `UnicodeEncodeError`, `UnicodeDecodeError` or `UnicodeTranslateError` that holds information about the problematic sequence of characters or bytes and their offset in the original string (see *Unicode Exception Objects* for functions to extract this information). The callback must either raise the given exception, or return a two-item tuple containing the replacement for the problematic sequence, and an integer giving the offset in the original string at which encoding/decoding should be resumed.

Return `0` on success, `-1` on error.

*PyObject** **PyCodec_LookupError**(const char **name*)
Lookup the error handling callback function registered under *name*. As a special case *NULL* can be passed, in which case the error handling callback for "strict" will be returned.

*PyObject** **PyCodec_StrictErrors**(*PyObject* **exc*)
Raise *exc* as an exception.

*PyObject** **PyCodec_IgnoreErrors**(*PyObject* **exc*)
Ignore the unicode error, skipping the faulty input.

*PyObject** **PyCodec_ReplaceErrors**(*PyObject* **exc*)
Replace the unicode encode error with `?` or `U+FFFD`.

*PyObject** **PyCodec_XMLCharRefReplaceErrors**(*PyObject* **exc*)
Replace the unicode encode error with XML character references.

*PyObject** **PyCodec_BackslashReplaceErrors**(*PyObject* **exc*)
Replace the unicode encode error with backslash escapes (`\x`, `\u` and `\U`).

*PyObject** **PyCodec_NameReplaceErrors**(*PyObject* **exc*)
Replace the unicode encode error with `\N{...}` escapes.

New in version 3.5.

CHAPTER

SEVEN

ABSTRACT OBJECTS LAYER

The functions in this chapter interact with Python objects regardless of their type, or with wide classes of object types (e.g. all numerical types, or all sequence types). When used on object types for which they do not apply, they will raise a Python exception.

It is not possible to use these functions on objects that are not properly initialized, such as a list object that has been created by *PyList_New()*, but whose items have not been set to some non-NULL value yet.

7.1 Object Protocol

*PyObject** **Py_NotImplemented**
The NotImplemented singleton, used to signal that an operation is not implemented for the given type combination.

Py_RETURN_NOTIMPLEMENTED
Properly handle returning *Py_NotImplemented* from within a C function (that is, increment the reference count of NotImplemented and return it).

int **PyObject_Print**(*PyObject *o*, FILE **fp*, int *flags*)
Print an object *o*, on file *fp*. Returns -1 on error. The flags argument is used to enable certain printing options. The only option currently supported is Py_PRINT_RAW; if given, the str() of the object is written instead of the repr().

int **PyObject_HasAttr**(*PyObject *o*, *PyObject *attr_name*)
Returns 1 if *o* has the attribute *attr_name*, and 0 otherwise. This is equivalent to the Python expression hasattr(o, attr_name). This function always succeeds.

int **PyObject_HasAttrString**(*PyObject *o*, const char **attr_name*)
Returns 1 if *o* has the attribute *attr_name*, and 0 otherwise. This is equivalent to the Python expression hasattr(o, attr_name). This function always succeeds.

*PyObject** **PyObject_GetAttr**(*PyObject *o*, *PyObject *attr_name*)
Return value: New reference. Retrieve an attribute named *attr_name* from object *o*. Returns the attribute value on success, or *NULL* on failure. This is the equivalent of the Python expression o.attr_name.

*PyObject** **PyObject_GetAttrString**(*PyObject *o*, const char **attr_name*)
Return value: New reference. Retrieve an attribute named *attr_name* from object *o*. Returns the attribute value on success, or *NULL* on failure. This is the equivalent of the Python expression o.attr_name.

*PyObject** **PyObject_GenericGetAttr**(*PyObject *o*, *PyObject *name*)
Generic attribute getter function that is meant to be put into a type object's tp_getattro slot. It looks for a descriptor in the dictionary of classes in the object's MRO as well as an attribute in the object's __dict__ (if present). As outlined in descriptors, data descriptors take preference over instance attributes, while non-data descriptors don't. Otherwise, an AttributeError is raised.

int **PyObject_SetAttr**(*PyObject* *o, *PyObject* *attr_name, *PyObject* *v)
Set the value of the attribute named *attr_name*, for object *o*, to the value *v*. Raise an exception and return `-1` on failure; return `0` on success. This is the equivalent of the Python statement `o.attr_name = v`.

If *v* is *NULL*, the attribute is deleted, however this feature is deprecated in favour of using *PyObject_DelAttr()*.

int **PyObject_SetAttrString**(*PyObject* *o, const char *attr_name, *PyObject* *v)
Set the value of the attribute named *attr_name*, for object *o*, to the value *v*. Raise an exception and return `-1` on failure; return `0` on success. This is the equivalent of the Python statement `o.attr_name = v`.

If *v* is *NULL*, the attribute is deleted, however this feature is deprecated in favour of using *PyObject_DelAttrString()*.

int **PyObject_GenericSetAttr**(*PyObject* *o, *PyObject* *name, *PyObject* *value)
Generic attribute setter and deleter function that is meant to be put into a type object's *tp_setattro* slot. It looks for a data descriptor in the dictionary of classes in the object's MRO, and if found it takes preference over setting or deleting the attribute in the instance dictionary. Otherwise, the attribute is set or deleted in the object's `__dict__` (if present). On success, `0` is returned, otherwise an `AttributeError` is raised and `-1` is returned.

int **PyObject_DelAttr**(*PyObject* *o, *PyObject* *attr_name)
Delete attribute named *attr_name*, for object *o*. Returns `-1` on failure. This is the equivalent of the Python statement `del o.attr_name`.

int **PyObject_DelAttrString**(*PyObject* *o, const char *attr_name)
Delete attribute named *attr_name*, for object *o*. Returns `-1` on failure. This is the equivalent of the Python statement `del o.attr_name`.

*PyObject** **PyObject_GenericGetDict**(*PyObject* *o, void *context)
A generic implementation for the getter of a `__dict__` descriptor. It creates the dictionary if necessary.

New in version 3.3.

int **PyObject_GenericSetDict**(*PyObject* *o, void *context)
A generic implementation for the setter of a `__dict__` descriptor. This implementation does not allow the dictionary to be deleted.

New in version 3.3.

*PyObject** **PyObject_RichCompare**(*PyObject* *o1, *PyObject* *o2, int *opid*)
Return value: New reference. Compare the values of *o1* and *o2* using the operation specified by *opid*, which must be one of `Py_LT`, `Py_LE`, `Py_EQ`, `Py_NE`, `Py_GT`, or `Py_GE`, corresponding to `<`, `<=`, `==`, `!=`, `>`, or `>=` respectively. This is the equivalent of the Python expression `o1 op o2`, where `op` is the operator corresponding to *opid*. Returns the value of the comparison on success, or *NULL* on failure.

int **PyObject_RichCompareBool**(*PyObject* *o1, *PyObject* *o2, int *opid*)
Compare the values of *o1* and *o2* using the operation specified by *opid*, which must be one of `Py_LT`, `Py_LE`, `Py_EQ`, `Py_NE`, `Py_GT`, or `Py_GE`, corresponding to `<`, `<=`, `==`, `!=`, `>`, or `>=` respectively. Returns `-1` on error, `0` if the result is false, `1` otherwise. This is the equivalent of the Python expression `o1 op o2`, where `op` is the operator corresponding to *opid*.

Note: If *o1* and *o2* are the same object, *PyObject_RichCompareBool()* will always return `1` for `Py_EQ` and `0` for `Py_NE`.

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*PyObject** **PyObject_Repr**(*PyObject* *o)
Return value: New reference. Compute a string representation of object *o*. Returns the string rep-

resentation on success, *NULL* on failure. This is the equivalent of the Python expression `repr(o)`. Called by the `repr()` built-in function.

Changed in version 3.4: This function now includes a debug assertion to help ensure that it does not silently discard an active exception.

*PyObject** **PyObject_ASCII**(*PyObject *o*)
As *PyObject_Repr()*, compute a string representation of object *o*, but escape the non-ASCII characters in the string returned by *PyObject_Repr()* with `\x`, `\u` or `\U` escapes. This generates a string similar to that returned by *PyObject_Repr()* in Python 2. Called by the `ascii()` built-in function.

*PyObject** **PyObject_Str**(*PyObject *o*)
Return value: New reference. Compute a string representation of object *o*. Returns the string representation on success, *NULL* on failure. This is the equivalent of the Python expression `str(o)`. Called by the `str()` built-in function and, therefore, by the `print()` function.

Changed in version 3.4: This function now includes a debug assertion to help ensure that it does not silently discard an active exception.

*PyObject** **PyObject_Bytes**(*PyObject *o*)
Compute a bytes representation of object *o*. *NULL* is returned on failure and a bytes object on success. This is equivalent to the Python expression `bytes(o)`, when *o* is not an integer. Unlike `bytes(o)`, a TypeError is raised when *o* is an integer instead of a zero-initialized bytes object.

int **PyObject_IsSubclass**(*PyObject *derived*, *PyObject *cls*)
Return `1` if the class *derived* is identical to or derived from the class *cls*, otherwise return `0`. In case of an error, return `-1`.

If *cls* is a tuple, the check will be done against every entry in *cls*. The result will be `1` when at least one of the checks returns `1`, otherwise it will be `0`.

If *cls* has a `__subclasscheck__()` method, it will be called to determine the subclass status as described in **PEP 3119**. Otherwise, *derived* is a subclass of *cls* if it is a direct or indirect subclass, i.e. contained in `cls.__mro__`.

Normally only class objects, i.e. instances of `type` or a derived class, are considered classes. However, objects can override this by having a `__bases__` attribute (which must be a tuple of base classes).

int **PyObject_IsInstance**(*PyObject *inst*, *PyObject *cls*)
Return `1` if *inst* is an instance of the class *cls* or a subclass of *cls*, or `0` if not. On error, returns `-1` and sets an exception.

If *cls* is a tuple, the check will be done against every entry in *cls*. The result will be `1` when at least one of the checks returns `1`, otherwise it will be `0`.

If *cls* has a `__instancecheck__()` method, it will be called to determine the subclass status as described in **PEP 3119**. Otherwise, *inst* is an instance of *cls* if its class is a subclass of *cls*.

An instance *inst* can override what is considered its class by having a `__class__` attribute.

An object *cls* can override if it is considered a class, and what its base classes are, by having a `__bases__` attribute (which must be a tuple of base classes).

int **PyCallable_Check**(*PyObject *o*)
Determine if the object *o* is callable. Return `1` if the object is callable and `0` otherwise. This function always succeeds.

*PyObject** **PyObject_Call**(*PyObject *callable*, *PyObject *args*, *PyObject *kwargs*)
Return value: New reference. Call a callable Python object *callable*, with arguments given by the tuple *args*, and named arguments given by the dictionary *kwargs*.

args must not be *NULL*, use an empty tuple if no arguments are needed. If no named arguments are needed, *kwargs* can be *NULL*.

Returns the result of the call on success, or *NULL* on failure.

This is the equivalent of the Python expression: `callable(*args, **kwargs)`.

*PyObject** **PyObject_CallObject**(*PyObject* **callable*, *PyObject* **args*)
Return value: New reference. Call a callable Python object *callable*, with arguments given by the tuple *args*. If no arguments are needed, then *args* can be *NULL*.

Returns the result of the call on success, or *NULL* on failure.

This is the equivalent of the Python expression: `callable(*args)`.

*PyObject** **PyObject_CallFunction**(*PyObject* **callable*, const char **format*, ...)
Return value: New reference. Call a callable Python object *callable*, with a variable number of C arguments. The C arguments are described using a *Py_BuildValue()* style format string. The format can be *NULL*, indicating that no arguments are provided.

Returns the result of the call on success, or *NULL* on failure.

This is the equivalent of the Python expression: `callable(*args)`.

Note that if you only pass *PyObject ** args, *PyObject_CallFunctionObjArgs()* is a faster alternative.

Changed in version 3.4: The type of *format* was changed from `char *`.

*PyObject** **PyObject_CallMethod**(*PyObject* **obj*, const char **name*, const char **format*, ...)
Return value: New reference. Call the method named *name* of object *obj* with a variable number of C arguments. The C arguments are described by a *Py_BuildValue()* format string that should produce a tuple.

The format can be *NULL*, indicating that no arguments are provided.

Returns the result of the call on success, or *NULL* on failure.

This is the equivalent of the Python expression: `obj.name(arg1, arg2, ...)`.

Note that if you only pass *PyObject ** args, *PyObject_CallMethodObjArgs()* is a faster alternative.

Changed in version 3.4: The types of *name* and *format* were changed from `char *`.

*PyObject** **PyObject_CallFunctionObjArgs**(*PyObject* **callable*, ..., NULL)
Return value: New reference. Call a callable Python object *callable*, with a variable number of *PyObject** arguments. The arguments are provided as a variable number of parameters followed by *NULL*.

Returns the result of the call on success, or *NULL* on failure.

This is the equivalent of the Python expression: `callable(arg1, arg2, ...)`.

*PyObject** **PyObject_CallMethodObjArgs**(*PyObject* **obj*, *PyObject* **name*, ..., NULL)
Return value: New reference. Calls a method of the Python object *obj*, where the name of the method is given as a Python string object in *name*. It is called with a variable number of *PyObject** arguments. The arguments are provided as a variable number of parameters followed by *NULL*. Returns the result of the call on success, or *NULL* on failure.

Py_hash_t **PyObject_Hash**(*PyObject* **o*)
Compute and return the hash value of an object *o*. On failure, return `-1`. This is the equivalent of the Python expression `hash(o)`.

Changed in version 3.2: The return type is now Py_hash_t. This is a signed integer the same size as Py_ssize_t.

Py_hash_t **PyObject_HashNotImplemented**(*PyObject* **o*)
Set a `TypeError` indicating that `type(o)` is not hashable and return `-1`. This function receives special treatment when stored in a `tp_hash` slot, allowing a type to explicitly indicate to the interpreter that it is not hashable.

int **PyObject_IsTrue**(*PyObject* *o)
Returns 1 if the object *o* is considered to be true, and 0 otherwise. This is equivalent to the Python expression `not not o`. On failure, return -1.

int **PyObject_Not**(*PyObject* *o)
Returns 0 if the object *o* is considered to be true, and 1 otherwise. This is equivalent to the Python expression `not o`. On failure, return -1.

*PyObject** **PyObject_Type**(*PyObject* *o)
Return value: New reference. When *o* is non-*NULL*, returns a type object corresponding to the object type of object *o*. On failure, raises `SystemError` and returns *NULL*. This is equivalent to the Python expression `type(o)`. This function increments the reference count of the return value. There's really no reason to use this function instead of the common expression `o->ob_type`, which returns a pointer of type *PyTypeObject**, except when the incremented reference count is needed.

int **PyObject_TypeCheck**(*PyObject* *o, *PyTypeObject* *type)
Return true if the object *o* is of type *type* or a subtype of *type*. Both parameters must be non-*NULL*.

Py_ssize_t **PyObject_Size**(*PyObject* *o)
Py_ssize_t **PyObject_Length**(*PyObject* *o)
Return the length of object *o*. If the object *o* provides either the sequence and mapping protocols, the sequence length is returned. On error, -1 is returned. This is the equivalent to the Python expression `len(o)`.

Py_ssize_t **PyObject_LengthHint**(*PyObject* *o, Py_ssize_t *default*)
Return an estimated length for the object *o*. First try to return its actual length, then an estimate using `__length_hint__()`, and finally return the default value. On error return -1. This is the equivalent to the Python expression `operator.length_hint(o, default)`.

New in version 3.4.

*PyObject** **PyObject_GetItem**(*PyObject* *o, *PyObject* *key)
Return value: New reference. Return element of *o* corresponding to the object *key* or *NULL* on failure. This is the equivalent of the Python expression `o[key]`.

int **PyObject_SetItem**(*PyObject* *o, *PyObject* *key, *PyObject* *v)
Map the object *key* to the value *v*. Raise an exception and return -1 on failure; return 0 on success. This is the equivalent of the Python statement `o[key] = v`.

int **PyObject_DelItem**(*PyObject* *o, *PyObject* *key)
Remove the mapping for the object *key* from the object *o*. Return -1 on failure. This is equivalent to the Python statement `del o[key]`.

*PyObject** **PyObject_Dir**(*PyObject* *o)
Return value: New reference. This is equivalent to the Python expression `dir(o)`, returning a (possibly empty) list of strings appropriate for the object argument, or *NULL* if there was an error. If the argument is *NULL*, this is like the Python `dir()`, returning the names of the current locals; in this case, if no execution frame is active then *NULL* is returned but *PyErr_Occurred()* will return false.

*PyObject** **PyObject_GetIter**(*PyObject* *o)
Return value: New reference. This is equivalent to the Python expression `iter(o)`. It returns a new iterator for the object argument, or the object itself if the object is already an iterator. Raises `TypeError` and returns *NULL* if the object cannot be iterated.

7.2 Number Protocol

int **PyNumber_Check**(*PyObject* *o)
Returns 1 if the object *o* provides numeric protocols, and false otherwise. This function always succeeds.

*PyObject** **PyNumber_Add**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the result of adding *o1* and *o2*, or *NULL* on failure. This is the equivalent of the Python expression `o1 + o2`.

*PyObject** **PyNumber_Subtract**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the result of subtracting *o2* from *o1*, or *NULL* on failure. This is the equivalent of the Python expression `o1 - o2`.

*PyObject** **PyNumber_Multiply**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the result of multiplying *o1* and *o2*, or *NULL* on failure. This is the equivalent of the Python expression `o1 * o2`.

*PyObject** **PyNumber_MatrixMultiply**(*PyObject *o1*, *PyObject *o2*)
Returns the result of matrix multiplication on *o1* and *o2*, or *NULL* on failure. This is the equivalent of the Python expression `o1 @ o2`.

New in version 3.5.

*PyObject** **PyNumber_FloorDivide**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Return the floor of *o1* divided by *o2*, or *NULL* on failure. This is equivalent to the "classic" division of integers.

*PyObject** **PyNumber_TrueDivide**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Return a reasonable approximation for the mathematical value of *o1* divided by *o2*, or *NULL* on failure. The return value is "approximate" because binary floating point numbers are approximate; it is not possible to represent all real numbers in base two. This function can return a floating point value when passed two integers.

*PyObject** **PyNumber_Remainder**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the remainder of dividing *o1* by *o2*, or *NULL* on failure. This is the equivalent of the Python expression `o1 % o2`.

*PyObject** **PyNumber_Divmod**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. See the built-in function `divmod()`. Returns *NULL* on failure. This is the equivalent of the Python expression `divmod(o1, o2)`.

*PyObject** **PyNumber_Power**(*PyObject *o1*, *PyObject *o2*, *PyObject *o3*)
Return value: New reference. See the built-in function `pow()`. Returns *NULL* on failure. This is the equivalent of the Python expression `pow(o1, o2, o3)`, where *o3* is optional. If *o3* is to be ignored, pass *Py_None* in its place (passing *NULL* for *o3* would cause an illegal memory access).

*PyObject** **PyNumber_Negative**(*PyObject *o*)
Return value: New reference. Returns the negation of *o* on success, or *NULL* on failure. This is the equivalent of the Python expression `-o`.

*PyObject** **PyNumber_Positive**(*PyObject *o*)
Return value: New reference. Returns *o* on success, or *NULL* on failure. This is the equivalent of the Python expression `+o`.

*PyObject** **PyNumber_Absolute**(*PyObject *o*)
Return value: New reference. Returns the absolute value of *o*, or *NULL* on failure. This is the equivalent of the Python expression `abs(o)`.

*PyObject** **PyNumber_Invert**(*PyObject *o*)
Return value: New reference. Returns the bitwise negation of *o* on success, or *NULL* on failure. This is the equivalent of the Python expression `~o`.

*PyObject** **PyNumber_Lshift**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the result of left shifting *o1* by *o2* on success, or *NULL* on failure. This is the equivalent of the Python expression `o1 << o2`.

*PyObject** **PyNumber_Rshift**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the result of right shifting *o1* by *o2* on success, or *NULL* on failure. This is the equivalent of the Python expression `o1 >> o2`.

*PyObject** **PyNumber_And**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the "bitwise and" of *o1* and *o2* on success and *NULL* on failure. This is the equivalent of the Python expression `o1 & o2`.

*PyObject** **PyNumber_Xor**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the "bitwise exclusive or" of *o1* by *o2* on success, or *NULL* on failure. This is the equivalent of the Python expression `o1 ^ o2`.

*PyObject** **PyNumber_Or**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the "bitwise or" of *o1* and *o2* on success, or *NULL* on failure. This is the equivalent of the Python expression `o1 | o2`.

*PyObject** **PyNumber_InPlaceAdd**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the result of adding *o1* and *o2*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 += o2`.

*PyObject** **PyNumber_InPlaceSubtract**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the result of subtracting *o2* from *o1*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 -= o2`.

*PyObject** **PyNumber_InPlaceMultiply**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the result of multiplying *o1* and *o2*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 *= o2`.

*PyObject** **PyNumber_InPlaceMatrixMultiply**(*PyObject *o1*, *PyObject *o2*)
Returns the result of matrix multiplication on *o1* and *o2*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 @= o2`.

New in version 3.5.

*PyObject** **PyNumber_InPlaceFloorDivide**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the mathematical floor of dividing *o1* by *o2*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 //= o2`.

*PyObject** **PyNumber_InPlaceTrueDivide**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Return a reasonable approximation for the mathematical value of *o1* divided by *o2*, or *NULL* on failure. The return value is "approximate" because binary floating point numbers are approximate; it is not possible to represent all real numbers in base two. This function can return a floating point value when passed two integers. The operation is done *in-place* when *o1* supports it.

*PyObject** **PyNumber_InPlaceRemainder**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the remainder of dividing *o1* by *o2*, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 %= o2`.

*PyObject** **PyNumber_InPlacePower**(*PyObject *o1*, *PyObject *o2*, *PyObject *o3*)
Return value: New reference. See the built-in function `pow()`. Returns *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 **= o2` when o3 is *Py_None*, or an in-place variant of `pow(o1, o2, o3)` otherwise. If *o3* is to be ignored, pass *Py_None* in its place (passing *NULL* for *o3* would cause an illegal memory access).

*PyObject** **PyNumber_InPlaceLshift**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the result of left shifting *o1* by *o2* on success, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 <<= o2`.

*PyObject** **PyNumber_InPlaceRshift**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the result of right shifting *o1* by *o2* on success, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 >>= o2`.

*PyObject** **PyNumber_InPlaceAnd**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the "bitwise and" of *o1* and *o2* on success and *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 &= o2`.

*PyObject** **PyNumber_InPlaceXor**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the "bitwise exclusive or" of *o1* by *o2* on success, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 ^= o2`.

*PyObject** **PyNumber_InPlaceOr**(*PyObject *o1*, *PyObject *o2*)
Return value: New reference. Returns the "bitwise or" of *o1* and *o2* on success, or *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python statement `o1 |= o2`.

*PyObject** **PyNumber_Long**(*PyObject *o*)
Return value: New reference. Returns the *o* converted to an integer object on success, or *NULL* on failure. This is the equivalent of the Python expression `int(o)`.

*PyObject** **PyNumber_Float**(*PyObject *o*)
Return value: New reference. Returns the *o* converted to a float object on success, or *NULL* on failure. This is the equivalent of the Python expression `float(o)`.

*PyObject** **PyNumber_Index**(*PyObject *o*)
Returns the *o* converted to a Python int on success or *NULL* with a `TypeError` exception raised on failure.

*PyObject** **PyNumber_ToBase**(*PyObject *n*, int *base*)
Returns the integer *n* converted to base *base* as a string. The *base* argument must be one of 2, 8, 10, or 16. For base 2, 8, or 16, the returned string is prefixed with a base marker of `'0b'`, `'0o'`, or `'0x'`, respectively. If *n* is not a Python int, it is converted with *PyNumber_Index()* first.

Py_ssize_t **PyNumber_AsSsize_t**(*PyObject *o*, *PyObject *exc*)
Returns *o* converted to a Py_ssize_t value if *o* can be interpreted as an integer. If the call fails, an exception is raised and `-1` is returned.

If *o* can be converted to a Python int but the attempt to convert to a Py_ssize_t value would raise an `OverflowError`, then the *exc* argument is the type of exception that will be raised (usually `IndexError` or `OverflowError`). If *exc* is *NULL*, then the exception is cleared and the value is clipped to *PY_SSIZE_T_MIN* for a negative integer or *PY_SSIZE_T_MAX* for a positive integer.

int **PyIndex_Check**(*PyObject *o*)
Returns `1` if *o* is an index integer (has the nb_index slot of the tp_as_number structure filled in), and `0` otherwise.

7.3 Sequence Protocol

int **PySequence_Check**(*PyObject *o*)
Return `1` if the object provides sequence protocol, and `0` otherwise. Note that it returns `1` for Python

classes with a `__getitem__()` method unless they are `dict` subclasses since in general case it is impossible to determine what the type of keys it supports. This function always succeeds.

Py_ssize_t **PySequence_Size**(*PyObject* *o*)
Py_ssize_t **PySequence_Length**(*PyObject* *o*)
Returns the number of objects in sequence *o* on success, and `-1` on failure. This is equivalent to the Python expression `len(o)`.

*PyObject** **PySequence_Concat**(*PyObject* *o1*, *PyObject* *o2*)
Return value: New reference. Return the concatenation of *o1* and *o2* on success, and *NULL* on failure. This is the equivalent of the Python expression `o1 + o2`.

*PyObject** **PySequence_Repeat**(*PyObject* *o*, Py_ssize_t *count*)
Return value: New reference. Return the result of repeating sequence object *o* *count* times, or *NULL* on failure. This is the equivalent of the Python expression `o * count`.

*PyObject** **PySequence_InPlaceConcat**(*PyObject* *o1*, *PyObject* *o2*)
Return value: New reference. Return the concatenation of *o1* and *o2* on success, and *NULL* on failure. The operation is done *in-place* when *o1* supports it. This is the equivalent of the Python expression `o1 += o2`.

*PyObject** **PySequence_InPlaceRepeat**(*PyObject* *o*, Py_ssize_t *count*)
Return value: New reference. Return the result of repeating sequence object *o* *count* times, or *NULL* on failure. The operation is done *in-place* when *o* supports it. This is the equivalent of the Python expression `o *= count`.

*PyObject** **PySequence_GetItem**(*PyObject* *o*, Py_ssize_t *i*)
Return value: New reference. Return the *i*th element of *o*, or *NULL* on failure. This is the equivalent of the Python expression `o[i]`.

*PyObject** **PySequence_GetSlice**(*PyObject* *o*, Py_ssize_t *i1*, Py_ssize_t *i2*)
Return value: New reference. Return the slice of sequence object *o* between *i1* and *i2*, or *NULL* on failure. This is the equivalent of the Python expression `o[i1:i2]`.

int **PySequence_SetItem**(*PyObject* *o*, Py_ssize_t *i*, *PyObject* *v*)
Assign object *v* to the *i*th element of *o*. Raise an exception and return `-1` on failure; return `0` on success. This is the equivalent of the Python statement `o[i] = v`. This function *does not* steal a reference to *v*.

If *v* is *NULL*, the element is deleted, however this feature is deprecated in favour of using *PySequence_DelItem()*.

int **PySequence_DelItem**(*PyObject* *o*, Py_ssize_t *i*)
Delete the *i*th element of object *o*. Returns `-1` on failure. This is the equivalent of the Python statement `del o[i]`.

int **PySequence_SetSlice**(*PyObject* *o*, Py_ssize_t *i1*, Py_ssize_t *i2*, *PyObject* *v*)
Assign the sequence object *v* to the slice in sequence object *o* from *i1* to *i2*. This is the equivalent of the Python statement `o[i1:i2] = v`.

int **PySequence_DelSlice**(*PyObject* *o*, Py_ssize_t *i1*, Py_ssize_t *i2*)
Delete the slice in sequence object *o* from *i1* to *i2*. Returns `-1` on failure. This is the equivalent of the Python statement `del o[i1:i2]`.

Py_ssize_t **PySequence_Count**(*PyObject* *o*, *PyObject* *value*)
Return the number of occurrences of *value* in *o*, that is, return the number of keys for which `o[key] == value`. On failure, return `-1`. This is equivalent to the Python expression `o.count(value)`.

int **PySequence_Contains**(*PyObject* *o*, *PyObject* *value*)
Determine if *o* contains *value*. If an item in *o* is equal to *value*, return `1`, otherwise return `0`. On error, return `-1`. This is equivalent to the Python expression `value in o`.

Py_ssize_t **PySequence_Index**(*PyObject* *o, *PyObject* *value)
Return the first index *i* for which `o[i] == value`. On error, return `-1`. This is equivalent to the Python expression `o.index(value)`.

*PyObject** **PySequence_List**(*PyObject* *o)
Return value: New reference. Return a list object with the same contents as the sequence or iterable *o*, or *NULL* on failure. The returned list is guaranteed to be new. This is equivalent to the Python expression `list(o)`.

*PyObject** **PySequence_Tuple**(*PyObject* *o)
Return value: New reference. Return a tuple object with the same contents as the sequence or iterable *o*, or *NULL* on failure. If *o* is a tuple, a new reference will be returned, otherwise a tuple will be constructed with the appropriate contents. This is equivalent to the Python expression `tuple(o)`.

*PyObject** **PySequence_Fast**(*PyObject* *o, const char *m)
Return value: New reference. Return the sequence or iterable *o* as a list, unless it is already a tuple or list, in which case *o* is returned. Use *PySequence_Fast_GET_ITEM()* to access the members of the result. Returns *NULL* on failure. If the object is not a sequence or iterable, raises `TypeError` with *m* as the message text.

Py_ssize_t **PySequence_Fast_GET_SIZE**(*PyObject* *o)
Returns the length of *o*, assuming that *o* was returned by *PySequence_Fast()* and that *o* is not *NULL*. The size can also be gotten by calling *PySequence_Size()* on *o*, but *PySequence_Fast_GET_SIZE()* is faster because it can assume *o* is a list or tuple.

*PyObject** **PySequence_Fast_GET_ITEM**(*PyObject* *o, Py_ssize_t *i*)
Return value: Borrowed reference. Return the *i*th element of *o*, assuming that *o* was returned by *PySequence_Fast()*, *o* is not *NULL*, and that *i* is within bounds.

*PyObject*** **PySequence_Fast_ITEMS**(*PyObject* *o)
Return the underlying array of PyObject pointers. Assumes that *o* was returned by *PySequence_Fast()* and *o* is not *NULL*.

Note, if a list gets resized, the reallocation may relocate the items array. So, only use the underlying array pointer in contexts where the sequence cannot change.

*PyObject** **PySequence_ITEM**(*PyObject* *o, Py_ssize_t *i*)
Return value: New reference. Return the *i*th element of *o* or *NULL* on failure. Macro form of *PySequence_GetItem()* but without checking that *PySequence_Check()* on *o* is true and without adjustment for negative indices.

7.4 Mapping Protocol

See also *PyObject_GetItem()*, *PyObject_SetItem()* and *PyObject_DelItem()*.

int **PyMapping_Check**(*PyObject* *o)
Return `1` if the object provides mapping protocol or supports slicing, and `0` otherwise. Note that it returns `1` for Python classes with a `__getitem__()` method since in general case it is impossible to determine what the type of keys it supports. This function always succeeds.

Py_ssize_t **PyMapping_Size**(*PyObject* *o)
Py_ssize_t **PyMapping_Length**(*PyObject* *o)
Returns the number of keys in object *o* on success, and `-1` on failure. This is equivalent to the Python expression `len(o)`.

*PyObject** **PyMapping_GetItemString**(*PyObject* *o, const char *key)
Return value: New reference. Return element of *o* corresponding to the string *key* or *NULL* on failure. This is the equivalent of the Python expression `o[key]`. See also *PyObject_GetItem()*.

int **PyMapping_SetItemString**(*PyObject* *o, const char *key, *PyObject* *v)
Map the string *key* to the value *v* in object *o*. Returns `-1` on failure. This is the equivalent of the Python statement `o[key] = v`. See also *PyObject_SetItem()*.

int **PyMapping_DelItem**(*PyObject* *o, *PyObject* *key)
Remove the mapping for the object *key* from the object *o*. Return `-1` on failure. This is equivalent to the Python statement `del o[key]`. This is an alias of *PyObject_DelItem()*.

int **PyMapping_DelItemString**(*PyObject* *o, const char *key)
Remove the mapping for the string *key* from the object *o*. Return `-1` on failure. This is equivalent to the Python statement `del o[key]`.

int **PyMapping_HasKey**(*PyObject* *o, *PyObject* *key)
Return `1` if the mapping object has the key *key* and `0` otherwise. This is equivalent to the Python expression `key in o`. This function always succeeds.

int **PyMapping_HasKeyString**(*PyObject* *o, const char *key)
Return `1` if the mapping object has the key *key* and `0` otherwise. This is equivalent to the Python expression `key in o`. This function always succeeds.

*PyObject** **PyMapping_Keys**(*PyObject* *o)
Return value: New reference. On success, return a list of the keys in object *o*. On failure, return *NULL*.

Changed in version 3.7: Previously, the function returned a list or a tuple.

*PyObject** **PyMapping_Values**(*PyObject* *o)
Return value: New reference. On success, return a list of the values in object *o*. On failure, return *NULL*.

Changed in version 3.7: Previously, the function returned a list or a tuple.

*PyObject** **PyMapping_Items**(*PyObject* *o)
Return value: New reference. On success, return a list of the items in object *o*, where each item is a tuple containing a key-value pair. On failure, return *NULL*.

Changed in version 3.7: Previously, the function returned a list or a tuple.

7.5 Iterator Protocol

There are two functions specifically for working with iterators.

int **PyIter_Check**(*PyObject* *o)
Return true if the object *o* supports the iterator protocol.

*PyObject** **PyIter_Next**(*PyObject* *o)
Return value: New reference. Return the next value from the iteration *o*. The object must be an iterator (it is up to the caller to check this). If there are no remaining values, returns *NULL* with no exception set. If an error occurs while retrieving the item, returns *NULL* and passes along the exception.

To write a loop which iterates over an iterator, the C code should look something like this:

```
PyObject *iterator = PyObject_GetIter(obj);
PyObject *item;

if (iterator == NULL) {
    /* propagate error */
}
```

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```
while (item = PyIter_Next(iterator)) {
    /* do something with item */
    ...
    /* release reference when done */
    Py_DECREF(item);
}

Py_DECREF(iterator);

if (PyErr_Occurred()) {
    /* propagate error */
}
else {
    /* continue doing useful work */
}
```

7.6 Buffer Protocol

Certain objects available in Python wrap access to an underlying memory array or *buffer*. Such objects include the built-in `bytes` and `bytearray`, and some extension types like `array.array`. Third-party libraries may define their own types for special purposes, such as image processing or numeric analysis.

While each of these types have their own semantics, they share the common characteristic of being backed by a possibly large memory buffer. It is then desirable, in some situations, to access that buffer directly and without intermediate copying.

Python provides such a facility at the C level in the form of the *buffer protocol*. This protocol has two sides:

- on the producer side, a type can export a "buffer interface" which allows objects of that type to expose information about their underlying buffer. This interface is described in the section *Buffer Object Structures*;
- on the consumer side, several means are available to obtain a pointer to the raw underlying data of an object (for example a method parameter).

Simple objects such as `bytes` and `bytearray` expose their underlying buffer in byte-oriented form. Other forms are possible; for example, the elements exposed by an `array.array` can be multi-byte values.

An example consumer of the buffer interface is the `write()` method of file objects: any object that can export a series of bytes through the buffer interface can be written to a file. While `write()` only needs read-only access to the internal contents of the object passed to it, other methods such as `readinto()` need write access to the contents of their argument. The buffer interface allows objects to selectively allow or reject exporting of read-write and read-only buffers.

There are two ways for a consumer of the buffer interface to acquire a buffer over a target object:

- call *PyObject_GetBuffer()* with the right parameters;
- call *PyArg_ParseTuple()* (or one of its siblings) with one of the `y*`, `w*` or `s*` *format codes*.

In both cases, *PyBuffer_Release()* must be called when the buffer isn't needed anymore. Failure to do so could lead to various issues such as resource leaks.

7.6.1 Buffer structure

Buffer structures (or simply "buffers") are useful as a way to expose the binary data from another object to the Python programmer. They can also be used as a zero-copy slicing mechanism. Using their ability

to reference a block of memory, it is possible to expose any data to the Python programmer quite easily. The memory could be a large, constant array in a C extension, it could be a raw block of memory for manipulation before passing to an operating system library, or it could be used to pass around structured data in its native, in-memory format.

Contrary to most data types exposed by the Python interpreter, buffers are not *PyObject* pointers but rather simple C structures. This allows them to be created and copied very simply. When a generic wrapper around a buffer is needed, a *memoryview* object can be created.

For short instructions how to write an exporting object, see *Buffer Object Structures*. For obtaining a buffer, see *PyObject_GetBuffer()*.

Py_buffer

void ***buf**
: A pointer to the start of the logical structure described by the buffer fields. This can be any location within the underlying physical memory block of the exporter. For example, with negative *strides* the value may point to the end of the memory block.

  For *contiguous* arrays, the value points to the beginning of the memory block.

void ***obj**
: A new reference to the exporting object. The reference is owned by the consumer and automatically decremented and set to *NULL* by *PyBuffer_Release()*. The field is the equivalent of the return value of any standard C-API function.

  As a special case, for *temporary* buffers that are wrapped by *PyMemoryView_FromBuffer()* or *PyBuffer_FillInfo()* this field is *NULL*. In general, exporting objects MUST NOT use this scheme.

Py_ssize_t **len**
: `product(shape) * itemsize`. For contiguous arrays, this is the length of the underlying memory block. For non-contiguous arrays, it is the length that the logical structure would have if it were copied to a contiguous representation.

  Accessing `((char *)buf)[0] up to ((char *)buf)[len-1]` is only valid if the buffer has been obtained by a request that guarantees contiguity. In most cases such a request will be *PyBUF_SIMPLE* or *PyBUF_WRITABLE*.

int **readonly**
: An indicator of whether the buffer is read-only. This field is controlled by the *PyBUF_WRITABLE* flag.

Py_ssize_t **itemsize**
: Item size in bytes of a single element. Same as the value of `struct.calcsize()` called on non-NULL *format* values.

  Important exception: If a consumer requests a buffer without the *PyBUF_FORMAT* flag, *format* will be set to *NULL*, but *itemsize* still has the value for the original format.

  If *shape* is present, the equality `product(shape) * itemsize == len` still holds and the consumer can use *itemsize* to navigate the buffer.

  If *shape* is *NULL* as a result of a *PyBUF_SIMPLE* or a *PyBUF_WRITABLE* request, the consumer must disregard *itemsize* and assume `itemsize == 1`.

const char ***format**
: A *NUL* terminated string in `struct` module style syntax describing the contents of a single item. If this is *NULL*, `"B"` (unsigned bytes) is assumed.

  This field is controlled by the *PyBUF_FORMAT* flag.

int **ndim**
: The number of dimensions the memory represents as an n-dimensional array. If it is `0`, *buf* points to a single item representing a scalar. In this case, *shape*, *strides* and *suboffsets* MUST be *NULL*.

  The macro `PyBUF_MAX_NDIM` limits the maximum number of dimensions to 64. Exporters MUST respect this limit, consumers of multi-dimensional buffers SHOULD be able to handle up to `PyBUF_MAX_NDIM` dimensions.

Py_ssize_t ***shape**
: An array of `Py_ssize_t` of length *ndim* indicating the shape of the memory as an n-dimensional array. Note that `shape[0] * ... * shape[ndim-1] * itemsize` MUST be equal to *len*.

  Shape values are restricted to `shape[n] >= 0`. The case `shape[n] == 0` requires special attention. See *complex arrays* for further information.

  The shape array is read-only for the consumer.

Py_ssize_t ***strides**
: An array of `Py_ssize_t` of length *ndim* giving the number of bytes to skip to get to a new element in each dimension.

  Stride values can be any integer. For regular arrays, strides are usually positive, but a consumer MUST be able to handle the case `strides[n] <= 0`. See *complex arrays* for further information.

  The strides array is read-only for the consumer.

Py_ssize_t ***suboffsets**
: An array of `Py_ssize_t` of length *ndim*. If `suboffsets[n] >= 0`, the values stored along the nth dimension are pointers and the suboffset value dictates how many bytes to add to each pointer after de-referencing. A suboffset value that is negative indicates that no de-referencing should occur (striding in a contiguous memory block).

  If all suboffsets are negative (i.e. no de-referencing is needed, then this field must be NULL (the default value).

  This type of array representation is used by the Python Imaging Library (PIL). See *complex arrays* for further information how to access elements of such an array.

  The suboffsets array is read-only for the consumer.

void ***internal**
: This is for use internally by the exporting object. For example, this might be re-cast as an integer by the exporter and used to store flags about whether or not the shape, strides, and suboffsets arrays must be freed when the buffer is released. The consumer MUST NOT alter this value.

7.6.2 Buffer request types

Buffers are usually obtained by sending a buffer request to an exporting object via *PyObject_GetBuffer()*. Since the complexity of the logical structure of the memory can vary drastically, the consumer uses the *flags* argument to specify the exact buffer type it can handle.

All *Py_buffer* fields are unambiguously defined by the request type.

request-independent fields

The following fields are not influenced by *flags* and must always be filled in with the correct values: *obj*, *buf*, *len*, *itemsize*, *ndim*.

readonly, format

`PyBUF_WRITABLE`
: Controls the *readonly* field. If set, the exporter MUST provide a writable buffer or else report failure. Otherwise, the exporter MAY provide either a read-only or writable buffer, but the choice MUST be consistent for all consumers.

`PyBUF_FORMAT`
: Controls the *format* field. If set, this field MUST be filled in correctly. Otherwise, this field MUST be *NULL*.

PyBUF_WRITABLE can be |'d to any of the flags in the next section. Since *PyBUF_SIMPLE* is defined as 0, *PyBUF_WRITABLE* can be used as a stand-alone flag to request a simple writable buffer.

PyBUF_FORMAT can be |'d to any of the flags except *PyBUF_SIMPLE*. The latter already implies format `B` (unsigned bytes).

shape, strides, suboffsets

The flags that control the logical structure of the memory are listed in decreasing order of complexity. Note that each flag contains all bits of the flags below it.

Request	shape	strides	suboffsets
`PyBUF_INDIRECT`	yes	yes	if needed
`PyBUF_STRIDES`	yes	yes	NULL
`PyBUF_ND`	yes	NULL	NULL
`PyBUF_SIMPLE`	NULL	NULL	NULL

contiguity requests

C or Fortran *contiguity* can be explicitly requested, with and without stride information. Without stride information, the buffer must be C-contiguous.

Request	shape	strides	suboffsets	contig
`PyBUF_C_CONTIGUOUS`	yes	yes	NULL	C
`PyBUF_F_CONTIGUOUS`	yes	yes	NULL	F
`PyBUF_ANY_CONTIGUOUS`	yes	yes	NULL	C or F
`PyBUF_ND`	yes	NULL	NULL	C

compound requests

All possible requests are fully defined by some combination of the flags in the previous section. For convenience, the buffer protocol provides frequently used combinations as single flags.

In the following table *U* stands for undefined contiguity. The consumer would have to call *PyBuffer_IsContiguous()* to determine contiguity.

Request	shape	strides	suboffsets	contig	readonly	format
PyBUF_FULL	yes	yes	if needed	U	0	yes
PyBUF_FULL_RO	yes	yes	if needed	U	1 or 0	yes
PyBUF_RECORDS	yes	yes	NULL	U	0	yes
PyBUF_RECORDS_RO	yes	yes	NULL	U	1 or 0	yes
PyBUF_STRIDED	yes	yes	NULL	U	0	NULL
PyBUF_STRIDED_RO	yes	yes	NULL	U	1 or 0	NULL
PyBUF_CONTIG	yes	NULL	NULL	C	0	NULL
PyBUF_CONTIG_RO	yes	NULL	NULL	C	1 or 0	NULL

7.6.3 Complex arrays

NumPy-style: shape and strides

The logical structure of NumPy-style arrays is defined by *itemsize*, *ndim*, *shape* and *strides*.

If `ndim == 0`, the memory location pointed to by *buf* is interpreted as a scalar of size *itemsize*. In that case, both *shape* and *strides* are *NULL*.

If *strides* is *NULL*, the array is interpreted as a standard n-dimensional C-array. Otherwise, the consumer must access an n-dimensional array as follows:

```
ptr = (char *)buf + indices[0] * strides[0] + ... + indices[n-1] * strides[n-1]
item = *((typeof(item) *)ptr);
```

As noted above, *buf* can point to any location within the actual memory block. An exporter can check the validity of a buffer with this function:

```
def verify_structure(memlen, itemsize, ndim, shape, strides, offset):
    """Verify that the parameters represent a valid array within
       the bounds of the allocated memory:
           char *mem: start of the physical memory block
           memlen: length of the physical memory block
           offset: (char *)buf - mem
    """
```

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```
    if offset % itemsize:
        return False
    if offset < 0 or offset+itemsize > memlen:
        return False
    if any(v % itemsize for v in strides):
        return False

    if ndim <= 0:
        return ndim == 0 and not shape and not strides
    if 0 in shape:
        return True

    imin = sum(strides[j]*(shape[j]-1) for j in range(ndim)
               if strides[j] <= 0)
    imax = sum(strides[j]*(shape[j]-1) for j in range(ndim)
               if strides[j] > 0)

    return 0 <= offset+imin and offset+imax+itemsize <= memlen
```

PIL-style: shape, strides and suboffsets

In addition to the regular items, PIL-style arrays can contain pointers that must be followed in order to get to the next element in a dimension. For example, the regular three-dimensional C-array `char v[2][2][3]` can also be viewed as an array of 2 pointers to 2 two-dimensional arrays: `char (*v[2])[2][3]`. In suboffsets representation, those two pointers can be embedded at the start of *buf*, pointing to two `char x[2][3]` arrays that can be located anywhere in memory.

Here is a function that returns a pointer to the element in an N-D array pointed to by an N-dimensional index when there are both non-NULL strides and suboffsets:

```
void *get_item_pointer(int ndim, void *buf, Py_ssize_t *strides,
                       Py_ssize_t *suboffsets, Py_ssize_t *indices) {
    char *pointer = (char*)buf;
    int i;
    for (i = 0; i < ndim; i++) {
        pointer += strides[i] * indices[i];
        if (suboffsets[i] >=0 ) {
            pointer = *((char**)pointer) + suboffsets[i];
        }
    }
    return (void*)pointer;
}
```

7.6.4 Buffer-related functions

int **PyObject_CheckBuffer**(*PyObject* *obj)
: Return 1 if *obj* supports the buffer interface otherwise 0. When 1 is returned, it doesn't guarantee that *PyObject_GetBuffer()* will succeed.

int **PyObject_GetBuffer**(*PyObject* *exporter, *Py_buffer* *view, int *flags*)
: Send a request to *exporter* to fill in *view* as specified by *flags*. If the exporter cannot provide a buffer of the exact type, it MUST raise `PyExc_BufferError`, set `view->obj` to *NULL* and return `-1`.

  On success, fill in *view*, set `view->obj` to a new reference to *exporter* and return 0. In the case of chained buffer providers that redirect requests to a single object, `view->obj` MAY refer to this object

instead of *exporter* (See *Buffer Object Structures*).

Successful calls to *PyObject_GetBuffer()* must be paired with calls to *PyBuffer_Release()*, similar to `malloc()` and `free()`. Thus, after the consumer is done with the buffer, *PyBuffer_Release()* must be called exactly once.

void **PyBuffer_Release**(*Py_buffer* *view)
Release the buffer *view* and decrement the reference count for `view->obj`. This function MUST be called when the buffer is no longer being used, otherwise reference leaks may occur.

It is an error to call this function on a buffer that was not obtained via *PyObject_GetBuffer()*.

Py_ssize_t **PyBuffer_SizeFromFormat**(const char *)
Return the implied *itemsize* from *format*. This function is not yet implemented.

int **PyBuffer_IsContiguous**(*Py_buffer* *view, char *order*)
Return `1` if the memory defined by the *view* is C-style (*order* is `'C'`) or Fortran-style (*order* is `'F'`) *contiguous* or either one (*order* is `'A'`). Return `0` otherwise.

int **PyBuffer_ToContiguous**(void *buf, *Py_buffer* *src, Py_ssize_t *len*, char *order*)
Copy *len* bytes from *src* to its contiguous representation in *buf*. *order* can be `'C'` or `'F'` (for C-style or Fortran-style ordering). `0` is returned on success, `-1` on error.

This function fails if *len* != *src->len*.

void **PyBuffer_FillContiguousStrides**(int *ndims*, Py_ssize_t *shape, Py_ssize_t *strides, int *itemsize*, char *order*)
Fill the *strides* array with byte-strides of a *contiguous* (C-style if *order* is `'C'` or Fortran-style if *order* is `'F'`) array of the given shape with the given number of bytes per element.

int **PyBuffer_FillInfo**(*Py_buffer* *view, *PyObject* *exporter, void *buf, Py_ssize_t *len*, int *readonly*, int *flags*)
Handle buffer requests for an exporter that wants to expose *buf* of size *len* with writability set according to *readonly*. *buf* is interpreted as a sequence of unsigned bytes.

The *flags* argument indicates the request type. This function always fills in *view* as specified by flags, unless *buf* has been designated as read-only and *PyBUF_WRITABLE* is set in *flags*.

On success, set `view->obj` to a new reference to *exporter* and return 0. Otherwise, raise `PyExc_BufferError`, set `view->obj` to *NULL* and return `-1`;

If this function is used as part of a *getbufferproc*, *exporter* MUST be set to the exporting object and *flags* must be passed unmodified. Otherwise, *exporter* MUST be NULL.

7.7 Old Buffer Protocol

Deprecated since version 3.0.

These functions were part of the "old buffer protocol" API in Python 2. In Python 3, this protocol doesn't exist anymore but the functions are still exposed to ease porting 2.x code. They act as a compatibility wrapper around the *new buffer protocol*, but they don't give you control over the lifetime of the resources acquired when a buffer is exported.

Therefore, it is recommended that you call *PyObject_GetBuffer()* (or the `y*` or `w*` *format codes* with the *PyArg_ParseTuple()* family of functions) to get a buffer view over an object, and *PyBuffer_Release()* when the buffer view can be released.

int **PyObject_AsCharBuffer**(*PyObject* *obj, const char **buffer, Py_ssize_t *buffer_len*)
Returns a pointer to a read-only memory location usable as character-based input. The *obj* argument must support the single-segment character buffer interface. On success, returns `0`, sets *buffer* to the memory location and *buffer_len* to the buffer length. Returns `-1` and sets a `TypeError` on error.

int **PyObject_AsReadBuffer**(*PyObject* **obj*, const void ***buffer*, Py_ssize_t **buffer_len*)
Returns a pointer to a read-only memory location containing arbitrary data. The *obj* argument must support the single-segment readable buffer interface. On success, returns `0`, sets *buffer* to the memory location and *buffer_len* to the buffer length. Returns `-1` and sets a `TypeError` on error.

int **PyObject_CheckReadBuffer**(*PyObject* **o*)
Returns `1` if *o* supports the single-segment readable buffer interface. Otherwise returns `0`.

int **PyObject_AsWriteBuffer**(*PyObject* **obj*, void ***buffer*, Py_ssize_t **buffer_len*)
Returns a pointer to a writable memory location. The *obj* argument must support the single-segment, character buffer interface. On success, returns `0`, sets *buffer* to the memory location and *buffer_len* to the buffer length. Returns `-1` and sets a `TypeError` on error.

CHAPTER

EIGHT

CONCRETE OBJECTS LAYER

The functions in this chapter are specific to certain Python object types. Passing them an object of the wrong type is not a good idea; if you receive an object from a Python program and you are not sure that it has the right type, you must perform a type check first; for example, to check that an object is a dictionary, use *PyDict_Check()*. The chapter is structured like the "family tree" of Python object types.

Warning: While the functions described in this chapter carefully check the type of the objects which are passed in, many of them do not check for *NULL* being passed instead of a valid object. Allowing *NULL* to be passed in can cause memory access violations and immediate termination of the interpreter.

8.1 Fundamental Objects

This section describes Python type objects and the singleton object `None`.

8.1.1 Type Objects

PyTypeObject
The C structure of the objects used to describe built-in types.

*PyObject** **PyType_Type**
This is the type object for type objects; it is the same object as `type` in the Python layer.

int **PyType_Check**(*PyObject *o*)
Return true if the object *o* is a type object, including instances of types derived from the standard type object. Return false in all other cases.

int **PyType_CheckExact**(*PyObject *o*)
Return true if the object *o* is a type object, but not a subtype of the standard type object. Return false in all other cases.

unsigned int **PyType_ClearCache**()
Clear the internal lookup cache. Return the current version tag.

long **PyType_GetFlags**(*PyTypeObject** *type*)
Return the *tp_flags* member of *type*. This function is primarily meant for use with *Py_LIMITED_API*; the individual flag bits are guaranteed to be stable across Python releases, but access to *tp_flags* itself is not part of the limited API.

New in version 3.2.

void **PyType_Modified**(*PyTypeObject *type*)
Invalidate the internal lookup cache for the type and all of its subtypes. This function must be called after any manual modification of the attributes or base classes of the type.

int **PyType_HasFeature**(*PyTypeObject* *o*, int *feature*)
Return true if the type object *o* sets the feature *feature*. Type features are denoted by single bit flags.

int **PyType_IS_GC**(*PyTypeObject* *o*)
Return true if the type object includes support for the cycle detector; this tests the type flag *Py_TPFLAGS_HAVE_GC*.

int **PyType_IsSubtype**(*PyTypeObject* *a*, *PyTypeObject* *b*)
Return true if *a* is a subtype of *b*.

This function only checks for actual subtypes, which means that `__subclasscheck__()` is not called on *b*. Call *PyObject_IsSubclass()* to do the same check that `issubclass()` would do.

*PyObject** **PyType_GenericAlloc**(*PyTypeObject* *type*, Py_ssize_t *nitems*)
Return value: New reference. Generic handler for the *tp_alloc* slot of a type object. Use Python's default memory allocation mechanism to allocate a new instance and initialize all its contents to *NULL*.

*PyObject** **PyType_GenericNew**(*PyTypeObject* *type*, *PyObject* *args*, *PyObject* *kwds*)
Return value: New reference. Generic handler for the *tp_new* slot of a type object. Create a new instance using the type's *tp_alloc* slot.

int **PyType_Ready**(*PyTypeObject* *type*)
Finalize a type object. This should be called on all type objects to finish their initialization. This function is responsible for adding inherited slots from a type's base class. Return `0` on success, or return `-1` and sets an exception on error.

*PyObject** **PyType_FromSpec**(PyType_Spec *spec*)
Creates and returns a heap type object from the *spec* passed to the function.

*PyObject** **PyType_FromSpecWithBases**(PyType_Spec *spec*, *PyObject* *bases*)
Creates and returns a heap type object from the *spec*. In addition to that, the created heap type contains all types contained by the *bases* tuple as base types. This allows the caller to reference other heap types as base types.

New in version 3.3.

void* **PyType_GetSlot**(*PyTypeObject* *type*, int *slot*)
Return the function pointer stored in the given slot. If the result is *NULL*, this indicates that either the slot is *NULL*, or that the function was called with invalid parameters. Callers will typically cast the result pointer into the appropriate function type.

New in version 3.4.

8.1.2 The `None` Object

Note that the *PyTypeObject* for `None` is not directly exposed in the Python/C API. Since `None` is a singleton, testing for object identity (using `==` in C) is sufficient. There is no `PyNone_Check()` function for the same reason.

*PyObject** **Py_None**
The Python `None` object, denoting lack of value. This object has no methods. It needs to be treated just like any other object with respect to reference counts.

Py_RETURN_NONE
Properly handle returning *Py_None* from within a C function (that is, increment the reference count of `None` and return it.)

8.2 Numeric Objects

8.2.1 Integer Objects

All integers are implemented as "long" integer objects of arbitrary size.

On error, most `PyLong_As*` APIs return `(return type)-1` which cannot be distinguished from a number. Use *PyErr_Occurred()* to disambiguate.

PyLongObject
This subtype of *PyObject* represents a Python integer object.

PyTypeObject **PyLong_Type**
This instance of *PyTypeObject* represents the Python integer type. This is the same object as `int` in the Python layer.

int **PyLong_Check**(*PyObject* *p)
Return true if its argument is a *PyLongObject* or a subtype of *PyLongObject*.

int **PyLong_CheckExact**(*PyObject* *p)
Return true if its argument is a *PyLongObject*, but not a subtype of *PyLongObject*.

*PyObject** **PyLong_FromLong**(long *v*)
Return value: New reference. Return a new *PyLongObject* object from *v*, or *NULL* on failure.

The current implementation keeps an array of integer objects for all integers between `-5` and `256`, when you create an int in that range you actually just get back a reference to the existing object. So it should be possible to change the value of `1`. I suspect the behaviour of Python in this case is undefined. :-)

*PyObject** **PyLong_FromUnsignedLong**(unsigned long *v*)
Return value: New reference. Return a new *PyLongObject* object from a C `unsigned long`, or *NULL* on failure.

*PyObject** **PyLong_FromSsize_t**(Py_ssize_t *v*)
Return a new *PyLongObject* object from a C `Py_ssize_t`, or *NULL* on failure.

*PyObject** **PyLong_FromSize_t**(size_t *v*)
Return a new *PyLongObject* object from a C `size_t`, or *NULL* on failure.

*PyObject** **PyLong_FromLongLong**(long long *v*)
Return value: New reference. Return a new *PyLongObject* object from a C `long long`, or *NULL* on failure.

*PyObject** **PyLong_FromUnsignedLongLong**(unsigned long long *v*)
Return value: New reference. Return a new *PyLongObject* object from a C `unsigned long long`, or *NULL* on failure.

*PyObject** **PyLong_FromDouble**(double *v*)
Return value: New reference. Return a new *PyLongObject* object from the integer part of *v*, or *NULL* on failure.

*PyObject** **PyLong_FromString**(const char **str*, char ***pend*, int *base*)
Return value: New reference. Return a new *PyLongObject* based on the string value in *str*, which is interpreted according to the radix in *base*. If *pend* is non-*NULL*, **pend* will point to the first character in *str* which follows the representation of the number. If *base* is `0`, *str* is interpreted using the integers definition; in this case, leading zeros in a non-zero decimal number raises a `ValueError`. If *base* is not `0`, it must be between `2` and `36`, inclusive. Leading spaces and single underscores after a base specifier and between digits are ignored. If there are no digits, `ValueError` will be raised.

*PyObject** **PyLong_FromUnicode**(*Py_UNICODE* *u*, Py_ssize_t *length*, int *base*)
Return value: New reference. Convert a sequence of Unicode digits to a Python integer value. The

Unicode string is first encoded to a byte string using `PyUnicode_EncodeDecimal()` and then converted using *PyLong_FromString()*.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyLong_FromUnicodeObject()*.

*PyObject** **PyLong_FromUnicodeObject**(*PyObject* *u, int *base*)
Convert a sequence of Unicode digits in the string *u* to a Python integer value. The Unicode string is first encoded to a byte string using `PyUnicode_EncodeDecimal()` and then converted using *PyLong_FromString()*.

New in version 3.3.

*PyObject** **PyLong_FromVoidPtr**(void *p)
Return value: New reference. Create a Python integer from the pointer *p*. The pointer value can be retrieved from the resulting value using *PyLong_AsVoidPtr()*.

long **PyLong_AsLong**(*PyObject* *obj)
Return a C `long` representation of *obj*. If *obj* is not an instance of *PyLongObject*, first call its `__int__()` method (if present) to convert it to a *PyLongObject*.

Raise `OverflowError` if the value of *obj* is out of range for a `long`.

Returns `-1` on error. Use *PyErr_Occurred()* to disambiguate.

long **PyLong_AsLongAndOverflow**(*PyObject* *obj, int *overflow)
Return a C `long` representation of *obj*. If *obj* is not an instance of *PyLongObject*, first call its `__int__()` method (if present) to convert it to a *PyLongObject*.

If the value of *obj* is greater than `LONG_MAX` or less than `LONG_MIN`, set **overflow* to `1` or `-1`, respectively, and return `-1`; otherwise, set **overflow* to `0`. If any other exception occurs set **overflow* to `0` and return `-1` as usual.

Returns `-1` on error. Use *PyErr_Occurred()* to disambiguate.

long long **PyLong_AsLongLong**(*PyObject* *obj)
Return a C `long long` representation of *obj*. If *obj* is not an instance of *PyLongObject*, first call its `__int__()` method (if present) to convert it to a *PyLongObject*.

Raise `OverflowError` if the value of *obj* is out of range for a `long`.

Returns `-1` on error. Use *PyErr_Occurred()* to disambiguate.

long long **PyLong_AsLongLongAndOverflow**(*PyObject* *obj, int *overflow)
Return a C `long long` representation of *obj*. If *obj* is not an instance of *PyLongObject*, first call its `__int__()` method (if present) to convert it to a *PyLongObject*.

If the value of *obj* is greater than `PY_LLONG_MAX` or less than `PY_LLONG_MIN`, set **overflow* to `1` or `-1`, respectively, and return `-1`; otherwise, set **overflow* to `0`. If any other exception occurs set **overflow* to `0` and return `-1` as usual.

Returns `-1` on error. Use *PyErr_Occurred()* to disambiguate.

New in version 3.2.

Py_ssize_t **PyLong_AsSsize_t**(*PyObject* *pylong)
Return a C `Py_ssize_t` representation of *pylong*. *pylong* must be an instance of *PyLongObject*.

Raise `OverflowError` if the value of *pylong* is out of range for a `Py_ssize_t`.

Returns `-1` on error. Use *PyErr_Occurred()* to disambiguate.

unsigned long **PyLong_AsUnsignedLong**(*PyObject* *pylong)
Return a C `unsigned long` representation of *pylong*. *pylong* must be an instance of *PyLongObject*.

Raise `OverflowError` if the value of *pylong* is out of range for a `unsigned long`.

Returns (unsigned long)-1 on error. Use *PyErr_Occurred()* to disambiguate.

size_t **PyLong_AsSize_t**(*PyObject* **pylong*)
Return a C size_t representation of *pylong*. *pylong* must be an instance of *PyLongObject*.

Raise OverflowError if the value of *pylong* is out of range for a size_t.

Returns (size_t)-1 on error. Use *PyErr_Occurred()* to disambiguate.

unsigned long long **PyLong_AsUnsignedLongLong**(*PyObject* **pylong*)
Return a C unsigned long long representation of *pylong*. *pylong* must be an instance of *PyLongObject*.

Raise OverflowError if the value of *pylong* is out of range for an unsigned long long.

Returns (unsigned long long)-1 on error. Use *PyErr_Occurred()* to disambiguate.

Changed in version 3.1: A negative *pylong* now raises OverflowError, not TypeError.

unsigned long **PyLong_AsUnsignedLongMask**(*PyObject* **obj*)
Return a C unsigned long representation of *obj*. If *obj* is not an instance of *PyLongObject*, first call its __int__() method (if present) to convert it to a *PyLongObject*.

If the value of *obj* is out of range for an unsigned long, return the reduction of that value modulo ULONG_MAX + 1.

Returns -1 on error. Use *PyErr_Occurred()* to disambiguate.

unsigned long long **PyLong_AsUnsignedLongLongMask**(*PyObject* **obj*)
Return a C unsigned long long representation of *obj*. If *obj* is not an instance of *PyLongObject*, first call its __int__() method (if present) to convert it to a *PyLongObject*.

If the value of *obj* is out of range for an unsigned long long, return the reduction of that value modulo PY_ULLONG_MAX + 1.

Returns -1 on error. Use *PyErr_Occurred()* to disambiguate.

double **PyLong_AsDouble**(*PyObject* **pylong*)
Return a C double representation of *pylong*. *pylong* must be an instance of *PyLongObject*.

Raise OverflowError if the value of *pylong* is out of range for a double.

Returns -1.0 on error. Use *PyErr_Occurred()* to disambiguate.

void* **PyLong_AsVoidPtr**(*PyObject* **pylong*)
Convert a Python integer *pylong* to a C void pointer. If *pylong* cannot be converted, an OverflowError will be raised. This is only assured to produce a usable void pointer for values created with *PyLong_FromVoidPtr()*.

Returns *NULL* on error. Use *PyErr_Occurred()* to disambiguate.

8.2.2 Boolean Objects

Booleans in Python are implemented as a subclass of integers. There are only two booleans, Py_False and Py_True. As such, the normal creation and deletion functions don't apply to booleans. The following macros are available, however.

int **PyBool_Check**(*PyObject* **o*)
Return true if *o* is of type PyBool_Type.

*PyObject** **Py_False**
The Python False object. This object has no methods. It needs to be treated just like any other object with respect to reference counts.

*PyObject** **Py_True**
The Python `True` object. This object has no methods. It needs to be treated just like any other object with respect to reference counts.

Py_RETURN_FALSE
Return `Py_False` from a function, properly incrementing its reference count.

Py_RETURN_TRUE
Return `Py_True` from a function, properly incrementing its reference count.

*PyObject** **PyBool_FromLong**(long *v*)
Return value: New reference. Return a new reference to `Py_True` or `Py_False` depending on the truth value of *v*.

8.2.3 Floating Point Objects

PyFloatObject
This subtype of *PyObject* represents a Python floating point object.

PyTypeObject **PyFloat_Type**
This instance of *PyTypeObject* represents the Python floating point type. This is the same object as `float` in the Python layer.

int **PyFloat_Check**(*PyObject *p*)
Return true if its argument is a *PyFloatObject* or a subtype of *PyFloatObject*.

int **PyFloat_CheckExact**(*PyObject *p*)
Return true if its argument is a *PyFloatObject*, but not a subtype of *PyFloatObject*.

*PyObject** **PyFloat_FromString**(*PyObject *str*)
Return value: New reference. Create a *PyFloatObject* object based on the string value in *str*, or *NULL* on failure.

*PyObject** **PyFloat_FromDouble**(double *v*)
Return value: New reference. Create a *PyFloatObject* object from *v*, or *NULL* on failure.

double **PyFloat_AsDouble**(*PyObject *pyfloat*)
Return a C `double` representation of the contents of *pyfloat*. If *pyfloat* is not a Python floating point object but has a `__float__()` method, this method will first be called to convert *pyfloat* into a float. This method returns `-1.0` upon failure, so one should call *PyErr_Occurred()* to check for errors.

double **PyFloat_AS_DOUBLE**(*PyObject *pyfloat*)
Return a C `double` representation of the contents of *pyfloat*, but without error checking.

*PyObject** **PyFloat_GetInfo**(void)
Return a structseq instance which contains information about the precision, minimum and maximum values of a float. It's a thin wrapper around the header file `float.h`.

double **PyFloat_GetMax**()
Return the maximum representable finite float *DBL_MAX* as C `double`.

double **PyFloat_GetMin**()
Return the minimum normalized positive float *DBL_MIN* as C `double`.

int **PyFloat_ClearFreeList**()
Clear the float free list. Return the number of items that could not be freed.

8.2.4 Complex Number Objects

Python's complex number objects are implemented as two distinct types when viewed from the C API: one is the Python object exposed to Python programs, and the other is a C structure which represents the actual

complex number value. The API provides functions for working with both.

Complex Numbers as C Structures

Note that the functions which accept these structures as parameters and return them as results do so *by value* rather than dereferencing them through pointers. This is consistent throughout the API.

Py_complex
The C structure which corresponds to the value portion of a Python complex number object. Most of the functions for dealing with complex number objects use structures of this type as input or output values, as appropriate. It is defined as:

```
typedef struct {
   double real;
   double imag;
} Py_complex;
```

Py_complex **_Py_c_sum**(*Py_complex left*, *Py_complex right*)
Return the sum of two complex numbers, using the C *Py_complex* representation.

Py_complex **_Py_c_diff**(*Py_complex left*, *Py_complex right*)
Return the difference between two complex numbers, using the C *Py_complex* representation.

Py_complex **_Py_c_neg**(*Py_complex complex*)
Return the negation of the complex number *complex*, using the C *Py_complex* representation.

Py_complex **_Py_c_prod**(*Py_complex left*, *Py_complex right*)
Return the product of two complex numbers, using the C *Py_complex* representation.

Py_complex **_Py_c_quot**(*Py_complex dividend*, *Py_complex divisor*)
Return the quotient of two complex numbers, using the C *Py_complex* representation.

If *divisor* is null, this method returns zero and sets `errno` to `EDOM`.

Py_complex **_Py_c_pow**(*Py_complex num*, *Py_complex exp*)
Return the exponentiation of *num* by *exp*, using the C *Py_complex* representation.

If *num* is null and *exp* is not a positive real number, this method returns zero and sets `errno` to `EDOM`.

Complex Numbers as Python Objects

PyComplexObject
This subtype of *PyObject* represents a Python complex number object.

PyTypeObject **PyComplex_Type**
This instance of *PyTypeObject* represents the Python complex number type. It is the same object as `complex` in the Python layer.

int **PyComplex_Check**(*PyObject* *p)
Return true if its argument is a *PyComplexObject* or a subtype of *PyComplexObject*.

int **PyComplex_CheckExact**(*PyObject* *p)
Return true if its argument is a *PyComplexObject*, but not a subtype of *PyComplexObject*.

*PyObject** **PyComplex_FromCComplex**(*Py_complex v*)
Return value: New reference. Create a new Python complex number object from a C *Py_complex* value.

*PyObject** **PyComplex_FromDoubles**(double *real*, double *imag*)
Return value: New reference. Return a new *PyComplexObject* object from *real* and *imag*.

double **PyComplex_RealAsDouble**(*PyObject* *op)
Return the real part of *op* as a C `double`.

double **PyComplex_ImagAsDouble**(*PyObject* *op)
Return the imaginary part of *op* as a C `double`.

Py_complex **PyComplex_AsCComplex**(*PyObject* *op)
Return the *Py_complex* value of the complex number *op*.

If *op* is not a Python complex number object but has a `__complex__()` method, this method will first be called to convert *op* to a Python complex number object. Upon failure, this method returns `-1.0` as a real value.

8.3 Sequence Objects

Generic operations on sequence objects were discussed in the previous chapter; this section deals with the specific kinds of sequence objects that are intrinsic to the Python language.

8.3.1 Bytes Objects

These functions raise `TypeError` when expecting a bytes parameter and are called with a non-bytes parameter.

PyBytesObject
This subtype of *PyObject* represents a Python bytes object.

PyTypeObject **PyBytes_Type**
This instance of *PyTypeObject* represents the Python bytes type; it is the same object as `bytes` in the Python layer.

int **PyBytes_Check**(*PyObject* *o)
Return true if the object *o* is a bytes object or an instance of a subtype of the bytes type.

int **PyBytes_CheckExact**(*PyObject* *o)
Return true if the object *o* is a bytes object, but not an instance of a subtype of the bytes type.

*PyObject** **PyBytes_FromString**(const char *v)
Return a new bytes object with a copy of the string *v* as value on success, and *NULL* on failure. The parameter *v* must not be *NULL*; it will not be checked.

*PyObject** **PyBytes_FromStringAndSize**(const char *v, Py_ssize_t *len*)
Return a new bytes object with a copy of the string *v* as value and length *len* on success, and *NULL* on failure. If *v* is *NULL*, the contents of the bytes object are uninitialized.

*PyObject** **PyBytes_FromFormat**(const char *format, ...)
Take a C `printf()`-style *format* string and a variable number of arguments, calculate the size of the resulting Python bytes object and return a bytes object with the values formatted into it. The variable arguments must be C types and must correspond exactly to the format characters in the *format* string. The following format characters are allowed:

Format Characters	Type	Comment
%%	*n/a*	The literal % character.
%c	int	A single byte, represented as a C int.
%d	int	Equivalent to `printf("%d")`.[1]
%u	unsigned int	Equivalent to `printf("%u")`.[1]
%ld	long	Equivalent to `printf("%ld")`.[1]
%lu	unsigned long	Equivalent to `printf("%lu")`.[1]
%zd	Py_ssize_t	Equivalent to `printf("%zd")`.[1]
%zu	size_t	Equivalent to `printf("%zu")`.[1]
%i	int	Equivalent to `printf("%i")`.[1]
%x	int	Equivalent to `printf("%x")`.[1]
%s	const char*	A null-terminated C character array.
%p	const void*	The hex representation of a C pointer. Mostly equivalent to `printf("%p")` except that it is guaranteed to start with the literal `0x` regardless of what the platform's `printf` yields.

An unrecognized format character causes all the rest of the format string to be copied as-is to the result object, and any extra arguments discarded.

*PyObject** **PyBytes_FromFormatV**(const char **format*, va_list *vargs*)
Identical to *PyBytes_FromFormat()* except that it takes exactly two arguments.

*PyObject** **PyBytes_FromObject**(*PyObject *o*)
Return the bytes representation of object *o* that implements the buffer protocol.

Py_ssize_t **PyBytes_Size**(*PyObject *o*)
Return the length of the bytes in bytes object *o*.

Py_ssize_t **PyBytes_GET_SIZE**(*PyObject *o*)
Macro form of *PyBytes_Size()* but without error checking.

char* **PyBytes_AsString**(*PyObject *o*)
Return a pointer to the contents of *o*. The pointer refers to the internal buffer of *o*, which consists of `len(o) + 1` bytes. The last byte in the buffer is always null, regardless of whether there are any other null bytes. The data must not be modified in any way, unless the object was just created using `PyBytes_FromStringAndSize(NULL, size)`. It must not be deallocated. If *o* is not a bytes object at all, *PyBytes_AsString()* returns *NULL* and raises `TypeError`.

char* **PyBytes_AS_STRING**(*PyObject *string*)
Macro form of *PyBytes_AsString()* but without error checking.

int **PyBytes_AsStringAndSize**(*PyObject *obj*, char ***buffer*, Py_ssize_t **length*)
Return the null-terminated contents of the object *obj* through the output variables *buffer* and *length*.

If *length* is *NULL*, the bytes object may not contain embedded null bytes; if it does, the function returns `-1` and a `ValueError` is raised.

The buffer refers to an internal buffer of *obj*, which includes an additional null byte at the end (not counted in *length*). The data must not be modified in any way, unless the object was just created using `PyBytes_FromStringAndSize(NULL, size)`. It must not be deallocated. If *obj* is not a bytes object at all, *PyBytes_AsStringAndSize()* returns `-1` and raises `TypeError`.

Changed in version 3.5: Previously, `TypeError` was raised when embedded null bytes were encountered in the bytes object.

void **PyBytes_Concat**(*PyObject **bytes*, *PyObject *newpart*)
Create a new bytes object in **bytes* containing the contents of *newpart* appended to *bytes*; the caller

[1] For integer specifiers (d, u, ld, lu, zd, zu, i, x): the 0-conversion flag has effect even when a precision is given.

will own the new reference. The reference to the old value of *bytes* will be stolen. If the new object cannot be created, the old reference to *bytes* will still be discarded and the value of **bytes* will be set to *NULL*; the appropriate exception will be set.

void **PyBytes_ConcatAndDel**(*PyObject* ***bytes*, *PyObject* **newpart*)
Create a new bytes object in **bytes* containing the contents of *newpart* appended to *bytes*. This version decrements the reference count of *newpart*.

int **_PyBytes_Resize**(*PyObject* ***bytes*, Py_ssize_t *newsize*)
A way to resize a bytes object even though it is "immutable". Only use this to build up a brand new bytes object; don't use this if the bytes may already be known in other parts of the code. It is an error to call this function if the refcount on the input bytes object is not one. Pass the address of an existing bytes object as an lvalue (it may be written into), and the new size desired. On success, **bytes* holds the resized bytes object and `0` is returned; the address in **bytes* may differ from its input value. If the reallocation fails, the original bytes object at **bytes* is deallocated, **bytes* is set to *NULL*, `MemoryError` is set, and `-1` is returned.

8.3.2 Byte Array Objects

PyByteArrayObject
This subtype of *PyObject* represents a Python bytearray object.

PyTypeObject **PyByteArray_Type**
This instance of *PyTypeObject* represents the Python bytearray type; it is the same object as `bytearray` in the Python layer.

Type check macros

int **PyByteArray_Check**(*PyObject* **o*)
Return true if the object *o* is a bytearray object or an instance of a subtype of the bytearray type.

int **PyByteArray_CheckExact**(*PyObject* **o*)
Return true if the object *o* is a bytearray object, but not an instance of a subtype of the bytearray type.

Direct API functions

*PyObject** **PyByteArray_FromObject**(*PyObject* **o*)
Return a new bytearray object from any object, *o*, that implements the *buffer protocol*.

*PyObject** **PyByteArray_FromStringAndSize**(const char **string*, Py_ssize_t *len*)
Create a new bytearray object from *string* and its length, *len*. On failure, *NULL* is returned.

*PyObject** **PyByteArray_Concat**(*PyObject* **a*, *PyObject* **b*)
Concat bytearrays *a* and *b* and return a new bytearray with the result.

Py_ssize_t **PyByteArray_Size**(*PyObject* **bytearray*)
Return the size of *bytearray* after checking for a *NULL* pointer.

char* **PyByteArray_AsString**(*PyObject* **bytearray*)
Return the contents of *bytearray* as a char array after checking for a *NULL* pointer. The returned array always has an extra null byte appended.

int **PyByteArray_Resize**(*PyObject* **bytearray*, Py_ssize_t *len*)
Resize the internal buffer of *bytearray* to *len*.

Macros

These macros trade safety for speed and they don't check pointers.

char* **PyByteArray_AS_STRING**(*PyObject *bytearray*)
Macro version of *PyByteArray_AsString()*.

Py_ssize_t **PyByteArray_GET_SIZE**(*PyObject *bytearray*)
Macro version of *PyByteArray_Size()*.

8.3.3 Unicode Objects and Codecs

Unicode Objects

Since the implementation of **PEP 393** in Python 3.3, Unicode objects internally use a variety of representations, in order to allow handling the complete range of Unicode characters while staying memory efficient. There are special cases for strings where all code points are below 128, 256, or 65536; otherwise, code points must be below 1114112 (which is the full Unicode range).

*Py_UNICODE** and UTF-8 representations are created on demand and cached in the Unicode object. The *Py_UNICODE** representation is deprecated and inefficient; it should be avoided in performance- or memory-sensitive situations.

Due to the transition between the old APIs and the new APIs, unicode objects can internally be in two states depending on how they were created:

- "canonical" unicode objects are all objects created by a non-deprecated unicode API. They use the most efficient representation allowed by the implementation.
- "legacy" unicode objects have been created through one of the deprecated APIs (typically *PyUnicode_FromUnicode()*) and only bear the *Py_UNICODE** representation; you will have to call *PyUnicode_READY()* on them before calling any other API.

Unicode Type

These are the basic Unicode object types used for the Unicode implementation in Python:

Py_UCS4
Py_UCS2
Py_UCS1
These types are typedefs for unsigned integer types wide enough to contain characters of 32 bits, 16 bits and 8 bits, respectively. When dealing with single Unicode characters, use *Py_UCS4*.

New in version 3.3.

Py_UNICODE
This is a typedef of **wchar_t**, which is a 16-bit type or 32-bit type depending on the platform.

Changed in version 3.3: In previous versions, this was a 16-bit type or a 32-bit type depending on whether you selected a "narrow" or "wide" Unicode version of Python at build time.

PyASCIIObject
PyCompactUnicodeObject
PyUnicodeObject
These subtypes of *PyObject* represent a Python Unicode object. In almost all cases, they shouldn't be used directly, since all API functions that deal with Unicode objects take and return *PyObject* pointers.

New in version 3.3.

PyTypeObject **PyUnicode_Type**
This instance of *PyTypeObject* represents the Python Unicode type. It is exposed to Python code as `str`.

The following APIs are really C macros and can be used to do fast checks and to access internal read-only data of Unicode objects:

int **PyUnicode_Check**(*PyObject* *o)
Return true if the object *o* is a Unicode object or an instance of a Unicode subtype.

int **PyUnicode_CheckExact**(*PyObject* *o)
Return true if the object *o* is a Unicode object, but not an instance of a subtype.

int **PyUnicode_READY**(*PyObject* *o)
Ensure the string object *o* is in the "canonical" representation. This is required before using any of the access macros described below.

Returns `0` on success and `-1` with an exception set on failure, which in particular happens if memory allocation fails.

New in version 3.3.

Py_ssize_t **PyUnicode_GET_LENGTH**(*PyObject* *o)
Return the length of the Unicode string, in code points. *o* has to be a Unicode object in the "canonical" representation (not checked).

New in version 3.3.

*Py_UCS1** **PyUnicode_1BYTE_DATA**(*PyObject* *o)
*Py_UCS2** **PyUnicode_2BYTE_DATA**(*PyObject* *o)
*Py_UCS4** **PyUnicode_4BYTE_DATA**(*PyObject* *o)
Return a pointer to the canonical representation cast to UCS1, UCS2 or UCS4 integer types for direct character access. No checks are performed if the canonical representation has the correct character size; use *PyUnicode_KIND()* to select the right macro. Make sure *PyUnicode_READY()* has been called before accessing this.

New in version 3.3.

PyUnicode_WCHAR_KIND
PyUnicode_1BYTE_KIND
PyUnicode_2BYTE_KIND
PyUnicode_4BYTE_KIND
Return values of the *PyUnicode_KIND()* macro.

New in version 3.3.

int **PyUnicode_KIND**(*PyObject* *o)
Return one of the PyUnicode kind constants (see above) that indicate how many bytes per character this Unicode object uses to store its data. *o* has to be a Unicode object in the "canonical" representation (not checked).

New in version 3.3.

void* **PyUnicode_DATA**(*PyObject* *o)
Return a void pointer to the raw unicode buffer. *o* has to be a Unicode object in the "canonical" representation (not checked).

New in version 3.3.

void **PyUnicode_WRITE**(int *kind*, void **data*, Py_ssize_t *index*, *Py_UCS4* *value*)
Write into a canonical representation *data* (as obtained with *PyUnicode_DATA()*). This macro does not do any sanity checks and is intended for usage in loops. The caller should cache the *kind* value and *data* pointer as obtained from other macro calls. *index* is the index in the string (starts at 0) and *value* is the new code point value which should be written to that location.

New in version 3.3.

Py_UCS4 **PyUnicode_READ**(int *kind*, void **data*, Py_ssize_t *index*)
Read a code point from a canonical representation *data* (as obtained with *PyUnicode_DATA()*). No checks or ready calls are performed.

New in version 3.3.

Py_UCS4 **PyUnicode_READ_CHAR**(*PyObject *o*, Py_ssize_t *index*)
Read a character from a Unicode object *o*, which must be in the "canonical" representation. This is less efficient than *PyUnicode_READ()* if you do multiple consecutive reads.

New in version 3.3.

PyUnicode_MAX_CHAR_VALUE(*PyObject *o*)
Return the maximum code point that is suitable for creating another string based on *o*, which must be in the "canonical" representation. This is always an approximation but more efficient than iterating over the string.

New in version 3.3.

int **PyUnicode_ClearFreeList**()
Clear the free list. Return the total number of freed items.

Py_ssize_t **PyUnicode_GET_SIZE**(*PyObject *o*)
Return the size of the deprecated *Py_UNICODE* representation, in code units (this includes surrogate pairs as 2 units). *o* has to be a Unicode object (not checked).

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style Unicode API, please migrate to using *PyUnicode_GET_LENGTH()*.

Py_ssize_t **PyUnicode_GET_DATA_SIZE**(*PyObject *o*)
Return the size of the deprecated *Py_UNICODE* representation in bytes. *o* has to be a Unicode object (not checked).

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style Unicode API, please migrate to using *PyUnicode_GET_LENGTH()*.

*Py_UNICODE** **PyUnicode_AS_UNICODE**(*PyObject *o*)
const char* **PyUnicode_AS_DATA**(*PyObject *o*)
Return a pointer to a *Py_UNICODE* representation of the object. The returned buffer is always terminated with an extra null code point. It may also contain embedded null code points, which would cause the string to be truncated when used in most C functions. The `AS_DATA` form casts the pointer to `const char *`. The *o* argument has to be a Unicode object (not checked).

Changed in version 3.3: This macro is now inefficient – because in many cases the *Py_UNICODE* representation does not exist and needs to be created – and can fail (return *NULL* with an exception set). Try to port the code to use the new `PyUnicode_nBYTE_DATA()` macros or use *PyUnicode_WRITE()* or *PyUnicode_READ()*.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style Unicode API, please migrate to using the `PyUnicode_nBYTE_DATA()` family of macros.

Unicode Character Properties

Unicode provides many different character properties. The most often needed ones are available through these macros which are mapped to C functions depending on the Python configuration.

int **Py_UNICODE_ISSPACE**(*Py_UNICODE ch*)
Return `1` or `0` depending on whether *ch* is a whitespace character.

int **Py_UNICODE_ISLOWER**(*Py_UNICODE ch*)
Return 1 or 0 depending on whether *ch* is a lowercase character.

int **Py_UNICODE_ISUPPER**(*Py_UNICODE ch*)
Return 1 or 0 depending on whether *ch* is an uppercase character.

int **Py_UNICODE_ISTITLE**(*Py_UNICODE ch*)
Return 1 or 0 depending on whether *ch* is a titlecase character.

int **Py_UNICODE_ISLINEBREAK**(*Py_UNICODE ch*)
Return 1 or 0 depending on whether *ch* is a linebreak character.

int **Py_UNICODE_ISDECIMAL**(*Py_UNICODE ch*)
Return 1 or 0 depending on whether *ch* is a decimal character.

int **Py_UNICODE_ISDIGIT**(*Py_UNICODE ch*)
Return 1 or 0 depending on whether *ch* is a digit character.

int **Py_UNICODE_ISNUMERIC**(*Py_UNICODE ch*)
Return 1 or 0 depending on whether *ch* is a numeric character.

int **Py_UNICODE_ISALPHA**(*Py_UNICODE ch*)
Return 1 or 0 depending on whether *ch* is an alphabetic character.

int **Py_UNICODE_ISALNUM**(*Py_UNICODE ch*)
Return 1 or 0 depending on whether *ch* is an alphanumeric character.

int **Py_UNICODE_ISPRINTABLE**(*Py_UNICODE ch*)
Return 1 or 0 depending on whether *ch* is a printable character. Nonprintable characters are those characters defined in the Unicode character database as "Other" or "Separator", excepting the ASCII space (0x20) which is considered printable. (Note that printable characters in this context are those which should not be escaped when `repr()` is invoked on a string. It has no bearing on the handling of strings written to `sys.stdout` or `sys.stderr`.)

These APIs can be used for fast direct character conversions:

Py_UNICODE **Py_UNICODE_TOLOWER**(*Py_UNICODE ch*)
Return the character *ch* converted to lower case.

Deprecated since version 3.3: This function uses simple case mappings.

Py_UNICODE **Py_UNICODE_TOUPPER**(*Py_UNICODE ch*)
Return the character *ch* converted to upper case.

Deprecated since version 3.3: This function uses simple case mappings.

Py_UNICODE **Py_UNICODE_TOTITLE**(*Py_UNICODE ch*)
Return the character *ch* converted to title case.

Deprecated since version 3.3: This function uses simple case mappings.

int **Py_UNICODE_TODECIMAL**(*Py_UNICODE ch*)
Return the character *ch* converted to a decimal positive integer. Return `-1` if this is not possible. This macro does not raise exceptions.

int **Py_UNICODE_TODIGIT**(*Py_UNICODE ch*)
Return the character *ch* converted to a single digit integer. Return `-1` if this is not possible. This macro does not raise exceptions.

double **Py_UNICODE_TONUMERIC**(*Py_UNICODE ch*)
Return the character *ch* converted to a double. Return `-1.0` if this is not possible. This macro does not raise exceptions.

These APIs can be used to work with surrogates:

`Py_UNICODE_IS_SURROGATE`(ch)
Check if *ch* is a surrogate (`0xD800 <= ch <= 0xDFFF`).

`Py_UNICODE_IS_HIGH_SURROGATE`(ch)
Check if *ch* is a high surrogate (`0xD800 <= ch <= 0xDBFF`).

`Py_UNICODE_IS_LOW_SURROGATE`(ch)
Check if *ch* is a low surrogate (`0xDC00 <= ch <= 0xDFFF`).

`Py_UNICODE_JOIN_SURROGATES`(high, low)
Join two surrogate characters and return a single Py_UCS4 value. *high* and *low* are respectively the leading and trailing surrogates in a surrogate pair.

Creating and accessing Unicode strings

To create Unicode objects and access their basic sequence properties, use these APIs:

*PyObject** **PyUnicode_New**(Py_ssize_t *size*, *Py_UCS4* *maxchar*)
Create a new Unicode object. *maxchar* should be the true maximum code point to be placed in the string. As an approximation, it can be rounded up to the nearest value in the sequence 127, 255, 65535, 1114111.

This is the recommended way to allocate a new Unicode object. Objects created using this function are not resizable.

New in version 3.3.

*PyObject** **PyUnicode_FromKindAndData**(int *kind*, const void **buffer*, Py_ssize_t *size*)
Create a new Unicode object with the given *kind* (possible values are *PyUnicode_1BYTE_KIND* etc., as returned by *PyUnicode_KIND()*). The *buffer* must point to an array of *size* units of 1, 2 or 4 bytes per character, as given by the kind.

New in version 3.3.

*PyObject** **PyUnicode_FromStringAndSize**(const char **u*, Py_ssize_t *size*)
Create a Unicode object from the char buffer *u*. The bytes will be interpreted as being UTF-8 encoded. The buffer is copied into the new object. If the buffer is not *NULL*, the return value might be a shared object, i.e. modification of the data is not allowed.

If *u* is *NULL*, this function behaves like *PyUnicode_FromUnicode()* with the buffer set to *NULL*. This usage is deprecated in favor of *PyUnicode_New()*.

PyObject ***PyUnicode_FromString**(const char **u*)
Create a Unicode object from a UTF-8 encoded null-terminated char buffer *u*.

*PyObject** **PyUnicode_FromFormat**(const char **format*, ...)
Take a C `printf()`-style *format* string and a variable number of arguments, calculate the size of the resulting Python unicode string and return a string with the values formatted into it. The variable arguments must be C types and must correspond exactly to the format characters in the *format* ASCII-encoded string. The following format characters are allowed:

Format Characters	Type	Comment
%%	*n/a*	The literal % character.
%c	int	A single character, represented as a C int.
%d	int	Equivalent to printf("%d").[1]
%u	unsigned int	Equivalent to printf("%u").[1]
%ld	long	Equivalent to printf("%ld").[1]
%li	long	Equivalent to printf("%li").[1]
%lu	unsigned long	Equivalent to printf("%lu").[1]
%lld	long long	Equivalent to printf("%lld").[1]
%lli	long long	Equivalent to printf("%lli").[1]
%llu	unsigned long long	Equivalent to printf("%llu").[1]
%zd	Py_ssize_t	Equivalent to printf("%zd").[1]
%zi	Py_ssize_t	Equivalent to printf("%zi").[1]
%zu	size_t	Equivalent to printf("%zu").[1]
%i	int	Equivalent to printf("%i").[1]
%x	int	Equivalent to printf("%x").[1]
%s	const char*	A null-terminated C character array.
%p	const void*	The hex representation of a C pointer. Mostly equivalent to printf("%p") except that it is guaranteed to start with the literal 0x regardless of what the platform's printf yields.
%A	PyObject*	The result of calling ascii().
%U	PyObject*	A unicode object.
%V	PyObject*, const char*	A unicode object (which may be *NULL*) and a null-terminated C character array as a second parameter (which will be used, if the first parameter is *NULL*).
%S	PyObject*	The result of calling *PyObject_Str()*.
%R	PyObject*	The result of calling *PyObject_Repr()*.

An unrecognized format character causes all the rest of the format string to be copied as-is to the result string, and any extra arguments discarded.

Note: The width formatter unit is number of characters rather than bytes. The precision formatter unit is number of bytes for "%s" and "%V" (if the PyObject* argument is NULL), and a number of characters for "%A", "%U", "%S", "%R" and "%V" (if the PyObject* argument is not NULL).

Changed in version 3.2: Support for "%lld" and "%llu" added.

Changed in version 3.3: Support for "%li", "%lli" and "%zi" added.

Changed in version 3.4: Support width and precision formatter for "%s", "%A", "%U", "%V", "%S", "%R" added.

*PyObject** **PyUnicode_FromFormatV**(const char **format*, va_list *vargs*)
Identical to *PyUnicode_FromFormat()* except that it takes exactly two arguments.

*PyObject** **PyUnicode_FromEncodedObject**(*PyObject* **obj*, const char **encoding*, const char **errors*)
Return value: New reference. Decode an encoded object *obj* to a Unicode object.

bytes, bytearray and other *bytes-like objects* are decoded according to the given *encoding* and using the error handling defined by *errors*. Both can be *NULL* to have the interface use the default values

[1] For integer specifiers (d, u, ld, li, lu, lld, lli, llu, zd, zi, zu, i, x): the 0-conversion flag has effect even when a precision is given.

(see *Built-in Codecs* for details).

All other objects, including Unicode objects, cause a `TypeError` to be set.

The API returns *NULL* if there was an error. The caller is responsible for decref'ing the returned objects.

Py_ssize_t **PyUnicode_GetLength**(*PyObject* **unicode*)
Return the length of the Unicode object, in code points.

New in version 3.3.

Py_ssize_t **PyUnicode_CopyCharacters**(*PyObject* **to*, Py_ssize_t *to_start*, *PyObject* **from*, Py_ssize_t *from_start*, Py_ssize_t *how_many*)
Copy characters from one Unicode object into another. This function performs character conversion when necessary and falls back to `memcpy()` if possible. Returns `-1` and sets an exception on error, otherwise returns the number of copied characters.

New in version 3.3.

Py_ssize_t **PyUnicode_Fill**(*PyObject* **unicode*, Py_ssize_t *start*, Py_ssize_t *length*, *Py_UCS4* *fill_char*)
Fill a string with a character: write *fill_char* into `unicode[start:start+length]`.

Fail if *fill_char* is bigger than the string maximum character, or if the string has more than 1 reference.

Return the number of written character, or return `-1` and raise an exception on error.

New in version 3.3.

int **PyUnicode_WriteChar**(*PyObject* **unicode*, Py_ssize_t *index*, *Py_UCS4* *character*)
Write a character to a string. The string must have been created through *PyUnicode_New()*. Since Unicode strings are supposed to be immutable, the string must not be shared, or have been hashed yet.

This function checks that *unicode* is a Unicode object, that the index is not out of bounds, and that the object can be modified safely (i.e. that it its reference count is one).

New in version 3.3.

Py_UCS4 **PyUnicode_ReadChar**(*PyObject* **unicode*, Py_ssize_t *index*)
Read a character from a string. This function checks that *unicode* is a Unicode object and the index is not out of bounds, in contrast to the macro version *PyUnicode_READ_CHAR()*.

New in version 3.3.

*PyObject** **PyUnicode_Substring**(*PyObject* **str*, Py_ssize_t *start*, Py_ssize_t *end*)
Return a substring of *str*, from character index *start* (included) to character index *end* (excluded). Negative indices are not supported.

New in version 3.3.

*Py_UCS4** **PyUnicode_AsUCS4**(*PyObject* **u*, *Py_UCS4* **buffer*, Py_ssize_t *buflen*, int *copy_null*)
Copy the string *u* into a UCS4 buffer, including a null character, if *copy_null* is set. Returns *NULL* and sets an exception on error (in particular, a `SystemError` if *buflen* is smaller than the length of *u*). *buffer* is returned on success.

New in version 3.3.

*Py_UCS4** **PyUnicode_AsUCS4Copy**(*PyObject* **u*)
Copy the string *u* into a new UCS4 buffer that is allocated using *PyMem_Malloc()*. If this fails, *NULL* is returned with a `MemoryError` set. The returned buffer always has an extra null code point appended.

New in version 3.3.

Deprecated Py_UNICODE APIs

Deprecated since version 3.3, will be removed in version 4.0.

These API functions are deprecated with the implementation of **PEP 393**. Extension modules can continue using them, as they will not be removed in Python 3.x, but need to be aware that their use can now cause performance and memory hits.

*PyObject** **PyUnicode_FromUnicode**(const *Py_UNICODE* **u*, Py_ssize_t *size*)

Return value: New reference. Create a Unicode object from the Py_UNICODE buffer *u* of the given size. *u* may be *NULL* which causes the contents to be undefined. It is the user's responsibility to fill in the needed data. The buffer is copied into the new object.

If the buffer is not *NULL*, the return value might be a shared object. Therefore, modification of the resulting Unicode object is only allowed when *u* is *NULL*.

If the buffer is *NULL*, *PyUnicode_READY()* must be called once the string content has been filled before using any of the access macros such as *PyUnicode_KIND()*.

Please migrate to using *PyUnicode_FromKindAndData()*, *PyUnicode_FromWideChar()* or *PyUnicode_New()*.

*Py_UNICODE** **PyUnicode_AsUnicode**(*PyObject* **unicode*)

Return a read-only pointer to the Unicode object's internal *Py_UNICODE* buffer, or *NULL* on error. This will create the *Py_UNICODE** representation of the object if it is not yet available. The buffer is always terminated with an extra null code point. Note that the resulting *Py_UNICODE* string may also contain embedded null code points, which would cause the string to be truncated when used in most C functions.

Please migrate to using *PyUnicode_AsUCS4()*, *PyUnicode_AsWideChar()*, *PyUnicode_ReadChar()* or similar new APIs.

*PyObject** **PyUnicode_TransformDecimalToASCII**(*Py_UNICODE* **s*, Py_ssize_t *size*)

Create a Unicode object by replacing all decimal digits in *Py_UNICODE* buffer of the given *size* by ASCII digits 0–9 according to their decimal value. Return *NULL* if an exception occurs.

*Py_UNICODE** **PyUnicode_AsUnicodeAndSize**(*PyObject* **unicode*, Py_ssize_t **size*)

Like *PyUnicode_AsUnicode()*, but also saves the *Py_UNICODE()* array length (excluding the extra null terminator) in *size*. Note that the resulting *Py_UNICODE** string may contain embedded null code points, which would cause the string to be truncated when used in most C functions.

New in version 3.3.

*Py_UNICODE** **PyUnicode_AsUnicodeCopy**(*PyObject* **unicode*)

Create a copy of a Unicode string ending with a null code point. Return *NULL* and raise a `MemoryError` exception on memory allocation failure, otherwise return a new allocated buffer (use *PyMem_Free()* to free the buffer). Note that the resulting *Py_UNICODE** string may contain embedded null code points, which would cause the string to be truncated when used in most C functions.

New in version 3.2.

Please migrate to using *PyUnicode_AsUCS4Copy()* or similar new APIs.

Py_ssize_t **PyUnicode_GetSize**(*PyObject* **unicode*)

Return the size of the deprecated *Py_UNICODE* representation, in code units (this includes surrogate pairs as 2 units).

Please migrate to using *PyUnicode_GetLength()*.

*PyObject** **PyUnicode_FromObject**(*PyObject* **obj*)

Return value: New reference. Copy an instance of a Unicode subtype to a new true Unicode object if necessary. If *obj* is already a true Unicode object (not a subtype), return the reference with incremented refcount.

Objects other than Unicode or its subtypes will cause a `TypeError`.

Locale Encoding

The current locale encoding can be used to decode text from the operating system.

*PyObject** **PyUnicode_DecodeLocaleAndSize**(const char **str*, Py_ssize_t *len*, const char **errors*)
Decode a string from UTF-8 on Android, or from the current locale encoding on other platforms. The supported error handlers are `"strict"` and `"surrogateescape"` (**PEP 383**). The decoder uses `"strict"` error handler if *errors* is `NULL`. *str* must end with a null character but cannot contain embedded null characters.

Use *PyUnicode_DecodeFSDefaultAndSize()* to decode a string from `Py_FileSystemDefaultEncoding` (the locale encoding read at Python startup).

This function ignores the Python UTF-8 mode.

See also:

The *Py_DecodeLocale()* function.

New in version 3.3.

Changed in version 3.7: The function now also uses the current locale encoding for the `surrogateescape` error handler, except on Android. Previously, *Py_DecodeLocale()* was used for the `surrogateescape`, and the current locale encoding was used for `strict`.

*PyObject** **PyUnicode_DecodeLocale**(const char **str*, const char **errors*)
Similar to *PyUnicode_DecodeLocaleAndSize()*, but compute the string length using `strlen()`.

New in version 3.3.

*PyObject** **PyUnicode_EncodeLocale**(*PyObject* **unicode*, const char **errors*)
Encode a Unicode object to UTF-8 on Android, or to the current locale encoding on other platforms. The supported error handlers are `"strict"` and `"surrogateescape"` (**PEP 383**). The encoder uses `"strict"` error handler if *errors* is `NULL`. Return a `bytes` object. *unicode* cannot contain embedded null characters.

Use *PyUnicode_EncodeFSDefault()* to encode a string to `Py_FileSystemDefaultEncoding` (the locale encoding read at Python startup).

This function ignores the Python UTF-8 mode.

See also:

The *Py_EncodeLocale()* function.

New in version 3.3.

Changed in version 3.7: The function now also uses the current locale encoding for the `surrogateescape` error handler, except on Android. Previously, *Py_EncodeLocale()* was used for the `surrogateescape`, and the current locale encoding was used for `strict`.

File System Encoding

To encode and decode file names and other environment strings, `Py_FileSystemDefaultEncoding` should be used as the encoding, and `Py_FileSystemDefaultEncodeErrors` should be used as the error handler (**PEP 383** and **PEP 529**). To encode file names to `bytes` during argument parsing, the `"O&"` converter should be used, passing *PyUnicode_FSConverter()* as the conversion function:

int **PyUnicode_FSConverter**(*PyObject** *obj*, void* *result*)
ParseTuple converter: encode `str` objects – obtained directly or through the `os.PathLike` interface – to `bytes` using *PyUnicode_EncodeFSDefault()*; `bytes` objects are output as-is. *result* must be a *PyBytesObject** which must be released when it is no longer used.

New in version 3.1.

Changed in version 3.6: Accepts a *path-like object*.

To decode file names to `str` during argument parsing, the `"O&"` converter should be used, passing *PyUnicode_FSDecoder()* as the conversion function:

int **PyUnicode_FSDecoder**(*PyObject** *obj*, void* *result*)
ParseTuple converter: decode `bytes` objects – obtained either directly or indirectly through the `os.PathLike` interface – to `str` using *PyUnicode_DecodeFSDefaultAndSize()*; `str` objects are output as-is. *result* must be a *PyUnicodeObject** which must be released when it is no longer used.

New in version 3.2.

Changed in version 3.6: Accepts a *path-like object*.

*PyObject** **PyUnicode_DecodeFSDefaultAndSize**(const char **s*, Py_ssize_t *size*)
Decode a string using `Py_FileSystemDefaultEncoding` and the `Py_FileSystemDefaultEncodeErrors` error handler.

If `Py_FileSystemDefaultEncoding` is not set, fall back to the locale encoding.

`Py_FileSystemDefaultEncoding` is initialized at startup from the locale encoding and cannot be modified later. If you need to decode a string from the current locale encoding, use *PyUnicode_DecodeLocaleAndSize()*.

See also:

The *Py_DecodeLocale()* function.

Changed in version 3.6: Use `Py_FileSystemDefaultEncodeErrors` error handler.

*PyObject** **PyUnicode_DecodeFSDefault**(const char **s*)
Decode a null-terminated string using `Py_FileSystemDefaultEncoding` and the `Py_FileSystemDefaultEncodeErrors` error handler.

If `Py_FileSystemDefaultEncoding` is not set, fall back to the locale encoding.

Use *PyUnicode_DecodeFSDefaultAndSize()* if you know the string length.

Changed in version 3.6: Use `Py_FileSystemDefaultEncodeErrors` error handler.

*PyObject** **PyUnicode_EncodeFSDefault**(*PyObject* **unicode*)
Encode a Unicode object to `Py_FileSystemDefaultEncoding` with the `Py_FileSystemDefaultEncodeErrors` error handler, and return `bytes`. Note that the resulting `bytes` object may contain null bytes.

If `Py_FileSystemDefaultEncoding` is not set, fall back to the locale encoding.

`Py_FileSystemDefaultEncoding` is initialized at startup from the locale encoding and cannot be modified later. If you need to encode a string to the current locale encoding, use *PyUnicode_EncodeLocale()*.

See also:

The *Py_EncodeLocale()* function.

New in version 3.2.

Changed in version 3.6: Use `Py_FileSystemDefaultEncodeErrors` error handler.

wchar_t Support

`wchar_t` support for platforms which support it:

*PyObject** **PyUnicode_FromWideChar**(const wchar_t **w*, Py_ssize_t *size*)
Return value: New reference. Create a Unicode object from the `wchar_t` buffer *w* of the given *size*. Passing `-1` as the *size* indicates that the function must itself compute the length, using wcslen. Return *NULL* on failure.

Py_ssize_t **PyUnicode_AsWideChar**(*PyUnicodeObject* **unicode*, wchar_t **w*, Py_ssize_t *size*)
Copy the Unicode object contents into the `wchar_t` buffer *w*. At most *size* `wchar_t` characters are copied (excluding a possibly trailing null termination character). Return the number of `wchar_t` characters copied or `-1` in case of an error. Note that the resulting `wchar_t*` string may or may not be null-terminated. It is the responsibility of the caller to make sure that the `wchar_t*` string is null-terminated in case this is required by the application. Also, note that the `wchar_t*` string might contain null characters, which would cause the string to be truncated when used with most C functions.

wchar_t* **PyUnicode_AsWideCharString**(*PyObject* **unicode*, Py_ssize_t **size*)
Convert the Unicode object to a wide character string. The output string always ends with a null character. If *size* is not *NULL*, write the number of wide characters (excluding the trailing null termination character) into **size*. Note that the resulting `wchar_t` string might contain null characters, which would cause the string to be truncated when used with most C functions. If *size* is *NULL* and the `wchar_t*` string contains null characters a `ValueError` is raised.

Returns a buffer allocated by `PyMem_Alloc()` (use *PyMem_Free()* to free it) on success. On error, returns *NULL* and **size* is undefined. Raises a `MemoryError` if memory allocation is failed.

New in version 3.2.

Changed in version 3.7: Raises a `ValueError` if *size* is *NULL* and the `wchar_t*` string contains null characters.

Built-in Codecs

Python provides a set of built-in codecs which are written in C for speed. All of these codecs are directly usable via the following functions.

Many of the following APIs take two arguments encoding and errors, and they have the same semantics as the ones of the built-in `str()` string object constructor.

Setting encoding to *NULL* causes the default encoding to be used which is ASCII. The file system calls should use *PyUnicode_FSConverter()* for encoding file names. This uses the variable `Py_FileSystemDefaultEncoding` internally. This variable should be treated as read-only: on some systems, it will be a pointer to a static string, on others, it will change at run-time (such as when the application invokes setlocale).

Error handling is set by errors which may also be set to *NULL* meaning to use the default handling defined for the codec. Default error handling for all built-in codecs is "strict" (`ValueError` is raised).

The codecs all use a similar interface. Only deviation from the following generic ones are documented for simplicity.

Generic Codecs

These are the generic codec APIs:

*PyObject** **PyUnicode_Decode**(const char **s*, Py_ssize_t *size*, const char **encoding*, const char **errors*)
Return value: New reference. Create a Unicode object by decoding *size* bytes of the encoded string *s*.

encoding and *errors* have the same meaning as the parameters of the same name in the `str()` built-in function. The codec to be used is looked up using the Python codec registry. Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_AsEncodedString**(*PyObject *unicode*, const char **encoding*, const char **errors*)

Return value: New reference. Encode a Unicode object and return the result as Python bytes object. *encoding* and *errors* have the same meaning as the parameters of the same name in the Unicode `encode()` method. The codec to be used is looked up using the Python codec registry. Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_Encode**(const *Py_UNICODE *s*, Py_ssize_t *size*, const char **encoding*, const char **errors*)

Return value: New reference. Encode the *Py_UNICODE* buffer *s* of the given *size* and return a Python bytes object. *encoding* and *errors* have the same meaning as the parameters of the same name in the Unicode `encode()` method. The codec to be used is looked up using the Python codec registry. Return *NULL* if an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsEncodedString()*.

UTF-8 Codecs

These are the UTF-8 codec APIs:

*PyObject** **PyUnicode_DecodeUTF8**(const char **s*, Py_ssize_t *size*, const char **errors*)

Return value: New reference. Create a Unicode object by decoding *size* bytes of the UTF-8 encoded string *s*. Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_DecodeUTF8Stateful**(const char **s*, Py_ssize_t *size*, const char **errors*, Py_ssize_t **consumed*)

Return value: New reference. If *consumed* is *NULL*, behave like *PyUnicode_DecodeUTF8()*. If *consumed* is not *NULL*, trailing incomplete UTF-8 byte sequences will not be treated as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in *consumed*.

*PyObject** **PyUnicode_AsUTF8String**(*PyObject *unicode*)

Return value: New reference. Encode a Unicode object using UTF-8 and return the result as Python bytes object. Error handling is "strict". Return *NULL* if an exception was raised by the codec.

const char* **PyUnicode_AsUTF8AndSize**(*PyObject *unicode*, Py_ssize_t **size*)

Return a pointer to the UTF-8 encoding of the Unicode object, and store the size of the encoded representation (in bytes) in *size*. The *size* argument can be *NULL*; in this case no size will be stored. The returned buffer always has an extra null byte appended (not included in *size*), regardless of whether there are any other null code points.

In the case of an error, *NULL* is returned with an exception set and no *size* is stored.

This caches the UTF-8 representation of the string in the Unicode object, and subsequent calls will return a pointer to the same buffer. The caller is not responsible for deallocating the buffer.

New in version 3.3.

Changed in version 3.7: The return type is now `const char *` rather of `char *`.

const char* **PyUnicode_AsUTF8**(*PyObject *unicode*)

As *PyUnicode_AsUTF8AndSize()*, but does not store the size.

New in version 3.3.

Changed in version 3.7: The return type is now `const char *` rather of `char *`.

*PyObject** **PyUnicode_EncodeUTF8**(const *Py_UNICODE* **s*, Py_ssize_t *size*, const char **errors*)
Return value: New reference. Encode the *Py_UNICODE* buffer *s* of the given *size* using UTF-8 and return a Python bytes object. Return *NULL* if an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsUTF8String()*, *PyUnicode_AsUTF8AndSize()* or *PyUnicode_AsEncodedString()*.

UTF-32 Codecs

These are the UTF-32 codec APIs:

*PyObject** **PyUnicode_DecodeUTF32**(const char **s*, Py_ssize_t *size*, const char **errors*, int **byteorder*)
Decode *size* bytes from a UTF-32 encoded buffer string and return the corresponding Unicode object. *errors* (if non-*NULL*) defines the error handling. It defaults to "strict".

If *byteorder* is non-*NULL*, the decoder starts decoding using the given byte order:

```
*byteorder == -1: little endian
*byteorder == 0:  native order
*byteorder == 1:  big endian
```

If `*byteorder` is zero, and the first four bytes of the input data are a byte order mark (BOM), the decoder switches to this byte order and the BOM is not copied into the resulting Unicode string. If `*byteorder` is `-1` or `1`, any byte order mark is copied to the output.

After completion, **byteorder* is set to the current byte order at the end of input data.

If *byteorder* is *NULL*, the codec starts in native order mode.

Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_DecodeUTF32Stateful**(const char **s*, Py_ssize_t *size*, const char **errors*, int **byteorder*, Py_ssize_t **consumed*)
If *consumed* is *NULL*, behave like *PyUnicode_DecodeUTF32()*. If *consumed* is not *NULL*, *PyUnicode_DecodeUTF32Stateful()* will not treat trailing incomplete UTF-32 byte sequences (such as a number of bytes not divisible by four) as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in *consumed*.

*PyObject** **PyUnicode_AsUTF32String**(*PyObject* **unicode*)
Return a Python byte string using the UTF-32 encoding in native byte order. The string always starts with a BOM mark. Error handling is "strict". Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_EncodeUTF32**(const *Py_UNICODE* **s*, Py_ssize_t *size*, const char **errors*, int *byteorder*)
Return a Python bytes object holding the UTF-32 encoded value of the Unicode data in *s*. Output is written according to the following byte order:

```
byteorder == -1: little endian
byteorder == 0:  native byte order (writes a BOM mark)
byteorder == 1:  big endian
```

If byteorder is `0`, the output string will always start with the Unicode BOM mark (U+FEFF). In the other two modes, no BOM mark is prepended.

If *Py_UNICODE_WIDE* is not defined, surrogate pairs will be output as a single code point.

Return *NULL* if an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsUTF32String()* or *PyUnicode_AsEncodedString()*.

UTF-16 Codecs

These are the UTF-16 codec APIs:

*PyObject** **PyUnicode_DecodeUTF16**(const char *s, Py_ssize_t *size*, const char *errors*, int *byteorder*)

Return value: New reference. Decode *size* bytes from a UTF-16 encoded buffer string and return the corresponding Unicode object. *errors* (if non-*NULL*) defines the error handling. It defaults to "strict".

If *byteorder* is non-*NULL*, the decoder starts decoding using the given byte order:

```
*byteorder == -1: little endian
*byteorder == 0:  native order
*byteorder == 1:  big endian
```

If `*byteorder` is zero, and the first two bytes of the input data are a byte order mark (BOM), the decoder switches to this byte order and the BOM is not copied into the resulting Unicode string. If `*byteorder` is `-1` or `1`, any byte order mark is copied to the output (where it will result in either a `\ufeff` or a `\ufffe` character).

After completion, **byteorder* is set to the current byte order at the end of input data.

If *byteorder* is *NULL*, the codec starts in native order mode.

Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_DecodeUTF16Stateful**(const char *s, Py_ssize_t *size*, const char *errors*, int *byteorder*, Py_ssize_t *consumed*)

Return value: New reference. If *consumed* is *NULL*, behave like *PyUnicode_DecodeUTF16()*. If *consumed* is not *NULL*, *PyUnicode_DecodeUTF16Stateful()* will not treat trailing incomplete UTF-16 byte sequences (such as an odd number of bytes or a split surrogate pair) as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in *consumed*.

*PyObject** **PyUnicode_AsUTF16String**(*PyObject* *unicode*)

Return value: New reference. Return a Python byte string using the UTF-16 encoding in native byte order. The string always starts with a BOM mark. Error handling is "strict". Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_EncodeUTF16**(const *Py_UNICODE* *s, Py_ssize_t *size*, const char *errors*, int *byteorder*)

Return value: New reference. Return a Python bytes object holding the UTF-16 encoded value of the Unicode data in *s*. Output is written according to the following byte order:

```
byteorder == -1: little endian
byteorder == 0:  native byte order (writes a BOM mark)
byteorder == 1:  big endian
```

If byteorder is `0`, the output string will always start with the Unicode BOM mark (U+FEFF). In the other two modes, no BOM mark is prepended.

If *Py_UNICODE_WIDE* is defined, a single *Py_UNICODE* value may get represented as a surrogate pair. If it is not defined, each *Py_UNICODE* values is interpreted as a UCS-2 character.

Return *NULL* if an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsUTF16String()* or *PyUnicode_AsEncodedString()*.

UTF-7 Codecs

These are the UTF-7 codec APIs:

*PyObject** **PyUnicode_DecodeUTF7**(const char **s*, Py_ssize_t *size*, const char **errors*)
Create a Unicode object by decoding *size* bytes of the UTF-7 encoded string *s*. Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_DecodeUTF7Stateful**(const char **s*, Py_ssize_t *size*, const char **errors*, Py_ssize_t **consumed*)
If *consumed* is *NULL*, behave like *PyUnicode_DecodeUTF7()*. If *consumed* is not *NULL*, trailing incomplete UTF-7 base-64 sections will not be treated as an error. Those bytes will not be decoded and the number of bytes that have been decoded will be stored in *consumed*.

*PyObject** **PyUnicode_EncodeUTF7**(const *Py_UNICODE* **s*, Py_ssize_t *size*, int *base64SetO*, int *base64WhiteSpace*, const char **errors*)
Encode the *Py_UNICODE* buffer of the given size using UTF-7 and return a Python bytes object. Return *NULL* if an exception was raised by the codec.

If *base64SetO* is nonzero, "Set O" (punctuation that has no otherwise special meaning) will be encoded in base-64. If *base64WhiteSpace* is nonzero, whitespace will be encoded in base-64. Both are set to zero for the Python "utf-7" codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsEncodedString()*.

Unicode-Escape Codecs

These are the "Unicode Escape" codec APIs:

*PyObject** **PyUnicode_DecodeUnicodeEscape**(const char **s*, Py_ssize_t *size*, const char **errors*)
Return value: New reference. Create a Unicode object by decoding *size* bytes of the Unicode-Escape encoded string *s*. Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_AsUnicodeEscapeString**(*PyObject* **unicode*)
Return value: New reference. Encode a Unicode object using Unicode-Escape and return the result as a bytes object. Error handling is "strict". Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_EncodeUnicodeEscape**(const *Py_UNICODE* **s*, Py_ssize_t *size*)
Return value: New reference. Encode the *Py_UNICODE* buffer of the given *size* using Unicode-Escape and return a bytes object. Return *NULL* if an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsUnicodeEscapeString()*.

Raw-Unicode-Escape Codecs

These are the "Raw Unicode Escape" codec APIs:

*PyObject** **PyUnicode_DecodeRawUnicodeEscape**(const char **s*, Py_ssize_t *size*, const char **errors*)
Return value: New reference. Create a Unicode object by decoding *size* bytes of the Raw-Unicode-Escape encoded string *s*. Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_AsRawUnicodeEscapeString**(*PyObject* **unicode*)
Return value: New reference. Encode a Unicode object using Raw-Unicode-Escape and return the result as a bytes object. Error handling is "strict". Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_EncodeRawUnicodeEscape**(const *Py_UNICODE* **s*, Py_ssize_t *size*, const char **errors*)
Return value: New reference. Encode the *Py_UNICODE* buffer of the given *size* using Raw-Unicode-Escape and return a bytes object. Return *NULL* if an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsRawUnicodeEscapeString()* or *PyUnicode_AsEncodedString()*.

Latin-1 Codecs

These are the Latin-1 codec APIs: Latin-1 corresponds to the first 256 Unicode ordinals and only these are accepted by the codecs during encoding.

*PyObject** **PyUnicode_DecodeLatin1**(const char **s*, Py_ssize_t *size*, const char **errors*)
Return value: New reference. Create a Unicode object by decoding *size* bytes of the Latin-1 encoded string *s*. Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_AsLatin1String**(*PyObject *unicode*)
Return value: New reference. Encode a Unicode object using Latin-1 and return the result as Python bytes object. Error handling is "strict". Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_EncodeLatin1**(const *Py_UNICODE *s*, Py_ssize_t *size*, const char **errors*)
Return value: New reference. Encode the *Py_UNICODE* buffer of the given *size* using Latin-1 and return a Python bytes object. Return *NULL* if an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsLatin1String()* or *PyUnicode_AsEncodedString()*.

ASCII Codecs

These are the ASCII codec APIs. Only 7-bit ASCII data is accepted. All other codes generate errors.

*PyObject** **PyUnicode_DecodeASCII**(const char **s*, Py_ssize_t *size*, const char **errors*)
Return value: New reference. Create a Unicode object by decoding *size* bytes of the ASCII encoded string *s*. Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_AsASCIIString**(*PyObject *unicode*)
Return value: New reference. Encode a Unicode object using ASCII and return the result as Python bytes object. Error handling is "strict". Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_EncodeASCII**(const *Py_UNICODE *s*, Py_ssize_t *size*, const char **errors*)
Return value: New reference. Encode the *Py_UNICODE* buffer of the given *size* using ASCII and return a Python bytes object. Return *NULL* if an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsASCIIString()* or *PyUnicode_AsEncodedString()*.

Character Map Codecs

This codec is special in that it can be used to implement many different codecs (and this is in fact what was done to obtain most of the standard codecs included in the `encodings` package). The codec uses mapping to encode and decode characters. The mapping objects provided must support the `__getitem__()` mapping interface; dictionaries and sequences work well.

These are the mapping codec APIs:

*PyObject** **PyUnicode_DecodeCharmap**(const char **data*, Py_ssize_t *size*, *PyObject *mapping*, const char **errors*)
Return value: New reference. Create a Unicode object by decoding *size* bytes of the encoded string *s* using the given *mapping* object. Return *NULL* if an exception was raised by the codec.

If *mapping* is *NULL*, Latin-1 decoding will be applied. Else *mapping* must map bytes ordinals (integers in the range from 0 to 255) to Unicode strings, integers (which are then interpreted as Unicode ordinals) or `None`. Unmapped data bytes – ones which cause a `LookupError`, as well as ones which get mapped to `None`, `0xFFFE` or `'\ufffe'`, are treated as undefined mappings and cause an error.

*PyObject** **PyUnicode_AsCharmapString**(*PyObject *unicode*, *PyObject *mapping*)
Return value: New reference. Encode a Unicode object using the given *mapping* object and return the result as a bytes object. Error handling is "strict". Return *NULL* if an exception was raised by the codec.

The *mapping* object must map Unicode ordinal integers to bytes objects, integers in the range from 0 to 255 or `None`. Unmapped character ordinals (ones which cause a `LookupError`) as well as mapped to `None` are treated as "undefined mapping" and cause an error.

*PyObject** **PyUnicode_EncodeCharmap**(const *Py_UNICODE *s*, Py_ssize_t *size*, *PyObject *mapping*, const char **errors*)
Return value: New reference. Encode the *Py_UNICODE* buffer of the given *size* using the given *mapping* object and return the result as a bytes object. Return *NULL* if an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsCharmapString()* or *PyUnicode_AsEncodedString()*.

The following codec API is special in that maps Unicode to Unicode.

*PyObject** **PyUnicode_Translate**(*PyObject *unicode*, *PyObject *mapping*, const char **errors*)
Return value: New reference. Translate a Unicode object using the given *mapping* object and return the resulting Unicode object. Return *NULL* if an exception was raised by the codec.

The *mapping* object must map Unicode ordinal integers to Unicode strings, integers (which are then interpreted as Unicode ordinals) or `None` (causing deletion of the character). Unmapped character ordinals (ones which cause a `LookupError`) are left untouched and are copied as-is.

*PyObject** **PyUnicode_TranslateCharmap**(const *Py_UNICODE *s*, Py_ssize_t *size*, *PyObject *mapping*, const char **errors*)
Return value: New reference. Translate a *Py_UNICODE* buffer of the given *size* by applying a character *mapping* table to it and return the resulting Unicode object. Return *NULL* when an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_Translate()*. or *generic codec based API*

MBCS codecs for Windows

These are the MBCS codec APIs. They are currently only available on Windows and use the Win32 MBCS converters to implement the conversions. Note that MBCS (or DBCS) is a class of encodings, not just one. The target encoding is defined by the user settings on the machine running the codec.

*PyObject** **PyUnicode_DecodeMBCS**(const char **s*, Py_ssize_t *size*, const char **errors*)
Return value: New reference. Create a Unicode object by decoding *size* bytes of the MBCS encoded string *s*. Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_DecodeMBCSStateful**(const char **s*, int *size*, const char **errors*, int **consumed*)
If *consumed* is *NULL*, behave like *PyUnicode_DecodeMBCS()*. If *consumed* is not *NULL*, *PyUnicode_DecodeMBCSStateful()* will not decode trailing lead byte and the number of bytes that have been decoded will be stored in *consumed*.

*PyObject** **PyUnicode_AsMBCSString**(*PyObject *unicode*)
Return value: New reference. Encode a Unicode object using MBCS and return the result as Python bytes object. Error handling is "strict". Return *NULL* if an exception was raised by the codec.

*PyObject** **PyUnicode_EncodeCodePage**(int *code_page*, *PyObject* **unicode*, const char **errors*)
Encode the Unicode object using the specified code page and return a Python bytes object. Return *NULL* if an exception was raised by the codec. Use `CP_ACP` code page to get the MBCS encoder.

New in version 3.3.

*PyObject** **PyUnicode_EncodeMBCS**(const *Py_UNICODE* **s*, Py_ssize_t *size*, const char **errors*)
Return value: New reference. Encode the *Py_UNICODE* buffer of the given *size* using MBCS and return a Python bytes object. Return *NULL* if an exception was raised by the codec.

Deprecated since version 3.3, will be removed in version 4.0: Part of the old-style *Py_UNICODE* API; please migrate to using *PyUnicode_AsMBCSString()*, *PyUnicode_EncodeCodePage()* or *PyUnicode_AsEncodedString()*.

Methods & Slots

Methods and Slot Functions

The following APIs are capable of handling Unicode objects and strings on input (we refer to them as strings in the descriptions) and return Unicode objects or integers as appropriate.

They all return *NULL* or `-1` if an exception occurs.

*PyObject** **PyUnicode_Concat**(*PyObject* **left*, *PyObject* **right*)
Return value: New reference. Concat two strings giving a new Unicode string.

*PyObject** **PyUnicode_Split**(*PyObject* **s*, *PyObject* **sep*, Py_ssize_t *maxsplit*)
Return value: New reference. Split a string giving a list of Unicode strings. If *sep* is *NULL*, splitting will be done at all whitespace substrings. Otherwise, splits occur at the given separator. At most *maxsplit* splits will be done. If negative, no limit is set. Separators are not included in the resulting list.

*PyObject** **PyUnicode_Splitlines**(*PyObject* **s*, int *keepend*)
Return value: New reference. Split a Unicode string at line breaks, returning a list of Unicode strings. CRLF is considered to be one line break. If *keepend* is `0`, the Line break characters are not included in the resulting strings.

*PyObject** **PyUnicode_Translate**(*PyObject* **str*, *PyObject* **table*, const char **errors*)
Translate a string by applying a character mapping table to it and return the resulting Unicode object.

The mapping table must map Unicode ordinal integers to Unicode ordinal integers or `None` (causing deletion of the character).

Mapping tables need only provide the `__getitem__()` interface; dictionaries and sequences work well. Unmapped character ordinals (ones which cause a `LookupError`) are left untouched and are copied as-is.

errors has the usual meaning for codecs. It may be *NULL* which indicates to use the default error handling.

*PyObject** **PyUnicode_Join**(*PyObject* **separator*, *PyObject* **seq*)
Return value: New reference. Join a sequence of strings using the given *separator* and return the resulting Unicode string.

Py_ssize_t **PyUnicode_Tailmatch**(*PyObject* **str*, *PyObject* **substr*, Py_ssize_t *start*, Py_ssize_t *end*, int *direction*)
Return `1` if *substr* matches `str[start:end]` at the given tail end (*direction* == `-1` means to do a prefix match, *direction* == `1` a suffix match), `0` otherwise. Return `-1` if an error occurred.

Py_ssize_t **PyUnicode_Find**(*PyObject* **str*, *PyObject* **substr*, Py_ssize_t *start*, Py_ssize_t *end*, int *direction*)
Return the first position of *substr* in `str[start:end]` using the given *direction* (*direction* == `1` means

to do a forward search, *direction* == `-1` a backward search). The return value is the index of the first match; a value of `-1` indicates that no match was found, and `-2` indicates that an error occurred and an exception has been set.

Py_ssize_t **PyUnicode_FindChar**(*PyObject* **str*, *Py_UCS4* *ch*, Py_ssize_t *start*, Py_ssize_t *end*, int *direction*)

Return the first position of the character *ch* in `str[start:end]` using the given *direction* (*direction* == `1` means to do a forward search, *direction* == `-1` a backward search). The return value is the index of the first match; a value of `-1` indicates that no match was found, and `-2` indicates that an error occurred and an exception has been set.

New in version 3.3.

Changed in version 3.7: *start* and *end* are now adjusted to behave like `str[start:end]`.

Py_ssize_t **PyUnicode_Count**(*PyObject* **str*, *PyObject* **substr*, Py_ssize_t *start*, Py_ssize_t *end*)

Return the number of non-overlapping occurrences of *substr* in `str[start:end]`. Return `-1` if an error occurred.

*PyObject** **PyUnicode_Replace**(*PyObject* **str*, *PyObject* **substr*, *PyObject* **replstr*, Py_ssize_t *maxcount*)

Return value: New reference. Replace at most *maxcount* occurrences of *substr* in *str* with *replstr* and return the resulting Unicode object. *maxcount* == `-1` means replace all occurrences.

int **PyUnicode_Compare**(*PyObject* **left*, *PyObject* **right*)

Compare two strings and return `-1`, `0`, `1` for less than, equal, and greater than, respectively.

This function returns `-1` upon failure, so one should call *PyErr_Occurred()* to check for errors.

int **PyUnicode_CompareWithASCIIString**(*PyObject* **uni*, const char **string*)

Compare a unicode object, *uni*, with *string* and return `-1`, `0`, `1` for less than, equal, and greater than, respectively. It is best to pass only ASCII-encoded strings, but the function interprets the input string as ISO-8859-1 if it contains non-ASCII characters.

This function does not raise exceptions.

*PyObject** **PyUnicode_RichCompare**(*PyObject* **left*, *PyObject* **right*, int *op*)

Rich compare two unicode strings and return one of the following:

- `NULL` in case an exception was raised
- `Py_True` or `Py_False` for successful comparisons
- `Py_NotImplemented` in case the type combination is unknown

Possible values for *op* are `Py_GT`, `Py_GE`, `Py_EQ`, `Py_NE`, `Py_LT`, and `Py_LE`.

*PyObject** **PyUnicode_Format**(*PyObject* **format*, *PyObject* **args*)

Return value: New reference. Return a new string object from *format* and *args*; this is analogous to `format % args`.

int **PyUnicode_Contains**(*PyObject* **container*, *PyObject* **element*)

Check whether *element* is contained in *container* and return true or false accordingly.

element has to coerce to a one element Unicode string. `-1` is returned if there was an error.

void **PyUnicode_InternInPlace**(*PyObject* ***string*)

Intern the argument **string* in place. The argument must be the address of a pointer variable pointing to a Python unicode string object. If there is an existing interned string that is the same as **string*, it sets **string* to it (decrementing the reference count of the old string object and incrementing the reference count of the interned string object), otherwise it leaves **string* alone and interns it (incrementing its reference count). (Clarification: even though there is a lot of talk about reference counts, think of this function as reference-count-neutral; you own the object after the call if and only if you owned it before the call.)

*PyObject** **PyUnicode_InternFromString**(const char *v)
A combination of *PyUnicode_FromString()* and *PyUnicode_InternInPlace()*, returning either a new unicode string object that has been interned, or a new ("owned") reference to an earlier interned string object with the same value.

8.3.4 Tuple Objects

PyTupleObject
This subtype of *PyObject* represents a Python tuple object.

PyTypeObject **PyTuple_Type**
This instance of *PyTypeObject* represents the Python tuple type; it is the same object as `tuple` in the Python layer.

int **PyTuple_Check**(*PyObject *p*)
Return true if *p* is a tuple object or an instance of a subtype of the tuple type.

int **PyTuple_CheckExact**(*PyObject *p*)
Return true if *p* is a tuple object, but not an instance of a subtype of the tuple type.

*PyObject** **PyTuple_New**(Py_ssize_t *len*)
Return value: New reference. Return a new tuple object of size *len*, or *NULL* on failure.

*PyObject** **PyTuple_Pack**(Py_ssize_t *n*, ...)
Return value: New reference. Return a new tuple object of size *n*, or *NULL* on failure. The tuple values are initialized to the subsequent *n* C arguments pointing to Python objects. `PyTuple_Pack(2, a, b)` is equivalent to `Py_BuildValue("(OO)", a, b)`.

Py_ssize_t **PyTuple_Size**(*PyObject *p*)
Take a pointer to a tuple object, and return the size of that tuple.

Py_ssize_t **PyTuple_GET_SIZE**(*PyObject *p*)
Return the size of the tuple *p*, which must be non-*NULL* and point to a tuple; no error checking is performed.

*PyObject** **PyTuple_GetItem**(*PyObject *p*, Py_ssize_t *pos*)
Return value: Borrowed reference. Return the object at position *pos* in the tuple pointed to by *p*. If *pos* is out of bounds, return *NULL* and sets an `IndexError` exception.

*PyObject** **PyTuple_GET_ITEM**(*PyObject *p*, Py_ssize_t *pos*)
Return value: Borrowed reference. Like *PyTuple_GetItem()*, but does no checking of its arguments.

*PyObject** **PyTuple_GetSlice**(*PyObject *p*, Py_ssize_t *low*, Py_ssize_t *high*)
Return value: New reference. Take a slice of the tuple pointed to by *p* from *low* to *high* and return it as a new tuple.

int **PyTuple_SetItem**(*PyObject *p*, Py_ssize_t *pos*, *PyObject *o*)
Insert a reference to object *o* at position *pos* of the tuple pointed to by *p*. Return `0` on success.

Note: This function "steals" a reference to *o*.

---

void **PyTuple_SET_ITEM**(*PyObject *p*, Py_ssize_t *pos*, *PyObject *o*)
Like *PyTuple_SetItem()*, but does no error checking, and should *only* be used to fill in brand new tuples.

Note: This function "steals" a reference to *o*.

---

int **_PyTuple_Resize**(*PyObject* ***p*, Py_ssize_t *newsize*)
Can be used to resize a tuple. *newsize* will be the new length of the tuple. Because tuples are *supposed* to be immutable, this should only be used if there is only one reference to the object. Do *not* use this if the tuple may already be known to some other part of the code. The tuple will always grow or shrink at the end. Think of this as destroying the old tuple and creating a new one, only more efficiently. Returns `0` on success. Client code should never assume that the resulting value of `*p` will be the same as before calling this function. If the object referenced by `*p` is replaced, the original `*p` is destroyed. On failure, returns `-1` and sets `*p` to *NULL*, and raises `MemoryError` or `SystemError`.

int **PyTuple_ClearFreeList**()
Clear the free list. Return the total number of freed items.

8.3.5 Struct Sequence Objects

Struct sequence objects are the C equivalent of `namedtuple()` objects, i.e. a sequence whose items can also be accessed through attributes. To create a struct sequence, you first have to create a specific struct sequence type.

*PyTypeObject** **PyStructSequence_NewType**(*PyStructSequence_Desc* **desc*)
Create a new struct sequence type from the data in *desc*, described below. Instances of the resulting type can be created with *PyStructSequence_New()*.

void **PyStructSequence_InitType**(*PyTypeObject* **type*, *PyStructSequence_Desc* **desc*)
Initializes a struct sequence type *type* from *desc* in place.

int **PyStructSequence_InitType2**(*PyTypeObject* **type*, *PyStructSequence_Desc* **desc*)
The same as `PyStructSequence_InitType`, but returns `0` on success and `-1` on failure.

New in version 3.4.

PyStructSequence_Desc
Contains the meta information of a struct sequence type to create.

Field	C Type	Meaning
`name`	`const char *`	name of the struct sequence type
`doc`	`const char *`	pointer to docstring for the type or NULL to omit
`fields`	`PyStructSequence_Field *`	pointer to *NULL*-terminated array with field names of the new type
`n_in_sequence`	`int`	number of fields visible to the Python side (if used as tuple)

PyStructSequence_Field
Describes a field of a struct sequence. As a struct sequence is modeled as a tuple, all fields are typed as *PyObject**. The index in the `fields` array of the *PyStructSequence_Desc* determines which field of the struct sequence is described.

Field	C Type	Meaning
`name`	`const char *`	name for the field or *NULL* to end the list of named fields, set to PyStructSequence_UnnamedField to leave unnamed
`doc`	`const char *`	field docstring or *NULL* to omit

char* **PyStructSequence_UnnamedField**
Special value for a field name to leave it unnamed.

*PyObject** **PyStructSequence_New**(*PyTypeObject* **type*)
Creates an instance of *type*, which must have been created with *PyStructSequence_NewType()*.

*PyObject** **PyStructSequence_GetItem**(*PyObject *p*, Py_ssize_t *pos*)
Return the object at position *pos* in the struct sequence pointed to by *p*. No bounds checking is performed.

*PyObject** **PyStructSequence_GET_ITEM**(*PyObject *p*, Py_ssize_t *pos*)
Macro equivalent of *PyStructSequence_GetItem()*.

void **PyStructSequence_SetItem**(*PyObject *p*, Py_ssize_t *pos*, *PyObject *o*)
Sets the field at index *pos* of the struct sequence *p* to value *o*. Like *PyTuple_SET_ITEM()*, this should only be used to fill in brand new instances.

Note: This function "steals" a reference to *o*.

---

*PyObject** **PyStructSequence_SET_ITEM**(*PyObject *p*, Py_ssize_t *pos*, *PyObject *o*)
Macro equivalent of *PyStructSequence_SetItem()*.

Note: This function "steals" a reference to *o*.

8.3.6 List Objects

PyListObject
This subtype of *PyObject* represents a Python list object.

PyTypeObject **PyList_Type**
This instance of *PyTypeObject* represents the Python list type. This is the same object as `list` in the Python layer.

int **PyList_Check**(*PyObject *p*)
Return true if *p* is a list object or an instance of a subtype of the list type.

int **PyList_CheckExact**(*PyObject *p*)
Return true if *p* is a list object, but not an instance of a subtype of the list type.

*PyObject** **PyList_New**(Py_ssize_t *len*)
Return value: New reference. Return a new list of length *len* on success, or *NULL* on failure.

Note: If *len* is greater than zero, the returned list object's items are set to `NULL`. Thus you cannot use abstract API functions such as *PySequence_SetItem()* or expose the object to Python code before setting all items to a real object with *PyList_SetItem()*.

Py_ssize_t **PyList_Size**(*PyObject *list*)
Return the length of the list object in *list*; this is equivalent to `len(list)` on a list object.

Py_ssize_t **PyList_GET_SIZE**(*PyObject *list*)
Macro form of *PyList_Size()* without error checking.

*PyObject** **PyList_GetItem**(*PyObject *list*, Py_ssize_t *index*)
Return value: Borrowed reference. Return the object at position *index* in the list pointed to by *list*. The position must be positive, indexing from the end of the list is not supported. If *index* is out of bounds, return *NULL* and set an `IndexError` exception.

*PyObject** **PyList_GET_ITEM**(*PyObject *list*, Py_ssize_t *i*)
Return value: Borrowed reference. Macro form of *PyList_GetItem()* without error checking.

int **PyList_SetItem**(*PyObject *list*, Py_ssize_t *index*, *PyObject *item*)
Set the item at index *index* in list to *item*. Return `0` on success or `-1` on failure.

Note: This function "steals" a reference to *item* and discards a reference to an item already in the list at the affected position.

void **PyList_SET_ITEM**(*PyObject* **list*, Py_ssize_t *i*, *PyObject* **o*)
Macro form of *PyList_SetItem()* without error checking. This is normally only used to fill in new lists where there is no previous content.

Note: This macro "steals" a reference to *item*, and, unlike *PyList_SetItem()*, does *not* discard a reference to any item that is being replaced; any reference in *list* at position *i* will be leaked.

int **PyList_Insert**(*PyObject* **list*, Py_ssize_t *index*, *PyObject* **item*)
Insert the item *item* into list *list* in front of index *index*. Return `0` if successful; return `-1` and set an exception if unsuccessful. Analogous to `list.insert(index, item)`.

int **PyList_Append**(*PyObject* **list*, *PyObject* **item*)
Append the object *item* at the end of list *list*. Return `0` if successful; return `-1` and set an exception if unsuccessful. Analogous to `list.append(item)`.

*PyObject** **PyList_GetSlice**(*PyObject* **list*, Py_ssize_t *low*, Py_ssize_t *high*)
Return value: New reference. Return a list of the objects in *list* containing the objects *between low* and *high*. Return *NULL* and set an exception if unsuccessful. Analogous to `list[low:high]`. Negative indices, as when slicing from Python, are not supported.

int **PyList_SetSlice**(*PyObject* **list*, Py_ssize_t *low*, Py_ssize_t *high*, *PyObject* **itemlist*)
Set the slice of *list* between *low* and *high* to the contents of *itemlist*. Analogous to `list[low:high] = itemlist`. The *itemlist* may be *NULL*, indicating the assignment of an empty list (slice deletion). Return `0` on success, `-1` on failure. Negative indices, as when slicing from Python, are not supported.

int **PyList_Sort**(*PyObject* **list*)
Sort the items of *list* in place. Return `0` on success, `-1` on failure. This is equivalent to `list.sort()`.

int **PyList_Reverse**(*PyObject* **list*)
Reverse the items of *list* in place. Return `0` on success, `-1` on failure. This is the equivalent of `list.reverse()`.

*PyObject** **PyList_AsTuple**(*PyObject* **list*)
Return value: New reference. Return a new tuple object containing the contents of *list*; equivalent to `tuple(list)`.

int **PyList_ClearFreeList**()
Clear the free list. Return the total number of freed items.

New in version 3.3.

8.4 Container Objects

8.4.1 Dictionary Objects

PyDictObject
This subtype of *PyObject* represents a Python dictionary object.

PyTypeObject **PyDict_Type**
This instance of *PyTypeObject* represents the Python dictionary type. This is the same object as `dict` in the Python layer.

int **PyDict_Check**(*PyObject* *p)
Return true if *p* is a dict object or an instance of a subtype of the dict type.

int **PyDict_CheckExact**(*PyObject* *p)
Return true if *p* is a dict object, but not an instance of a subtype of the dict type.

*PyObject** **PyDict_New**()
Return value: New reference. Return a new empty dictionary, or *NULL* on failure.

*PyObject** **PyDictProxy_New**(*PyObject* *mapping)
Return value: New reference. Return a `types.MappingProxyType` object for a mapping which enforces read-only behavior. This is normally used to create a view to prevent modification of the dictionary for non-dynamic class types.

void **PyDict_Clear**(*PyObject* *p)
Empty an existing dictionary of all key-value pairs.

int **PyDict_Contains**(*PyObject* *p, *PyObject* *key)
Determine if dictionary *p* contains *key*. If an item in *p* is matches *key*, return `1`, otherwise return `0`. On error, return `-1`. This is equivalent to the Python expression `key in p`.

*PyObject** **PyDict_Copy**(*PyObject* *p)
Return value: New reference. Return a new dictionary that contains the same key-value pairs as *p*.

int **PyDict_SetItem**(*PyObject* *p, *PyObject* *key, *PyObject* *val)
Insert *value* into the dictionary *p* with a key of *key*. *key* must be *hashable*; if it isn't, `TypeError` will be raised. Return `0` on success or `-1` on failure.

int **PyDict_SetItemString**(*PyObject* *p, const char *key, *PyObject* *val)
Insert *value* into the dictionary *p* using *key* as a key. *key* should be a `const char*`. The key object is created using `PyUnicode_FromString(key)`. Return `0` on success or `-1` on failure.

int **PyDict_DelItem**(*PyObject* *p, *PyObject* *key)
Remove the entry in dictionary *p* with key *key*. *key* must be hashable; if it isn't, `TypeError` is raised. Return `0` on success or `-1` on failure.

int **PyDict_DelItemString**(*PyObject* *p, const char *key)
Remove the entry in dictionary *p* which has a key specified by the string *key*. Return `0` on success or `-1` on failure.

*PyObject** **PyDict_GetItem**(*PyObject* *p, *PyObject* *key)
Return value: Borrowed reference. Return the object from dictionary *p* which has a key *key*. Return *NULL* if the key *key* is not present, but *without* setting an exception.

*PyObject** **PyDict_GetItemWithError**(*PyObject* *p, *PyObject* *key)
Return value: Borrowed reference. Variant of *PyDict_GetItem()* that does not suppress exceptions. Return *NULL* **with** an exception set if an exception occurred. Return *NULL* **without** an exception set if the key wasn't present.

*PyObject** **PyDict_GetItemString**(*PyObject* *p, const char *key)
Return value: Borrowed reference. This is the same as *PyDict_GetItem()*, but *key* is specified as a `const char*`, rather than a *PyObject**.

*PyObject** **PyDict_SetDefault**(*PyObject* *p, *PyObject* *key, *PyObject* *default)
Return value: Borrowed reference. This is the same as the Python-level `dict.setdefault()`. If present, it returns the value corresponding to *key* from the dictionary *p*. If the key is not in the dict, it is inserted with value *defaultobj* and *defaultobj* is returned. This function evaluates the hash function of *key* only once, instead of evaluating it independently for the lookup and the insertion.

New in version 3.4.

*PyObject** **PyDict_Items**(*PyObject* *p)
Return value: New reference. Return a *PyListObject* containing all the items from the dictionary.

*PyObject** **PyDict_Keys**(*PyObject *p*)
Return value: New reference. Return a *PyListObject* containing all the keys from the dictionary.

*PyObject** **PyDict_Values**(*PyObject *p*)
Return value: New reference. Return a *PyListObject* containing all the values from the dictionary *p*.

Py_ssize_t **PyDict_Size**(*PyObject *p*)
Return the number of items in the dictionary. This is equivalent to `len(p)` on a dictionary.

int **PyDict_Next**(*PyObject *p*, Py_ssize_t *ppos*, *PyObject **pkey*, *PyObject **pvalue*)
Iterate over all key-value pairs in the dictionary *p*. The `Py_ssize_t` referred to by *ppos* must be initialized to `0` prior to the first call to this function to start the iteration; the function returns true for each pair in the dictionary, and false once all pairs have been reported. The parameters *pkey* and *pvalue* should either point to *PyObject** variables that will be filled in with each key and value, respectively, or may be *NULL*. Any references returned through them are borrowed. *ppos* should not be altered during iteration. Its value represents offsets within the internal dictionary structure, and since the structure is sparse, the offsets are not consecutive.

For example:

```
PyObject *key, *value;
Py_ssize_t pos = 0;

while (PyDict_Next(self->dict, &pos, &key, &value)) {
    /* do something interesting with the values... */
    ...
}
```

The dictionary *p* should not be mutated during iteration. It is safe to modify the values of the keys as you iterate over the dictionary, but only so long as the set of keys does not change. For example:

```
PyObject *key, *value;
Py_ssize_t pos = 0;

while (PyDict_Next(self->dict, &pos, &key, &value)) {
    long i = PyLong_AsLong(value);
    if (i == -1 && PyErr_Occurred()) {
        return -1;
    }
    PyObject *o = PyLong_FromLong(i + 1);
    if (o == NULL)
        return -1;
    if (PyDict_SetItem(self->dict, key, o) < 0) {
        Py_DECREF(o);
        return -1;
    }
    Py_DECREF(o);
}
```

int **PyDict_Merge**(*PyObject *a*, *PyObject *b*, int *override*)
Iterate over mapping object *b* adding key-value pairs to dictionary *a*. *b* may be a dictionary, or any object supporting *PyMapping_Keys()* and *PyObject_GetItem()*. If *override* is true, existing pairs in *a* will be replaced if a matching key is found in *b*, otherwise pairs will only be added if there is not a matching key in *a*. Return `0` on success or `-1` if an exception was raised.

int **PyDict_Update**(*PyObject *a*, *PyObject *b*)
This is the same as `PyDict_Merge(a, b, 1)` in C, and is similar to `a.update(b)` in Python except that *PyDict_Update()* doesn't fall back to the iterating over a sequence of key value pairs if the second argument has no "keys" attribute. Return `0` on success or `-1` if an exception was raised.

int **PyDict_MergeFromSeq2**(*PyObject* *a, *PyObject* *seq2, int *override*)
Update or merge into dictionary *a*, from the key-value pairs in *seq2*. *seq2* must be an iterable object producing iterable objects of length 2, viewed as key-value pairs. In case of duplicate keys, the last wins if *override* is true, else the first wins. Return `0` on success or `-1` if an exception was raised. Equivalent Python (except for the return value):

```
def PyDict_MergeFromSeq2(a, seq2, override):
    for key, value in seq2:
        if override or key not in a:
            a[key] = value
```

int **PyDict_ClearFreeList**()
Clear the free list. Return the total number of freed items.

New in version 3.3.

8.4.2 Set Objects

This section details the public API for `set` and `frozenset` objects. Any functionality not listed below is best accessed using the either the abstract object protocol (including *PyObject_CallMethod()*, *PyObject_RichCompareBool()*, *PyObject_Hash()*, *PyObject_Repr()*, *PyObject_IsTrue()*, *PyObject_Print()*, and *PyObject_GetIter()*) or the abstract number protocol (including *PyNumber_And()*, *PyNumber_Subtract()*, *PyNumber_Or()*, *PyNumber_Xor()*, *PyNumber_InPlaceAnd()*, *PyNumber_InPlaceSubtract()*, *PyNumber_InPlaceOr()*, and *PyNumber_InPlaceXor()*).

PySetObject
This subtype of *PyObject* is used to hold the internal data for both `set` and `frozenset` objects. It is like a *PyDictObject* in that it is a fixed size for small sets (much like tuple storage) and will point to a separate, variable sized block of memory for medium and large sized sets (much like list storage). None of the fields of this structure should be considered public and are subject to change. All access should be done through the documented API rather than by manipulating the values in the structure.

PyTypeObject **PySet_Type**
This is an instance of *PyTypeObject* representing the Python `set` type.

PyTypeObject **PyFrozenSet_Type**
This is an instance of *PyTypeObject* representing the Python `frozenset` type.

The following type check macros work on pointers to any Python object. Likewise, the constructor functions work with any iterable Python object.

int **PySet_Check**(*PyObject* *p)
Return true if *p* is a `set` object or an instance of a subtype.

int **PyFrozenSet_Check**(*PyObject* *p)
Return true if *p* is a `frozenset` object or an instance of a subtype.

int **PyAnySet_Check**(*PyObject* *p)
Return true if *p* is a `set` object, a `frozenset` object, or an instance of a subtype.

int **PyAnySet_CheckExact**(*PyObject* *p)
Return true if *p* is a `set` object or a `frozenset` object but not an instance of a subtype.

int **PyFrozenSet_CheckExact**(*PyObject* *p)
Return true if *p* is a `frozenset` object but not an instance of a subtype.

*PyObject** **PySet_New**(*PyObject* *iterable)
Return value: New reference. Return a new `set` containing objects returned by the *iterable*. The *iterable* may be *NULL* to create a new empty set. Return the new set on success or *NULL* on failure.

Raise `TypeError` if *iterable* is not actually iterable. The constructor is also useful for copying a set (`c=set(s)`).

*PyObject** **PyFrozenSet_New**(*PyObject *iterable*)
Return value: New reference. Return a new `frozenset` containing objects returned by the *iterable*. The *iterable* may be *NULL* to create a new empty frozenset. Return the new set on success or *NULL* on failure. Raise `TypeError` if *iterable* is not actually iterable.

The following functions and macros are available for instances of `set` or `frozenset` or instances of their subtypes.

Py_ssize_t **PySet_Size**(*PyObject *anyset*)
Return the length of a `set` or `frozenset` object. Equivalent to `len(anyset)`. Raises a `PyExc_SystemError` if *anyset* is not a `set`, `frozenset`, or an instance of a subtype.

Py_ssize_t **PySet_GET_SIZE**(*PyObject *anyset*)
Macro form of *PySet_Size()* without error checking.

int **PySet_Contains**(*PyObject *anyset*, *PyObject *key*)
Return `1` if found, `0` if not found, and `-1` if an error is encountered. Unlike the Python `__contains__()` method, this function does not automatically convert unhashable sets into temporary frozensets. Raise a `TypeError` if the *key* is unhashable. Raise `PyExc_SystemError` if *anyset* is not a `set`, `frozenset`, or an instance of a subtype.

int **PySet_Add**(*PyObject *set*, *PyObject *key*)
Add *key* to a `set` instance. Also works with `frozenset` instances (like *PyTuple_SetItem()* it can be used to fill-in the values of brand new frozensets before they are exposed to other code). Return `0` on success or `-1` on failure. Raise a `TypeError` if the *key* is unhashable. Raise a `MemoryError` if there is no room to grow. Raise a `SystemError` if *set* is not an instance of `set` or its subtype.

The following functions are available for instances of `set` or its subtypes but not for instances of `frozenset` or its subtypes.

int **PySet_Discard**(*PyObject *set*, *PyObject *key*)
Return `1` if found and removed, `0` if not found (no action taken), and `-1` if an error is encountered. Does not raise `KeyError` for missing keys. Raise a `TypeError` if the *key* is unhashable. Unlike the Python `discard()` method, this function does not automatically convert unhashable sets into temporary frozensets. Raise `PyExc_SystemError` if *set* is not an instance of `set` or its subtype.

*PyObject** **PySet_Pop**(*PyObject *set*)
Return value: New reference. Return a new reference to an arbitrary object in the *set*, and removes the object from the *set*. Return *NULL* on failure. Raise `KeyError` if the set is empty. Raise a `SystemError` if *set* is not an instance of `set` or its subtype.

int **PySet_Clear**(*PyObject *set*)
Empty an existing set of all elements.

int **PySet_ClearFreeList**()
Clear the free list. Return the total number of freed items.

New in version 3.3.

8.5 Function Objects

8.5.1 Function Objects

There are a few functions specific to Python functions.

PyFunctionObject
The C structure used for functions.

PyTypeObject **PyFunction_Type**
This is an instance of *PyTypeObject* and represents the Python function type. It is exposed to Python programmers as `types.FunctionType`.

int **PyFunction_Check**(*PyObject *o*)
Return true if *o* is a function object (has type *PyFunction_Type*). The parameter must not be *NULL*.

*PyObject** **PyFunction_New**(*PyObject *code*, *PyObject *globals*)
Return value: New reference. Return a new function object associated with the code object *code*. *globals* must be a dictionary with the global variables accessible to the function.

The function's docstring and name are retrieved from the code object. *__module__* is retrieved from *globals*. The argument defaults, annotations and closure are set to *NULL*. *__qualname__* is set to the same value as the function's name.

*PyObject** **PyFunction_NewWithQualName**(*PyObject *code*, *PyObject *globals*, *PyObject *qualname*)
Return value: New reference. As *PyFunction_New()*, but also allows setting the function object's `__qualname__` attribute. *qualname* should be a unicode object or NULL; if NULL, the `__qualname__` attribute is set to the same value as its `__name__` attribute.

New in version 3.3.

*PyObject** **PyFunction_GetCode**(*PyObject *op*)
Return value: Borrowed reference. Return the code object associated with the function object *op*.

*PyObject** **PyFunction_GetGlobals**(*PyObject *op*)
Return value: Borrowed reference. Return the globals dictionary associated with the function object *op*.

*PyObject** **PyFunction_GetModule**(*PyObject *op*)
Return value: Borrowed reference. Return the *__module__* attribute of the function object *op*. This is normally a string containing the module name, but can be set to any other object by Python code.

*PyObject** **PyFunction_GetDefaults**(*PyObject *op*)
Return value: Borrowed reference. Return the argument default values of the function object *op*. This can be a tuple of arguments or *NULL*.

int **PyFunction_SetDefaults**(*PyObject *op*, *PyObject *defaults*)
Set the argument default values for the function object *op*. *defaults* must be *Py_None* or a tuple.

Raises `SystemError` and returns `-1` on failure.

*PyObject** **PyFunction_GetClosure**(*PyObject *op*)
Return value: Borrowed reference. Return the closure associated with the function object *op*. This can be *NULL* or a tuple of cell objects.

int **PyFunction_SetClosure**(*PyObject *op*, *PyObject *closure*)
Set the closure associated with the function object *op*. *closure* must be *Py_None* or a tuple of cell objects.

Raises `SystemError` and returns `-1` on failure.

PyObject ***PyFunction_GetAnnotations**(*PyObject *op*)
Return the annotations of the function object *op*. This can be a mutable dictionary or *NULL*.

int **PyFunction_SetAnnotations**(*PyObject *op*, *PyObject *annotations*)
Set the annotations for the function object *op*. *annotations* must be a dictionary or *Py_None*.

Raises `SystemError` and returns `-1` on failure.

8.5.2 Instance Method Objects

An instance method is a wrapper for a *PyCFunction* and the new way to bind a *PyCFunction* to a class object. It replaces the former call `PyMethod_New(func, NULL, class)`.

PyTypeObject **PyInstanceMethod_Type**
This instance of *PyTypeObject* represents the Python instance method type. It is not exposed to Python programs.

int **PyInstanceMethod_Check**(*PyObject *o*)
Return true if *o* is an instance method object (has type *PyInstanceMethod_Type*). The parameter must not be *NULL*.

*PyObject** **PyInstanceMethod_New**(*PyObject *func*)
Return a new instance method object, with *func* being any callable object *func* is the function that will be called when the instance method is called.

*PyObject** **PyInstanceMethod_Function**(*PyObject *im*)
Return the function object associated with the instance method *im*.

*PyObject** **PyInstanceMethod_GET_FUNCTION**(*PyObject *im*)
Macro version of *PyInstanceMethod_Function()* which avoids error checking.

8.5.3 Method Objects

Methods are bound function objects. Methods are always bound to an instance of a user-defined class. Unbound methods (methods bound to a class object) are no longer available.

PyTypeObject **PyMethod_Type**
This instance of *PyTypeObject* represents the Python method type. This is exposed to Python programs as `types.MethodType`.

int **PyMethod_Check**(*PyObject *o*)
Return true if *o* is a method object (has type *PyMethod_Type*). The parameter must not be *NULL*.

*PyObject** **PyMethod_New**(*PyObject *func*, *PyObject *self*)
Return value: New reference. Return a new method object, with *func* being any callable object and *self* the instance the method should be bound. *func* is the function that will be called when the method is called. *self* must not be *NULL*.

*PyObject** **PyMethod_Function**(*PyObject *meth*)
Return value: Borrowed reference. Return the function object associated with the method *meth*.

*PyObject** **PyMethod_GET_FUNCTION**(*PyObject *meth*)
Return value: Borrowed reference. Macro version of *PyMethod_Function()* which avoids error checking.

*PyObject** **PyMethod_Self**(*PyObject *meth*)
Return value: Borrowed reference. Return the instance associated with the method *meth*.

*PyObject** **PyMethod_GET_SELF**(*PyObject *meth*)
Return value: Borrowed reference. Macro version of *PyMethod_Self()* which avoids error checking.

int **PyMethod_ClearFreeList**()
Clear the free list. Return the total number of freed items.

8.5.4 Cell Objects

"Cell" objects are used to implement variables referenced by multiple scopes. For each such variable, a cell object is created to store the value; the local variables of each stack frame that references the value contains

a reference to the cells from outer scopes which also use that variable. When the value is accessed, the value contained in the cell is used instead of the cell object itself. This de-referencing of the cell object requires support from the generated byte-code; these are not automatically de-referenced when accessed. Cell objects are not likely to be useful elsewhere.

PyCellObject
The C structure used for cell objects.

PyTypeObject **PyCell_Type**
The type object corresponding to cell objects.

int **PyCell_Check**(ob)
Return true if *ob* is a cell object; *ob* must not be *NULL*.

*PyObject** **PyCell_New**(*PyObject *ob*)
Return value: New reference. Create and return a new cell object containing the value *ob*. The parameter may be *NULL*.

*PyObject** **PyCell_Get**(*PyObject *cell*)
Return value: New reference. Return the contents of the cell *cell*.

*PyObject** **PyCell_GET**(*PyObject *cell*)
Return value: Borrowed reference. Return the contents of the cell *cell*, but without checking that *cell* is non-*NULL* and a cell object.

int **PyCell_Set**(*PyObject *cell*, *PyObject *value*)
Set the contents of the cell object *cell* to *value*. This releases the reference to any current content of the cell. *value* may be *NULL*. *cell* must be non-*NULL*; if it is not a cell object, `-1` will be returned. On success, `0` will be returned.

void **PyCell_SET**(*PyObject *cell*, *PyObject *value*)
Sets the value of the cell object *cell* to *value*. No reference counts are adjusted, and no checks are made for safety; *cell* must be non-*NULL* and must be a cell object.

8.5.5 Code Objects

Code objects are a low-level detail of the CPython implementation. Each one represents a chunk of executable code that hasn't yet been bound into a function.

PyCodeObject
The C structure of the objects used to describe code objects. The fields of this type are subject to change at any time.

PyTypeObject **PyCode_Type**
This is an instance of *PyTypeObject* representing the Python `code` type.

int **PyCode_Check**(*PyObject *co*)
Return true if *co* is a `code` object.

int **PyCode_GetNumFree**(*PyCodeObject *co*)
Return the number of free variables in *co*.

*PyCodeObject** **PyCode_New**(int *argcount*, int *kwonlyargcount*, int *nlocals*, int *stacksize*, int *flags*, *PyObject *code*, *PyObject *consts*, *PyObject *names*, *PyObject *varnames*, *PyObject *freevars*, *PyObject *cellvars*, *PyObject *filename*, *PyObject *name*, int *firstlineno*, *PyObject *lnotab*)
Return a new code object. If you need a dummy code object to create a frame, use *PyCode_NewEmpty()* instead. Calling *PyCode_New()* directly can bind you to a precise Python version since the definition of the bytecode changes often.

*PyCodeObject** **PyCode_NewEmpty**(const char **filename*, const char **funcname*, int *firstlineno*)
Return a new empty code object with the specified filename, function name, and first line number. It is illegal to `exec()` or `eval()` the resulting code object.

8.6 Other Objects

8.6.1 File Objects

These APIs are a minimal emulation of the Python 2 C API for built-in file objects, which used to rely on the buffered I/O (`FILE*`) support from the C standard library. In Python 3, files and streams use the new `io` module, which defines several layers over the low-level unbuffered I/O of the operating system. The functions described below are convenience C wrappers over these new APIs, and meant mostly for internal error reporting in the interpreter; third-party code is advised to access the `io` APIs instead.

PyFile_FromFd(int *fd*, const char **name*, const char **mode*, int *buffering*, const char **encoding*, const char **errors*, const char **newline*, int *closefd*)
Create a Python file object from the file descriptor of an already opened file *fd*. The arguments *name*, *encoding*, *errors* and *newline* can be *NULL* to use the defaults; *buffering* can be *-1* to use the default. *name* is ignored and kept for backward compatibility. Return *NULL* on failure. For a more comprehensive description of the arguments, please refer to the `io.open()` function documentation.

> **Warning:** Since Python streams have their own buffering layer, mixing them with OS-level file descriptors can produce various issues (such as unexpected ordering of data).

Changed in version 3.2: Ignore *name* attribute.

int **PyObject_AsFileDescriptor**(*PyObject* **p*)
Return the file descriptor associated with *p* as an `int`. If the object is an integer, its value is returned. If not, the object's `fileno()` method is called if it exists; the method must return an integer, which is returned as the file descriptor value. Sets an exception and returns `-1` on failure.

*PyObject** **PyFile_GetLine**(*PyObject* **p*, int *n*)
Return value: New reference. Equivalent to `p.readline([n])`, this function reads one line from the object *p*. *p* may be a file object or any object with a `readline()` method. If *n* is `0`, exactly one line is read, regardless of the length of the line. If *n* is greater than `0`, no more than *n* bytes will be read from the file; a partial line can be returned. In both cases, an empty string is returned if the end of the file is reached immediately. If *n* is less than `0`, however, one line is read regardless of length, but `EOFError` is raised if the end of the file is reached immediately.

int **PyFile_WriteObject**(*PyObject* **obj*, *PyObject* **p*, int *flags*)
Write object *obj* to file object *p*. The only supported flag for *flags* is `Py_PRINT_RAW`; if given, the `str()` of the object is written instead of the `repr()`. Return `0` on success or `-1` on failure; the appropriate exception will be set.

int **PyFile_WriteString**(const char **s*, *PyObject* **p*)
Write string *s* to file object *p*. Return `0` on success or `-1` on failure; the appropriate exception will be set.

8.6.2 Module Objects

PyTypeObject **PyModule_Type**
This instance of *PyTypeObject* represents the Python module type. This is exposed to Python programs as `types.ModuleType`.

int **PyModule_Check**(*PyObject* *p)
Return true if *p* is a module object, or a subtype of a module object.

int **PyModule_CheckExact**(*PyObject* *p)
Return true if *p* is a module object, but not a subtype of *PyModule_Type*.

*PyObject** **PyModule_NewObject**(*PyObject* *name)
Return a new module object with the `__name__` attribute set to *name*. The module's `__name__`, `__doc__`, `__package__`, and `__loader__` attributes are filled in (all but `__name__` are set to `None`); the caller is responsible for providing a `__file__` attribute.

New in version 3.3.

Changed in version 3.4: `__package__` and `__loader__` are set to `None`.

*PyObject** **PyModule_New**(const char *name)
Return value: New reference. Similar to *PyModule_NewObject()*, but the name is a UTF-8 encoded string instead of a Unicode object.

*PyObject** **PyModule_GetDict**(*PyObject* *module)
Return value: Borrowed reference. Return the dictionary object that implements *module*'s namespace; this object is the same as the `__dict__` attribute of the module object. If *module* is not a module object (or a subtype of a module object), `SystemError` is raised and *NULL* is returned.

It is recommended extensions use other `PyModule_*()` and `PyObject_*()` functions rather than directly manipulate a module's `__dict__`.

*PyObject** **PyModule_GetNameObject**(*PyObject* *module)
Return *module*'s `__name__` value. If the module does not provide one, or if it is not a string, `SystemError` is raised and *NULL* is returned.

New in version 3.3.

const char* **PyModule_GetName**(*PyObject* *module)
Similar to *PyModule_GetNameObject()* but return the name encoded to `'utf-8'`.

void* **PyModule_GetState**(*PyObject* *module)
Return the "state" of the module, that is, a pointer to the block of memory allocated at module creation time, or *NULL*. See *PyModuleDef.m_size*.

*PyModuleDef** **PyModule_GetDef**(*PyObject* *module)
Return a pointer to the *PyModuleDef* struct from which the module was created, or *NULL* if the module wasn't created from a definition.

*PyObject** **PyModule_GetFilenameObject**(*PyObject* *module)
Return the name of the file from which *module* was loaded using *module*'s `__file__` attribute. If this is not defined, or if it is not a unicode string, raise `SystemError` and return *NULL*; otherwise return a reference to a Unicode object.

New in version 3.2.

const char* **PyModule_GetFilename**(*PyObject* *module)
Similar to *PyModule_GetFilenameObject()* but return the filename encoded to 'utf-8'.

Deprecated since version 3.2: *PyModule_GetFilename()* raises `UnicodeEncodeError` on unencodable filenames, use *PyModule_GetFilenameObject()* instead.

Initializing C modules

Modules objects are usually created from extension modules (shared libraries which export an initialization function), or compiled-in modules (where the initialization function is added using *PyImport_AppendInittab()*). See building or extending-with-embedding for details.

The initialization function can either pass a module definition instance to *PyModule_Create()*, and return the resulting module object, or request "multi-phase initialization" by returning the definition struct itself.

PyModuleDef

The module definition struct, which holds all information needed to create a module object. There is usually only one statically initialized variable of this type for each module.

PyModuleDef_Base **m_base**

Always initialize this member to `PyModuleDef_HEAD_INIT`.

const char ***m_name**

Name for the new module.

const char ***m_doc**

Docstring for the module; usually a docstring variable created with `PyDoc_STRVAR()` is used.

Py_ssize_t **m_size**

Module state may be kept in a per-module memory area that can be retrieved with *PyModule_GetState()*, rather than in static globals. This makes modules safe for use in multiple sub-interpreters.

This memory area is allocated based on *m_size* on module creation, and freed when the module object is deallocated, after the `m_free` function has been called, if present.

Setting `m_size` to `-1` means that the module does not support sub-interpreters, because it has global state.

Setting it to a non-negative value means that the module can be re-initialized and specifies the additional amount of memory it requires for its state. Non-negative `m_size` is required for multi-phase initialization.

See **PEP 3121** for more details.

*PyMethodDef** **m_methods**

A pointer to a table of module-level functions, described by *PyMethodDef* values. Can be *NULL* if no functions are present.

*PyModuleDef_Slot** **m_slots**

An array of slot definitions for multi-phase initialization, terminated by a `{0, NULL}` entry. When using single-phase initialization, *m_slots* must be *NULL*.

Changed in version 3.5: Prior to version 3.5, this member was always set to *NULL*, and was defined as:

inquiry **m_reload**

traverseproc **m_traverse**

A traversal function to call during GC traversal of the module object, or *NULL* if not needed. This function may be called before module state is allocated (*PyModule_GetState()* may return *NULL*), and before the *Py_mod_exec* function is executed.

inquiry **m_clear**

A clear function to call during GC clearing of the module object, or *NULL* if not needed. This function may be called before module state is allocated (*PyModule_GetState()* may return *NULL*), and before the *Py_mod_exec* function is executed.

freefunc **m_free**

A function to call during deallocation of the module object, or *NULL* if not needed. This function may be called before module state is allocated (*PyModule_GetState()* may return *NULL*), and before the *Py_mod_exec* function is executed.

Single-phase initialization

The module initialization function may create and return the module object directly. This is referred to as "single-phase initialization", and uses one of the following two module creation functions:

*PyObject** **PyModule_Create**(*PyModuleDef* **def*)
Create a new module object, given the definition in *def*. This behaves like *PyModule_Create2()* with *module_api_version* set to PYTHON_API_VERSION.

*PyObject** **PyModule_Create2**(*PyModuleDef* **def*, int *module_api_version*)
Create a new module object, given the definition in *def*, assuming the API version *module_api_version*. If that version does not match the version of the running interpreter, a RuntimeWarning is emitted.

Note: Most uses of this function should be using *PyModule_Create()* instead; only use this if you are sure you need it.

Before it is returned from in the initialization function, the resulting module object is typically populated using functions like *PyModule_AddObject()*.

Multi-phase initialization

An alternate way to specify extensions is to request "multi-phase initialization". Extension modules created this way behave more like Python modules: the initialization is split between the *creation phase*, when the module object is created, and the *execution phase*, when it is populated. The distinction is similar to the __new__() and __init__() methods of classes.

Unlike modules created using single-phase initialization, these modules are not singletons: if the *sys.modules* entry is removed and the module is re-imported, a new module object is created, and the old module is subject to normal garbage collection – as with Python modules. By default, multiple modules created from the same definition should be independent: changes to one should not affect the others. This means that all state should be specific to the module object (using e.g. using *PyModule_GetState()*), or its contents (such as the module's __dict__ or individual classes created with *PyType_FromSpec()*).

All modules created using multi-phase initialization are expected to support *sub-interpreters*. Making sure multiple modules are independent is typically enough to achieve this.

To request multi-phase initialization, the initialization function (PyInit_modulename) returns a *PyModuleDef* instance with non-empty *m_slots*. Before it is returned, the PyModuleDef instance must be initialized with the following function:

*PyObject** **PyModuleDef_Init**(*PyModuleDef* **def*)
Ensures a module definition is a properly initialized Python object that correctly reports its type and reference count.

Returns *def* cast to PyObject*, or *NULL* if an error occurred.

New in version 3.5.

The *m_slots* member of the module definition must point to an array of PyModuleDef_Slot structures:

PyModuleDef_Slot

int **slot**
A slot ID, chosen from the available values explained below.

void* **value**
Value of the slot, whose meaning depends on the slot ID.

New in version 3.5.

The *m_slots* array must be terminated by a slot with id 0.

The available slot types are:

`Py_mod_create`
: Specifies a function that is called to create the module object itself. The *value* pointer of this slot must point to a function of the signature:

  *PyObject** `create_module`(*PyObject *spec*, *PyModuleDef *def*)

  The function receives a `ModuleSpec` instance, as defined in **PEP 451**, and the module definition. It should return a new module object, or set an error and return *NULL*.

  This function should be kept minimal. In particular, it should not call arbitrary Python code, as trying to import the same module again may result in an infinite loop.

  Multiple `Py_mod_create` slots may not be specified in one module definition.

  If `Py_mod_create` is not specified, the import machinery will create a normal module object using *PyModule_New()*. The name is taken from *spec*, not the definition, to allow extension modules to dynamically adjust to their place in the module hierarchy and be imported under different names through symlinks, all while sharing a single module definition.

  There is no requirement for the returned object to be an instance of *PyModule_Type*. Any type can be used, as long as it supports setting and getting import-related attributes. However, only `PyModule_Type` instances may be returned if the `PyModuleDef` has non-*NULL* `m_traverse`, `m_clear`, `m_free`; non-zero `m_size`; or slots other than `Py_mod_create`.

`Py_mod_exec`
: Specifies a function that is called to *execute* the module. This is equivalent to executing the code of a Python module: typically, this function adds classes and constants to the module. The signature of the function is:

  int `exec_module`(*PyObject** *module*)

  If multiple `Py_mod_exec` slots are specified, they are processed in the order they appear in the *m_slots* array.

See **PEP 489** for more details on multi-phase initialization.

Low-level module creation functions

The following functions are called under the hood when using multi-phase initialization. They can be used directly, for example when creating module objects dynamically. Note that both `PyModule_FromDefAndSpec` and `PyModule_ExecDef` must be called to fully initialize a module.

PyObject * `PyModule_FromDefAndSpec`(*PyModuleDef *def*, *PyObject *spec*)
: Create a new module object, given the definition in *module* and the ModuleSpec *spec*. This behaves like *PyModule_FromDefAndSpec2()* with *module_api_version* set to `PYTHON_API_VERSION`.

  New in version 3.5.

PyObject * `PyModule_FromDefAndSpec2`(*PyModuleDef *def*, *PyObject *spec*, int *module_api_version*)
: Create a new module object, given the definition in *module* and the ModuleSpec *spec*, assuming the API version *module_api_version*. If that version does not match the version of the running interpreter, a `RuntimeWarning` is emitted.

  Note: Most uses of this function should be using *PyModule_FromDefAndSpec()* instead; only use this if you are sure you need it.

New in version 3.5.

int **PyModule_ExecDef**(*PyObject* *module, *PyModuleDef* *def)
Process any execution slots (*Py_mod_exec*) given in *def*.

New in version 3.5.

int **PyModule_SetDocString**(*PyObject* *module, const char *docstring)
Set the docstring for *module* to *docstring*. This function is called automatically when creating a module from `PyModuleDef`, using either `PyModule_Create` or `PyModule_FromDefAndSpec`.

New in version 3.5.

int **PyModule_AddFunctions**(*PyObject* *module, *PyMethodDef* *functions)
Add the functions from the *NULL* terminated *functions* array to *module*. Refer to the *PyMethodDef* documentation for details on individual entries (due to the lack of a shared module namespace, module level "functions" implemented in C typically receive the module as their first parameter, making them similar to instance methods on Python classes). This function is called automatically when creating a module from `PyModuleDef`, using either `PyModule_Create` or `PyModule_FromDefAndSpec`.

New in version 3.5.

Support functions

The module initialization function (if using single phase initialization) or a function called from a module execution slot (if using multi-phase initialization), can use the following functions to help initialize the module state:

int **PyModule_AddObject**(*PyObject* *module, const char *name, *PyObject* *value)
Add an object to *module* as *name*. This is a convenience function which can be used from the module's initialization function. This steals a reference to *value*. Return `-1` on error, `0` on success.

int **PyModule_AddIntConstant**(*PyObject* *module, const char *name, long *value*)
Add an integer constant to *module* as *name*. This convenience function can be used from the module's initialization function. Return `-1` on error, `0` on success.

int **PyModule_AddStringConstant**(*PyObject* *module, const char *name, const char *value)
Add a string constant to *module* as *name*. This convenience function can be used from the module's initialization function. The string *value* must be *NULL*-terminated. Return `-1` on error, `0` on success.

int **PyModule_AddIntMacro**(*PyObject* *module, macro)
Add an int constant to *module*. The name and the value are taken from *macro*. For example `PyModule_AddIntMacro(module, AF_INET)` adds the int constant *AF_INET* with the value of *AF_INET* to *module*. Return `-1` on error, `0` on success.

int **PyModule_AddStringMacro**(*PyObject* *module, macro)
Add a string constant to *module*.

Module lookup

Single-phase initialization creates singleton modules that can be looked up in the context of the current interpreter. This allows the module object to be retrieved later with only a reference to the module definition.

These functions will not work on modules created using multi-phase initialization, since multiple such modules can be created from a single definition.

*PyObject** **PyState_FindModule**(*PyModuleDef* *def)
Returns the module object that was created from *def* for the current interpreter. This method requires

that the module object has been attached to the interpreter state with *PyState_AddModule()* beforehand. In case the corresponding module object is not found or has not been attached to the interpreter state yet, it returns *NULL*.

int **PyState_AddModule**(*PyObject* *module*, *PyModuleDef* *def*)
Attaches the module object passed to the function to the interpreter state. This allows the module object to be accessible via *PyState_FindModule()*.

Only effective on modules created using single-phase initialization.

New in version 3.3.

int **PyState_RemoveModule**(*PyModuleDef* *def*)
Removes the module object created from *def* from the interpreter state.

New in version 3.3.

8.6.3 Iterator Objects

Python provides two general-purpose iterator objects. The first, a sequence iterator, works with an arbitrary sequence supporting the `__getitem__()` method. The second works with a callable object and a sentinel value, calling the callable for each item in the sequence, and ending the iteration when the sentinel value is returned.

PyTypeObject **PySeqIter_Type**
Type object for iterator objects returned by *PySeqIter_New()* and the one-argument form of the `iter()` built-in function for built-in sequence types.

int **PySeqIter_Check**(op)
Return true if the type of *op* is *PySeqIter_Type*.

*PyObject** **PySeqIter_New**(*PyObject* *seq*)
Return value: New reference. Return an iterator that works with a general sequence object, *seq*. The iteration ends when the sequence raises `IndexError` for the subscripting operation.

PyTypeObject **PyCallIter_Type**
Type object for iterator objects returned by *PyCallIter_New()* and the two-argument form of the `iter()` built-in function.

int **PyCallIter_Check**(op)
Return true if the type of *op* is *PyCallIter_Type*.

*PyObject** **PyCallIter_New**(*PyObject* *callable*, *PyObject* *sentinel*)
Return value: New reference. Return a new iterator. The first parameter, *callable*, can be any Python callable object that can be called with no parameters; each call to it should return the next item in the iteration. When *callable* returns a value equal to *sentinel*, the iteration will be terminated.

8.6.4 Descriptor Objects

"Descriptors" are objects that describe some attribute of an object. They are found in the dictionary of type objects.

PyTypeObject **PyProperty_Type**
The type object for the built-in descriptor types.

*PyObject** **PyDescr_NewGetSet**(*PyTypeObject* *type*, struct *PyGetSetDef* *getset*)
Return value: New reference.

*PyObject** **PyDescr_NewMember**(*PyTypeObject* *type*, struct *PyMemberDef* *meth*)
Return value: New reference.

*PyObject** **PyDescr_NewMethod**(*PyTypeObject* **type*, struct *PyMethodDef* **meth*)
Return value: New reference.

*PyObject** **PyDescr_NewWrapper**(*PyTypeObject* **type*, struct wrapperbase **wrapper*, void **wrapped*)
Return value: New reference.

*PyObject** **PyDescr_NewClassMethod**(*PyTypeObject* **type*, *PyMethodDef* **method*)
Return value: New reference.

int **PyDescr_IsData**(*PyObject* **descr*)
Return true if the descriptor objects *descr* describes a data attribute, or false if it describes a method. *descr* must be a descriptor object; there is no error checking.

*PyObject** **PyWrapper_New**(*PyObject* *, *PyObject* *)
Return value: New reference.

8.6.5 Slice Objects

PyTypeObject **PySlice_Type**
The type object for slice objects. This is the same as `slice` in the Python layer.

int **PySlice_Check**(*PyObject* **ob*)
Return true if *ob* is a slice object; *ob* must not be *NULL*.

*PyObject** **PySlice_New**(*PyObject* **start*, *PyObject* **stop*, *PyObject* **step*)
Return value: New reference. Return a new slice object with the given values. The *start*, *stop*, and *step* parameters are used as the values of the slice object attributes of the same names. Any of the values may be *NULL*, in which case the `None` will be used for the corresponding attribute. Return *NULL* if the new object could not be allocated.

int **PySlice_GetIndices**(*PyObject* **slice*, Py_ssize_t *length*, Py_ssize_t **start*, Py_ssize_t **stop*, Py_ssize_t **step*)
Retrieve the start, stop and step indices from the slice object *slice*, assuming a sequence of length *length*. Treats indices greater than *length* as errors.

Returns `0` on success and `-1` on error with no exception set (unless one of the indices was not `None` and failed to be converted to an integer, in which case `-1` is returned with an exception set).

You probably do not want to use this function.

Changed in version 3.2: The parameter type for the *slice* parameter was `PySliceObject*` before.

int **PySlice_GetIndicesEx**(*PyObject* **slice*, Py_ssize_t *length*, Py_ssize_t **start*, Py_ssize_t **stop*, Py_ssize_t **step*, Py_ssize_t **slicelength*)
Usable replacement for *PySlice_GetIndices()*. Retrieve the start, stop, and step indices from the slice object *slice* assuming a sequence of length *length*, and store the length of the slice in *slicelength*. Out of bounds indices are clipped in a manner consistent with the handling of normal slices.

Returns `0` on success and `-1` on error with exception set.

Note: This function is considered not safe for resizable sequences. Its invocation should be replaced by a combination of *PySlice_Unpack()* and *PySlice_AdjustIndices()* where

```
if (PySlice_GetIndicesEx(slice, length, &start, &stop, &step, &slicelength) < 0) {
    // return error
}
```

is replaced by

```
if (PySlice_Unpack(slice, &start, &stop, &step) < 0) {
    // return error
}
slicelength = PySlice_AdjustIndices(length, &start, &stop, step);
```

Changed in version 3.2: The parameter type for the *slice* parameter was `PySliceObject*` before.

Changed in version 3.6.1: If `Py_LIMITED_API` is not set or set to the value between `0x03050400` and `0x03060000` (not including) or `0x03060100` or higher `PySlice_GetIndicesEx()` is implemented as a macro using `PySlice_Unpack()` and `PySlice_AdjustIndices()`. Arguments *start*, *stop* and *step* are evaluated more than once.

Deprecated since version 3.6.1: If `Py_LIMITED_API` is set to the value less than `0x03050400` or between `0x03060000` and `0x03060100` (not including) `PySlice_GetIndicesEx()` is a deprecated function.

int **PySlice_Unpack**(*PyObject* *slice, Py_ssize_t *start, Py_ssize_t *stop, Py_ssize_t *step)

Extract the start, stop and step data members from a slice object as C integers. Silently reduce values larger than `PY_SSIZE_T_MAX` to `PY_SSIZE_T_MAX`, silently boost the start and stop values less than `PY_SSIZE_T_MIN` to `PY_SSIZE_T_MIN`, and silently boost the step values less than `-PY_SSIZE_T_MAX` to `-PY_SSIZE_T_MAX`.

Return `-1` on error, `0` on success.

New in version 3.6.1.

Py_ssize_t **PySlice_AdjustIndices**(Py_ssize_t *length*, Py_ssize_t *start, Py_ssize_t *stop, Py_ssize_t *step*)

Adjust start/end slice indices assuming a sequence of the specified length. Out of bounds indices are clipped in a manner consistent with the handling of normal slices.

Return the length of the slice. Always successful. Doesn't call Python code.

New in version 3.6.1.

8.6.6 Ellipsis Object

PyObject ***Py_Ellipsis**

The Python `Ellipsis` object. This object has no methods. It needs to be treated just like any other object with respect to reference counts. Like *Py_None* it is a singleton object.

8.6.7 MemoryView objects

A `memoryview` object exposes the C level *buffer interface* as a Python object which can then be passed around like any other object.

PyObject ***PyMemoryView_FromObject**(*PyObject* *obj)

Create a memoryview object from an object that provides the buffer interface. If *obj* supports writable buffer exports, the memoryview object will be read/write, otherwise it may be either read-only or read/write at the discretion of the exporter.

PyObject ***PyMemoryView_FromMemory**(char *mem, Py_ssize_t *size*, int *flags*)

Create a memoryview object using *mem* as the underlying buffer. *flags* can be one of `PyBUF_READ` or `PyBUF_WRITE`.

New in version 3.3.

PyObject ***PyMemoryView_FromBuffer**(*Py_buffer* *view)

Create a memoryview object wrapping the given buffer structure *view*. For simple byte buffers, *PyMemoryView_FromMemory()* is the preferred function.

PyObject ***PyMemoryView_GetContiguous**(*PyObject *obj*, int *buffertype*, char *order*)
Create a memoryview object to a *contiguous* chunk of memory (in either 'C' or 'F'ortran *order*) from an object that defines the buffer interface. If memory is contiguous, the memoryview object points to the original memory. Otherwise, a copy is made and the memoryview points to a new bytes object.

int **PyMemoryView_Check**(*PyObject *obj*)
Return true if the object *obj* is a memoryview object. It is not currently allowed to create subclasses of `memoryview`.

Py_buffer ***PyMemoryView_GET_BUFFER**(*PyObject *mview*)
Return a pointer to the memoryview's private copy of the exporter's buffer. *mview* **must** be a memoryview instance; this macro doesn't check its type, you must do it yourself or you will risk crashes.

Py_buffer ***PyMemoryView_GET_BASE**(*PyObject *mview*)
Return either a pointer to the exporting object that the memoryview is based on or *NULL* if the memoryview has been created by one of the functions *PyMemoryView_FromMemory()* or *PyMemoryView_FromBuffer()*. *mview* **must** be a memoryview instance.

8.6.8 Weak Reference Objects

Python supports *weak references* as first-class objects. There are two specific object types which directly implement weak references. The first is a simple reference object, and the second acts as a proxy for the original object as much as it can.

int **PyWeakref_Check**(ob)
Return true if *ob* is either a reference or proxy object.

int **PyWeakref_CheckRef**(ob)
Return true if *ob* is a reference object.

int **PyWeakref_CheckProxy**(ob)
Return true if *ob* is a proxy object.

*PyObject** **PyWeakref_NewRef**(*PyObject *ob*, *PyObject *callback*)
Return value: New reference. Return a weak reference object for the object *ob*. This will always return a new reference, but is not guaranteed to create a new object; an existing reference object may be returned. The second parameter, *callback*, can be a callable object that receives notification when *ob* is garbage collected; it should accept a single parameter, which will be the weak reference object itself. *callback* may also be `None` or *NULL*. If *ob* is not a weakly-referencable object, or if *callback* is not callable, `None`, or *NULL*, this will return *NULL* and raise `TypeError`.

*PyObject** **PyWeakref_NewProxy**(*PyObject *ob*, *PyObject *callback*)
Return value: New reference. Return a weak reference proxy object for the object *ob*. This will always return a new reference, but is not guaranteed to create a new object; an existing proxy object may be returned. The second parameter, *callback*, can be a callable object that receives notification when *ob* is garbage collected; it should accept a single parameter, which will be the weak reference object itself. *callback* may also be `None` or *NULL*. If *ob* is not a weakly-referencable object, or if *callback* is not callable, `None`, or *NULL*, this will return *NULL* and raise `TypeError`.

*PyObject** **PyWeakref_GetObject**(*PyObject *ref*)
Return value: Borrowed reference. Return the referenced object from a weak reference, *ref*. If the referent is no longer live, returns `Py_None`.

Note: This function returns a **borrowed reference** to the referenced object. This means that you should always call *Py_INCREF()* on the object except if you know that it cannot be destroyed while you are still using it.

---

*PyObject** **PyWeakref_GET_OBJECT**(*PyObject* *ref*)
Return value: Borrowed reference. Similar to *PyWeakref_GetObject()*, but implemented as a macro that does no error checking.

8.6.9 Capsules

Refer to using-capsules for more information on using these objects.

New in version 3.1.

PyCapsule
This subtype of *PyObject* represents an opaque value, useful for C extension modules who need to pass an opaque value (as a `void*` pointer) through Python code to other C code. It is often used to make a C function pointer defined in one module available to other modules, so the regular import mechanism can be used to access C APIs defined in dynamically loaded modules.

PyCapsule_Destructor
The type of a destructor callback for a capsule. Defined as:

```
typedef void (*PyCapsule_Destructor)(PyObject *);
```

See *PyCapsule_New()* for the semantics of PyCapsule_Destructor callbacks.

int **PyCapsule_CheckExact**(*PyObject* *p*)
Return true if its argument is a *PyCapsule*.

*PyObject** **PyCapsule_New**(void *pointer, const char *name, *PyCapsule_Destructor* destructor)
Return value: New reference. Create a *PyCapsule* encapsulating the *pointer*. The *pointer* argument may not be *NULL*.

On failure, set an exception and return *NULL*.

The *name* string may either be *NULL* or a pointer to a valid C string. If non-*NULL*, this string must outlive the capsule. (Though it is permitted to free it inside the *destructor*.)

If the *destructor* argument is not *NULL*, it will be called with the capsule as its argument when it is destroyed.

If this capsule will be stored as an attribute of a module, the *name* should be specified as `modulename.attributename`. This will enable other modules to import the capsule using *PyCapsule_Import()*.

void* **PyCapsule_GetPointer**(*PyObject* *capsule, const char *name*)
Retrieve the *pointer* stored in the capsule. On failure, set an exception and return *NULL*.

The *name* parameter must compare exactly to the name stored in the capsule. If the name stored in the capsule is *NULL*, the *name* passed in must also be *NULL*. Python uses the C function `strcmp()` to compare capsule names.

PyCapsule_Destructor **PyCapsule_GetDestructor**(*PyObject* *capsule*)
Return the current destructor stored in the capsule. On failure, set an exception and return *NULL*.

It is legal for a capsule to have a *NULL* destructor. This makes a *NULL* return code somewhat ambiguous; use *PyCapsule_IsValid()* or *PyErr_Occurred()* to disambiguate.

void* **PyCapsule_GetContext**(*PyObject* *capsule*)
Return the current context stored in the capsule. On failure, set an exception and return *NULL*.

It is legal for a capsule to have a *NULL* context. This makes a *NULL* return code somewhat ambiguous; use *PyCapsule_IsValid()* or *PyErr_Occurred()* to disambiguate.

const char* **PyCapsule_GetName**(*PyObject* *capsule*)
Return the current name stored in the capsule. On failure, set an exception and return *NULL*.

It is legal for a capsule to have a *NULL* name. This makes a *NULL* return code somewhat ambiguous; use *PyCapsule_IsValid()* or *PyErr_Occurred()* to disambiguate.

void* **PyCapsule_Import**(const char **name*, int *no_block*)
Import a pointer to a C object from a capsule attribute in a module. The *name* parameter should specify the full name to the attribute, as in `module.attribute`. The *name* stored in the capsule must match this string exactly. If *no_block* is true, import the module without blocking (using *PyImport_ImportModuleNoBlock()*). If *no_block* is false, import the module conventionally (using *PyImport_ImportModule()*).

Return the capsule's internal *pointer* on success. On failure, set an exception and return *NULL*.

int **PyCapsule_IsValid**(*PyObject* **capsule*, const char **name*)
Determines whether or not *capsule* is a valid capsule. A valid capsule is non-*NULL*, passes *PyCapsule_CheckExact()*, has a non-*NULL* pointer stored in it, and its internal name matches the *name* parameter. (See *PyCapsule_GetPointer()* for information on how capsule names are compared.)

In other words, if *PyCapsule_IsValid()* returns a true value, calls to any of the accessors (any function starting with `PyCapsule_Get()`) are guaranteed to succeed.

Return a nonzero value if the object is valid and matches the name passed in. Return `0` otherwise. This function will not fail.

int **PyCapsule_SetContext**(*PyObject* **capsule*, void **context*)
Set the context pointer inside *capsule* to *context*.

Return `0` on success. Return nonzero and set an exception on failure.

int **PyCapsule_SetDestructor**(*PyObject* **capsule*, *PyCapsule_Destructor* *destructor*)
Set the destructor inside *capsule* to *destructor*.

Return `0` on success. Return nonzero and set an exception on failure.

int **PyCapsule_SetName**(*PyObject* **capsule*, const char **name*)
Set the name inside *capsule* to *name*. If non-*NULL*, the name must outlive the capsule. If the previous *name* stored in the capsule was not *NULL*, no attempt is made to free it.

Return `0` on success. Return nonzero and set an exception on failure.

int **PyCapsule_SetPointer**(*PyObject* **capsule*, void **pointer*)
Set the void pointer inside *capsule* to *pointer*. The pointer may not be *NULL*.

Return `0` on success. Return nonzero and set an exception on failure.

8.6.10 Generator Objects

Generator objects are what Python uses to implement generator iterators. They are normally created by iterating over a function that yields values, rather than explicitly calling *PyGen_New()* or *PyGen_NewWithQualName()*.

PyGenObject
The C structure used for generator objects.

PyTypeObject **PyGen_Type**
The type object corresponding to generator objects.

int **PyGen_Check**(*PyObject* **ob*)
Return true if *ob* is a generator object; *ob* must not be *NULL*.

int **PyGen_CheckExact**(*PyObject* **ob*)
Return true if *ob*'s type is *PyGen_Type*; *ob* must not be *NULL*.

*PyObject** **PyGen_New**(*PyFrameObject *frame*)
Return value: New reference. Create and return a new generator object based on the *frame* object. A reference to *frame* is stolen by this function. The argument must not be *NULL*.

*PyObject** **PyGen_NewWithQualName**(*PyFrameObject *frame*, *PyObject *name*, *PyObject *qualname*)
Return value: New reference. Create and return a new generator object based on the *frame* object, with `__name__` and `__qualname__` set to *name* and *qualname*. A reference to *frame* is stolen by this function. The *frame* argument must not be *NULL*.

8.6.11 Coroutine Objects

New in version 3.5.

Coroutine objects are what functions declared with an `async` keyword return.

PyCoroObject
The C structure used for coroutine objects.

PyTypeObject **PyCoro_Type**
The type object corresponding to coroutine objects.

int **PyCoro_CheckExact**(*PyObject *ob*)
Return true if *ob*'s type is *PyCoro_Type*; *ob* must not be *NULL*.

*PyObject** **PyCoro_New**(*PyFrameObject *frame*, *PyObject *name*, *PyObject *qualname*)
Return value: New reference. Create and return a new coroutine object based on the *frame* object, with `__name__` and `__qualname__` set to *name* and *qualname*. A reference to *frame* is stolen by this function. The *frame* argument must not be *NULL*.

8.6.12 Context Variables Objects

New in version 3.7.

This section details the public C API for the `contextvars` module.

PyContext
The C structure used to represent a `contextvars.Context` object.

PyContextVar
The C structure used to represent a `contextvars.ContextVar` object.

PyContextToken
The C structure used to represent a `contextvars.Token` object.

PyTypeObject **PyContext_Type**
The type object representing the *context* type.

PyTypeObject **PyContextVar_Type**
The type object representing the *context variable* type.

PyTypeObject **PyContextToken_Type**
The type object representing the *context variable token* type.

Type-check macros:

int **PyContext_CheckExact**(*PyObject *o*)
Return true if *o* is of type *PyContext_Type*. *o* must not be *NULL*. This function always succeeds.

int **PyContextVar_CheckExact**(*PyObject *o*)
Return true if *o* is of type *PyContextVar_Type*. *o* must not be *NULL*. This function always succeeds.

int **PyContextToken_CheckExact**(*PyObject* *o)
Return true if *o* is of type *PyContextToken_Type*. *o* must not be *NULL*. This function always succeeds.

Context object management functions:

PyContext ***PyContext_New**(void)
Return value: New reference. Create a new empty context object. Returns `NULL` if an error has occurred.

PyContext ***PyContext_Copy**(*PyContext* *ctx)
Return value: New reference. Create a shallow copy of the passed *ctx* context object. Returns `NULL` if an error has occurred.

PyContext ***PyContext_CopyCurrent**(void)
Return value: New reference. Create a shallow copy of the current thread context. Returns `NULL` if an error has occurred.

int **PyContext_Enter**(*PyContext* *ctx)
Set *ctx* as the current context for the current thread. Returns `0` on success, and `-1` on error.

int **PyContext_Exit**(*PyContext* *ctx)
Deactivate the *ctx* context and restore the previous context as the current context for the current thread. Returns `0` on success, and `-1` on error.

int **PyContext_ClearFreeList**()
Clear the context variable free list. Return the total number of freed items. This function always succeeds.

Context variable functions:

PyContextVar ***PyContextVar_New**(const char *name, *PyObject* *def)
Return value: New reference. Create a new `ContextVar` object. The *name* parameter is used for introspection and debug purposes. The *def* parameter may optionally specify the default value for the context variable. If an error has occurred, this function returns `NULL`.

int **PyContextVar_Get**(*PyContextVar* *var, *PyObject* *default_value, *PyObject* **value)
Get the value of a context variable. Returns `-1` if an error has occurred during lookup, and `0` if no error occurred, whether or not a value was found.

If the context variable was found, *value* will be a pointer to it. If the context variable was *not* found, *value* will point to:

- *default_value*, if not `NULL`;
- the default value of *var*, if not `NULL`;
- `NULL`

If the value was found, the function will create a new reference to it.

PyContextToken ***PyContextVar_Set**(*PyContextVar* *var, *PyObject* *value)
Return value: New reference. Set the value of *var* to *value* in the current context. Returns a pointer to a *PyContextToken* object, or `NULL` if an error has occurred.

int **PyContextVar_Reset**(*PyContextVar* *var, *PyContextToken* *token)
Reset the state of the *var* context variable to that it was in before *PyContextVar_Set()* that returned the *token* was called. This function returns `0` on success and `-1` on error.

8.6.13 DateTime Objects

Various date and time objects are supplied by the `datetime` module. Before using any of these functions, the header file `datetime.h` must be included in your source (note that this is not included by `Python.h`), and the macro `PyDateTime_IMPORT` must be invoked, usually as part of the module initialisation function. The

macro puts a pointer to a C structure into a static variable, `PyDateTimeAPI`, that is used by the following macros.

Macro for access to the UTC singleton:

*PyObject** **PyDateTime_TimeZone_UTC**
Returns the time zone singleton representing UTC, the same object as `datetime.timezone.utc`.

New in version 3.7.

Type-check macros:

int **PyDate_Check**(*PyObject *ob*)
Return true if *ob* is of type `PyDateTime_DateType` or a subtype of `PyDateTime_DateType`. *ob* must not be *NULL*.

int **PyDate_CheckExact**(*PyObject *ob*)
Return true if *ob* is of type `PyDateTime_DateType`. *ob* must not be *NULL*.

int **PyDateTime_Check**(*PyObject *ob*)
Return true if *ob* is of type `PyDateTime_DateTimeType` or a subtype of `PyDateTime_DateTimeType`. *ob* must not be *NULL*.

int **PyDateTime_CheckExact**(*PyObject *ob*)
Return true if *ob* is of type `PyDateTime_DateTimeType`. *ob* must not be *NULL*.

int **PyTime_Check**(*PyObject *ob*)
Return true if *ob* is of type `PyDateTime_TimeType` or a subtype of `PyDateTime_TimeType`. *ob* must not be *NULL*.

int **PyTime_CheckExact**(*PyObject *ob*)
Return true if *ob* is of type `PyDateTime_TimeType`. *ob* must not be *NULL*.

int **PyDelta_Check**(*PyObject *ob*)
Return true if *ob* is of type `PyDateTime_DeltaType` or a subtype of `PyDateTime_DeltaType`. *ob* must not be *NULL*.

int **PyDelta_CheckExact**(*PyObject *ob*)
Return true if *ob* is of type `PyDateTime_DeltaType`. *ob* must not be *NULL*.

int **PyTZInfo_Check**(*PyObject *ob*)
Return true if *ob* is of type `PyDateTime_TZInfoType` or a subtype of `PyDateTime_TZInfoType`. *ob* must not be *NULL*.

int **PyTZInfo_CheckExact**(*PyObject *ob*)
Return true if *ob* is of type `PyDateTime_TZInfoType`. *ob* must not be *NULL*.

Macros to create objects:

*PyObject** **PyDate_FromDate**(int *year*, int *month*, int *day*)
Return value: New reference. Return a `datetime.date` object with the specified year, month and day.

*PyObject** **PyDateTime_FromDateAndTime**(int *year*, int *month*, int *day*, int *hour*, int *minute*, int *second*, int *usecond*)
Return value: New reference. Return a `datetime.datetime` object with the specified year, month, day, hour, minute, second and microsecond.

*PyObject** **PyTime_FromTime**(int *hour*, int *minute*, int *second*, int *usecond*)
Return value: New reference. Return a `datetime.time` object with the specified hour, minute, second and microsecond.

*PyObject** **PyDelta_FromDSU**(int *days*, int *seconds*, int *useconds*)
Return value: New reference. Return a `datetime.timedelta` object representing the given number of days, seconds and microseconds. Normalization is performed so that the resulting number of microseconds and seconds lie in the ranges documented for `datetime.timedelta` objects.

*PyObject** **PyTimeZone_FromOffset**(PyDateTime_DeltaType* *offset*)
Return value: New reference. Return a `datetime.timezone` object with an unnamed fixed offset represented by the *offset* argument.

New in version 3.7.

*PyObject** **PyTimeZone_FromOffsetAndName**(PyDateTime_DeltaType* *offset*, PyUnicode* *name*)
Return value: New reference. Return a `datetime.timezone` object with a fixed offset represented by the *offset* argument and with tzname *name*.

New in version 3.7.

Macros to extract fields from date objects. The argument must be an instance of `PyDateTime_Date`, including subclasses (such as `PyDateTime_DateTime`). The argument must not be *NULL*, and the type is not checked:

int **PyDateTime_GET_YEAR**(PyDateTime_Date **o*)
Return the year, as a positive int.

int **PyDateTime_GET_MONTH**(PyDateTime_Date **o*)
Return the month, as an int from 1 through 12.

int **PyDateTime_GET_DAY**(PyDateTime_Date **o*)
Return the day, as an int from 1 through 31.

Macros to extract fields from datetime objects. The argument must be an instance of `PyDateTime_DateTime`, including subclasses. The argument must not be *NULL*, and the type is not checked:

int **PyDateTime_DATE_GET_HOUR**(PyDateTime_DateTime **o*)
Return the hour, as an int from 0 through 23.

int **PyDateTime_DATE_GET_MINUTE**(PyDateTime_DateTime **o*)
Return the minute, as an int from 0 through 59.

int **PyDateTime_DATE_GET_SECOND**(PyDateTime_DateTime **o*)
Return the second, as an int from 0 through 59.

int **PyDateTime_DATE_GET_MICROSECOND**(PyDateTime_DateTime **o*)
Return the microsecond, as an int from 0 through 999999.

Macros to extract fields from time objects. The argument must be an instance of `PyDateTime_Time`, including subclasses. The argument must not be *NULL*, and the type is not checked:

int **PyDateTime_TIME_GET_HOUR**(PyDateTime_Time **o*)
Return the hour, as an int from 0 through 23.

int **PyDateTime_TIME_GET_MINUTE**(PyDateTime_Time **o*)
Return the minute, as an int from 0 through 59.

int **PyDateTime_TIME_GET_SECOND**(PyDateTime_Time **o*)
Return the second, as an int from 0 through 59.

int **PyDateTime_TIME_GET_MICROSECOND**(PyDateTime_Time **o*)
Return the microsecond, as an int from 0 through 999999.

Macros to extract fields from time delta objects. The argument must be an instance of `PyDateTime_Delta`, including subclasses. The argument must not be *NULL*, and the type is not checked:

int **PyDateTime_DELTA_GET_DAYS**(PyDateTime_Delta **o*)
Return the number of days, as an int from -999999999 to 999999999.

New in version 3.3.

int **PyDateTime_DELTA_GET_SECONDS**(PyDateTime_Delta **o*)
Return the number of seconds, as an int from 0 through 86399.

New in version 3.3.

int **PyDateTime_DELTA_GET_MICROSECONDS**(PyDateTime_Delta **o*)
Return the number of microseconds, as an int from 0 through 999999.

New in version 3.3.

Macros for the convenience of modules implementing the DB API:

*PyObject** **PyDateTime_FromTimestamp**(*PyObject* **args*)
Return value: New reference. Create and return a new `datetime.datetime` object given an argument tuple suitable for passing to `datetime.datetime.fromtimestamp()`.

*PyObject** **PyDate_FromTimestamp**(*PyObject* **args*)
Return value: New reference. Create and return a new `datetime.date` object given an argument tuple suitable for passing to `datetime.date.fromtimestamp()`.

CHAPTER

NINE

INITIALIZATION, FINALIZATION, AND THREADS

9.1 Before Python Initialization

In an application embedding Python, the *Py_Initialize()* function must be called before using any other Python/C API functions; with the exception of a few functions and the *global configuration variables*.

The following functions can be safely called before Python is initialized:

- Configuration functions:
  - *PyImport_AppendInittab()*
  - *PyImport_ExtendInittab()*
  - `PyInitFrozenExtensions()`
  - *PyMem_SetAllocator()*
  - *PyMem_SetupDebugHooks()*
  - *PyObject_SetArenaAllocator()*
  - *Py_SetPath()*
  - *Py_SetProgramName()*
  - *Py_SetPythonHome()*
  - *Py_SetStandardStreamEncoding()*
  - *PySys_AddWarnOption()*
  - *PySys_AddXOption()*
  - *PySys_ResetWarnOptions()*
- Informative functions:
  - *PyMem_GetAllocator()*
  - *PyObject_GetArenaAllocator()*
  - *Py_GetBuildInfo()*
  - *Py_GetCompiler()*
  - *Py_GetCopyright()*
  - *Py_GetPlatform()*
  - *Py_GetVersion()*
- Utilities:
  - *Py_DecodeLocale()*
- Memory allocators:

- *PyMem_RawMalloc()*
- *PyMem_RawRealloc()*
- *PyMem_RawCalloc()*
- *PyMem_RawFree()*

Note: The following functions **should not be called** before *Py_Initialize()*: *Py_EncodeLocale()*, *Py_GetPath()*, *Py_GetPrefix()*, *Py_GetExecPrefix()*, *Py_GetProgramFullPath()*, *Py_GetPythonHome()*, *Py_GetProgramName()* and *PyEval_InitThreads()*.

9.2 Global configuration variables

Python has variables for the global configuration to control different features and options. By default, these flags are controlled by command line options.

When a flag is set by an option, the value of the flag is the number of times that the option was set. For example, `-b` sets *Py_BytesWarningFlag* to 1 and `-bb` sets *Py_BytesWarningFlag* to 2.

Py_BytesWarningFlag
Issue a warning when comparing `bytes` or `bytearray` with `str` or `bytes` with `int`. Issue an error if greater or equal to 2.

Set by the `-b` option.

Py_DebugFlag
Turn on parser debugging output (for expert only, depending on compilation options).

Set by the `-d` option and the `PYTHONDEBUG` environment variable.

Py_DontWriteBytecodeFlag
If set to non-zero, Python won't try to write `.pyc` files on the import of source modules.

Set by the `-B` option and the `PYTHONDONTWRITEBYTECODE` environment variable.

Py_FrozenFlag
Suppress error messages when calculating the module search path in *Py_GetPath()*.

Private flag used by `_freeze_importlib` and `frozenmain` programs.

Py_HashRandomizationFlag
Set to `1` if the `PYTHONHASHSEED` environment variable is set to a non-empty string.

If the flag is non-zero, read the `PYTHONHASHSEED` environment variable to initialize the secret hash seed.

Py_IgnoreEnvironmentFlag
Ignore all `PYTHON*` environment variables, e.g. `PYTHONPATH` and `PYTHONHOME`, that might be set.

Set by the `-E` and `-I` options.

Py_InspectFlag
When a script is passed as first argument or the `-c` option is used, enter interactive mode after executing the script or the command, even when `sys.stdin` does not appear to be a terminal.

Set by the `-i` option and the `PYTHONINSPECT` environment variable.

Py_InteractiveFlag
Set by the `-i` option.

Py_IsolatedFlag
Run Python in isolated mode. In isolated mode `sys.path` contains neither the script's directory nor the user's site-packages directory.

Set by the `-I` option.

New in version 3.4.

`Py_LegacyWindowsFSEncodingFlag`
If the flag is non-zero, use the `mbcs` encoding instead of the UTF-8 encoding for the filesystem encoding.

Set to `1` if the `PYTHONLEGACYWINDOWSFSENCODING` environment variable is set to a non-empty string.

See **PEP 529** for more details.

Availability: Windows.

`Py_LegacyWindowsStdioFlag`
If the flag is non-zero, use `io.FileIO` instead of `WindowsConsoleIO` for `sys` standard streams.

Set to `1` if the `PYTHONLEGACYWINDOWSSTDIO` environment variable is set to a non-empty string.

See **PEP 528** for more details.

Availability: Windows.

`Py_NoSiteFlag`
Disable the import of the module `site` and the site-dependent manipulations of `sys.path` that it entails. Also disable these manipulations if `site` is explicitly imported later (call `site.main()` if you want them to be triggered).

Set by the `-S` option.

`Py_NoUserSiteDirectory`
Don't add the `user site-packages directory` to `sys.path`.

Set by the `-s` and `-I` options, and the `PYTHONNOUSERSITE` environment variable.

`Py_OptimizeFlag`
Set by the `-O` option and the `PYTHONOPTIMIZE` environment variable.

`Py_QuietFlag`
Don't display the copyright and version messages even in interactive mode.

Set by the `-q` option.

New in version 3.2.

`Py_UnbufferedStdioFlag`
Force the stdout and stderr streams to be unbuffered.

Set by the `-u` option and the `PYTHONUNBUFFERED` environment variable.

`Py_VerboseFlag`
Print a message each time a module is initialized, showing the place (filename or built-in module) from which it is loaded. If greater or equal to `2`, print a message for each file that is checked for when searching for a module. Also provides information on module cleanup at exit.

Set by the `-v` option and the `PYTHONVERBOSE` environment variable.

9.3 Initializing and finalizing the interpreter

void `Py_Initialize()`
Initialize the Python interpreter. In an application embedding Python, this should be called before using any other Python/C API functions; see *Before Python Initialization* for the few exceptions.

This initializes the table of loaded modules (`sys.modules`), and creates the fundamental modules `builtins`, `__main__` and `sys`. It also initializes the module search path (`sys.path`). It does not set

`sys.argv`; use *PySys_SetArgvEx()* for that. This is a no-op when called for a second time (without calling *Py_FinalizeEx()* first). There is no return value; it is a fatal error if the initialization fails.

Note: On Windows, changes the console mode from `O_TEXT` to `O_BINARY`, which will also affect non-Python uses of the console using the C Runtime.

---

void **Py_InitializeEx**(int *initsigs*)
This function works like *Py_Initialize()* if *initsigs* is `1`. If *initsigs* is `0`, it skips initialization registration of signal handlers, which might be useful when Python is embedded.

int **Py_IsInitialized**()
Return true (nonzero) when the Python interpreter has been initialized, false (zero) if not. After *Py_FinalizeEx()* is called, this returns false until *Py_Initialize()* is called again.

int **Py_FinalizeEx**()
Undo all initializations made by *Py_Initialize()* and subsequent use of Python/C API functions, and destroy all sub-interpreters (see *Py_NewInterpreter()* below) that were created and not yet destroyed since the last call to *Py_Initialize()*. Ideally, this frees all memory allocated by the Python interpreter. This is a no-op when called for a second time (without calling *Py_Initialize()* again first). Normally the return value is `0`. If there were errors during finalization (flushing buffered data), `-1` is returned.

This function is provided for a number of reasons. An embedding application might want to restart Python without having to restart the application itself. An application that has loaded the Python interpreter from a dynamically loadable library (or DLL) might want to free all memory allocated by Python before unloading the DLL. During a hunt for memory leaks in an application a developer might want to free all memory allocated by Python before exiting from the application.

Bugs and caveats: The destruction of modules and objects in modules is done in random order; this may cause destructors (`__del__()` methods) to fail when they depend on other objects (even functions) or modules. Dynamically loaded extension modules loaded by Python are not unloaded. Small amounts of memory allocated by the Python interpreter may not be freed (if you find a leak, please report it). Memory tied up in circular references between objects is not freed. Some memory allocated by extension modules may not be freed. Some extensions may not work properly if their initialization routine is called more than once; this can happen if an application calls *Py_Initialize()* and *Py_FinalizeEx()* more than once.

New in version 3.6.

void **Py_Finalize**()
This is a backwards-compatible version of *Py_FinalizeEx()* that disregards the return value.

9.4 Process-wide parameters

int **Py_SetStandardStreamEncoding**(const char **encoding*, const char **errors*)
This function should be called before *Py_Initialize()*, if it is called at all. It specifies which encoding and error handling to use with standard IO, with the same meanings as in `str.encode()`.

It overrides `PYTHONIOENCODING` values, and allows embedding code to control IO encoding when the environment variable does not work.

`encoding` and/or `errors` may be NULL to use `PYTHONIOENCODING` and/or default values (depending on other settings).

Note that `sys.stderr` always uses the "backslashreplace" error handler, regardless of this (or any other) setting.

If *Py_FinalizeEx()* is called, this function will need to be called again in order to affect subsequent calls to *Py_Initialize()*.

Returns `0` if successful, a nonzero value on error (e.g. calling after the interpreter has already been initialized).

New in version 3.4.

void **Py_SetProgramName**(const wchar_t **name*)
This function should be called before *Py_Initialize()* is called for the first time, if it is called at all. It tells the interpreter the value of the `argv[0]` argument to the `main()` function of the program (converted to wide characters). This is used by *Py_GetPath()* and some other functions below to find the Python run-time libraries relative to the interpreter executable. The default value is `'python'`. The argument should point to a zero-terminated wide character string in static storage whose contents will not change for the duration of the program's execution. No code in the Python interpreter will change the contents of this storage.

Use *Py_DecodeLocale()* to decode a bytes string to get a `wchar_*` string.

wchar* **Py_GetProgramName**()
Return the program name set with *Py_SetProgramName()*, or the default. The returned string points into static storage; the caller should not modify its value.

wchar_t* **Py_GetPrefix**()
Return the *prefix* for installed platform-independent files. This is derived through a number of complicated rules from the program name set with *Py_SetProgramName()* and some environment variables; for example, if the program name is `'/usr/local/bin/python'`, the prefix is `'/usr/local'`. The returned string points into static storage; the caller should not modify its value. This corresponds to the `prefix` variable in the top-level `Makefile` and the `--prefix` argument to the `configure` script at build time. The value is available to Python code as `sys.prefix`. It is only useful on Unix. See also the next function.

wchar_t* **Py_GetExecPrefix**()
Return the *exec-prefix* for installed platform-*dependent* files. This is derived through a number of complicated rules from the program name set with *Py_SetProgramName()* and some environment variables; for example, if the program name is `'/usr/local/bin/python'`, the exec-prefix is `'/usr/local'`. The returned string points into static storage; the caller should not modify its value. This corresponds to the `exec_prefix` variable in the top-level `Makefile` and the `--exec-prefix` argument to the `configure` script at build time. The value is available to Python code as `sys.exec_prefix`. It is only useful on Unix.

Background: The exec-prefix differs from the prefix when platform dependent files (such as executables and shared libraries) are installed in a different directory tree. In a typical installation, platform dependent files may be installed in the `/usr/local/plat` subtree while platform independent may be installed in `/usr/local`.

Generally speaking, a platform is a combination of hardware and software families, e.g. Sparc machines running the Solaris 2.x operating system are considered the same platform, but Intel machines running Solaris 2.x are another platform, and Intel machines running Linux are yet another platform. Different major revisions of the same operating system generally also form different platforms. Non-Unix operating systems are a different story; the installation strategies on those systems are so different that the prefix and exec-prefix are meaningless, and set to the empty string. Note that compiled Python bytecode files are platform independent (but not independent from the Python version by which they were compiled!).

System administrators will know how to configure the `mount` or `automount` programs to share `/usr/local` between platforms while having `/usr/local/plat` be a different filesystem for each platform.

wchar_t* **Py_GetProgramFullPath**()
Return the full program name of the Python executable; this is computed as a side-effect of deriving

the default module search path from the program name (set by *Py_SetProgramName()* above). The returned string points into static storage; the caller should not modify its value. The value is available to Python code as `sys.executable`.

wchar_t* **Py_GetPath**()
Return the default module search path; this is computed from the program name (set by *Py_SetProgramName()* above) and some environment variables. The returned string consists of a series of directory names separated by a platform dependent delimiter character. The delimiter character is `':'` on Unix and Mac OS X, `';'` on Windows. The returned string points into static storage; the caller should not modify its value. The list `sys.path` is initialized with this value on interpreter startup; it can be (and usually is) modified later to change the search path for loading modules.

void **Py_SetPath**(const wchar_t *)
Set the default module search path. If this function is called before *Py_Initialize()*, then *Py_GetPath()* won't attempt to compute a default search path but uses the one provided instead. This is useful if Python is embedded by an application that has full knowledge of the location of all modules. The path components should be separated by the platform dependent delimiter character, which is `':'` on Unix and Mac OS X, `';'` on Windows.

This also causes `sys.executable` to be set only to the raw program name (see *Py_SetProgramName()*) and for `sys.prefix` and `sys.exec_prefix` to be empty. It is up to the caller to modify these if required after calling *Py_Initialize()*.

Use *Py_DecodeLocale()* to decode a bytes string to get a `wchar_*` string.

The path argument is copied internally, so the caller may free it after the call completes.

const char* **Py_GetVersion**()
Return the version of this Python interpreter. This is a string that looks something like

```
"3.0a5+ (py3k:63103M, May 12 2008, 00:53:55) \n[GCC 4.2.3]"
```

The first word (up to the first space character) is the current Python version; the first three characters are the major and minor version separated by a period. The returned string points into static storage; the caller should not modify its value. The value is available to Python code as `sys.version`.

const char* **Py_GetPlatform**()
Return the platform identifier for the current platform. On Unix, this is formed from the "official" name of the operating system, converted to lower case, followed by the major revision number; e.g., for Solaris 2.x, which is also known as SunOS 5.x, the value is `'sunos5'`. On Mac OS X, it is `'darwin'`. On Windows, it is `'win'`. The returned string points into static storage; the caller should not modify its value. The value is available to Python code as `sys.platform`.

const char* **Py_GetCopyright**()
Return the official copyright string for the current Python version, for example

`'Copyright 1991-1995 Stichting Mathematisch Centrum, Amsterdam'`

The returned string points into static storage; the caller should not modify its value. The value is available to Python code as `sys.copyright`.

const char* **Py_GetCompiler**()
Return an indication of the compiler used to build the current Python version, in square brackets, for example:

```
"[GCC 2.7.2.2]"
```

The returned string points into static storage; the caller should not modify its value. The value is available to Python code as part of the variable `sys.version`.

const char* **Py_GetBuildInfo**()
Return information about the sequence number and build date and time of the current Python interpreter instance, for example

```
"#67, Aug  1 1997, 22:34:28"
```

The returned string points into static storage; the caller should not modify its value. The value is available to Python code as part of the variable `sys.version`.

void **PySys_SetArgvEx**(int *argc*, wchar_t **argv*, int *updatepath*)
Set `sys.argv` based on *argc* and *argv*. These parameters are similar to those passed to the program's `main()` function with the difference that the first entry should refer to the script file to be executed rather than the executable hosting the Python interpreter. If there isn't a script that will be run, the first entry in *argv* can be an empty string. If this function fails to initialize `sys.argv`, a fatal condition is signalled using *Py_FatalError()*.

If *updatepath* is zero, this is all the function does. If *updatepath* is non-zero, the function also modifies `sys.path` according to the following algorithm:

- If the name of an existing script is passed in `argv[0]`, the absolute path of the directory where the script is located is prepended to `sys.path`.
- Otherwise (that is, if *argc* is `0` or `argv[0]` doesn't point to an existing file name), an empty string is prepended to `sys.path`, which is the same as prepending the current working directory (`"."`).

Use *Py_DecodeLocale()* to decode a bytes string to get a `wchar_*` string.

Note: It is recommended that applications embedding the Python interpreter for purposes other than executing a single script pass `0` as *updatepath*, and update `sys.path` themselves if desired. See CVE-2008-5983.

On versions before 3.1.3, you can achieve the same effect by manually popping the first `sys.path` element after having called *PySys_SetArgv()*, for example using:

```
PyRun_SimpleString("import sys; sys.path.pop(0)\n");
```

New in version 3.1.3.

void **PySys_SetArgv**(int *argc*, wchar_t **argv*)
This function works like *PySys_SetArgvEx()* with *updatepath* set to `1` unless the `python` interpreter was started with the `-I`.

Use *Py_DecodeLocale()* to decode a bytes string to get a `wchar_*` string.

Changed in version 3.4: The *updatepath* value depends on `-I`.

void **Py_SetPythonHome**(const wchar_t *home)
Set the default "home" directory, that is, the location of the standard Python libraries. See `PYTHONHOME` for the meaning of the argument string.

The argument should point to a zero-terminated character string in static storage whose contents will not change for the duration of the program's execution. No code in the Python interpreter will change the contents of this storage.

Use *Py_DecodeLocale()* to decode a bytes string to get a `wchar_*` string.

w_char* **Py_GetPythonHome**()
Return the default "home", that is, the value set by a previous call to *Py_SetPythonHome()*, or the value of the `PYTHONHOME` environment variable if it is set.

9.5 Thread State and the Global Interpreter Lock

The Python interpreter is not fully thread-safe. In order to support multi-threaded Python programs, there's a global lock, called the *global interpreter lock* or *GIL*, that must be held by the current thread before it can safely access Python objects. Without the lock, even the simplest operations could cause problems in a multi-threaded program: for example, when two threads simultaneously increment the reference count of the same object, the reference count could end up being incremented only once instead of twice.

Therefore, the rule exists that only the thread that has acquired the *GIL* may operate on Python objects or call Python/C API functions. In order to emulate concurrency of execution, the interpreter regularly tries to switch threads (see `sys.setswitchinterval()`). The lock is also released around potentially blocking I/O operations like reading or writing a file, so that other Python threads can run in the meantime.

The Python interpreter keeps some thread-specific bookkeeping information inside a data structure called *PyThreadState*. There's also one global variable pointing to the current *PyThreadState*: it can be retrieved using *PyThreadState_Get()*.

9.5.1 Releasing the GIL from extension code

Most extension code manipulating the *GIL* has the following simple structure:

```
Save the thread state in a local variable.
Release the global interpreter lock.
... Do some blocking I/O operation ...
Reacquire the global interpreter lock.
Restore the thread state from the local variable.
```

This is so common that a pair of macros exists to simplify it:

```
Py_BEGIN_ALLOW_THREADS
... Do some blocking I/O operation ...
Py_END_ALLOW_THREADS
```

The *Py_BEGIN_ALLOW_THREADS* macro opens a new block and declares a hidden local variable; the *Py_END_ALLOW_THREADS* macro closes the block.

The block above expands to the following code:

```
PyThreadState *_save;

_save = PyEval_SaveThread();
... Do some blocking I/O operation ...
PyEval_RestoreThread(_save);
```

Here is how these functions work: the global interpreter lock is used to protect the pointer to the current thread state. When releasing the lock and saving the thread state, the current thread state pointer must be retrieved before the lock is released (since another thread could immediately acquire the lock and store its own thread state in the global variable). Conversely, when acquiring the lock and restoring the thread state, the lock must be acquired before storing the thread state pointer.

Note: Calling system I/O functions is the most common use case for releasing the GIL, but it can also be useful before calling long-running computations which don't need access to Python objects, such as compression or cryptographic functions operating over memory buffers. For example, the standard `zlib` and `hashlib` modules release the GIL when compressing or hashing data.

9.5.2 Non-Python created threads

When threads are created using the dedicated Python APIs (such as the `threading` module), a thread state is automatically associated to them and the code showed above is therefore correct. However, when threads are created from C (for example by a third-party library with its own thread management), they don't hold the GIL, nor is there a thread state structure for them.

If you need to call Python code from these threads (often this will be part of a callback API provided by the aforementioned third-party library), you must first register these threads with the interpreter by creating a thread state data structure, then acquiring the GIL, and finally storing their thread state pointer, before you can start using the Python/C API. When you are done, you should reset the thread state pointer, release the GIL, and finally free the thread state data structure.

The *PyGILState_Ensure()* and *PyGILState_Release()* functions do all of the above automatically. The typical idiom for calling into Python from a C thread is:

```
PyGILState_STATE gstate;
gstate = PyGILState_Ensure();

/* Perform Python actions here. */
result = CallSomeFunction();
/* evaluate result or handle exception */

/* Release the thread. No Python API allowed beyond this point. */
PyGILState_Release(gstate);
```

Note that the `PyGILState_*()` functions assume there is only one global interpreter (created automatically by *Py_Initialize()*). Python supports the creation of additional interpreters (using *Py_NewInterpreter()*), but mixing multiple interpreters and the `PyGILState_*()` API is unsupported.

Another important thing to note about threads is their behaviour in the face of the C `fork()` call. On most systems with `fork()`, after a process forks only the thread that issued the fork will exist. That also means any locks held by other threads will never be released. Python solves this for `os.fork()` by acquiring the locks it uses internally before the fork, and releasing them afterwards. In addition, it resets any lock-objects in the child. When extending or embedding Python, there is no way to inform Python of additional (non-Python) locks that need to be acquired before or reset after a fork. OS facilities such as `pthread_atfork()` would need to be used to accomplish the same thing. Additionally, when extending or embedding Python, calling `fork()` directly rather than through `os.fork()` (and returning to or calling into Python) may result in a deadlock by one of Python's internal locks being held by a thread that is defunct after the fork. *PyOS_AfterFork_Child()* tries to reset the necessary locks, but is not always able to.

9.5.3 High-level API

These are the most commonly used types and functions when writing C extension code, or when embedding the Python interpreter:

PyInterpreterState

This data structure represents the state shared by a number of cooperating threads. Threads belonging to the same interpreter share their module administration and a few other internal items. There are no public members in this structure.

Threads belonging to different interpreters initially share nothing, except process state like available memory, open file descriptors and such. The global interpreter lock is also shared by all threads, regardless of to which interpreter they belong.

PyThreadState

This data structure represents the state of a single thread. The only public data member is *PyInterpreterState* ***interp**, which points to this thread's interpreter state.

void **PyEval_InitThreads**()
Initialize and acquire the global interpreter lock. It should be called in the main thread before creating a second thread or engaging in any other thread operations such as `PyEval_ReleaseThread(tstate)`. It is not needed before calling *PyEval_SaveThread()* or *PyEval_RestoreThread()*.

This is a no-op when called for a second time.

Changed in version 3.7: This function is now called by *Py_Initialize()*, so you don't have to call it yourself anymore.

Changed in version 3.2: This function cannot be called before *Py_Initialize()* anymore.

int **PyEval_ThreadsInitialized**()
Returns a non-zero value if *PyEval_InitThreads()* has been called. This function can be called without holding the GIL, and therefore can be used to avoid calls to the locking API when running single-threaded.

Changed in version 3.7: The *GIL* is now initialized by *Py_Initialize()*.

*PyThreadState** **PyEval_SaveThread**()
Release the global interpreter lock (if it has been created and thread support is enabled) and reset the thread state to *NULL*, returning the previous thread state (which is not *NULL*). If the lock has been created, the current thread must have acquired it.

void **PyEval_RestoreThread**(*PyThreadState* *tstate)
Acquire the global interpreter lock (if it has been created and thread support is enabled) and set the thread state to *tstate*, which must not be *NULL*. If the lock has been created, the current thread must not have acquired it, otherwise deadlock ensues.

*PyThreadState** **PyThreadState_Get**()
Return the current thread state. The global interpreter lock must be held. When the current thread state is *NULL*, this issues a fatal error (so that the caller needn't check for *NULL*).

*PyThreadState** **PyThreadState_Swap**(*PyThreadState* *tstate)
Swap the current thread state with the thread state given by the argument *tstate*, which may be *NULL*. The global interpreter lock must be held and is not released.

void **PyEval_ReInitThreads**()
This function is called from *PyOS_AfterFork_Child()* to ensure that newly created child processes don't hold locks referring to threads which are not running in the child process.

The following functions use thread-local storage, and are not compatible with sub-interpreters:

PyGILState_STATE **PyGILState_Ensure**()
Ensure that the current thread is ready to call the Python C API regardless of the current state of Python, or of the global interpreter lock. This may be called as many times as desired by a thread as long as each call is matched with a call to *PyGILState_Release()*. In general, other thread-related APIs may be used between *PyGILState_Ensure()* and *PyGILState_Release()* calls as long as the thread state is restored to its previous state before the Release(). For example, normal usage of the *Py_BEGIN_ALLOW_THREADS* and *Py_END_ALLOW_THREADS* macros is acceptable.

The return value is an opaque "handle" to the thread state when *PyGILState_Ensure()* was called, and must be passed to *PyGILState_Release()* to ensure Python is left in the same state. Even though recursive calls are allowed, these handles *cannot* be shared - each unique call to *PyGILState_Ensure()* must save the handle for its call to *PyGILState_Release()*.

When the function returns, the current thread will hold the GIL and be able to call arbitrary Python code. Failure is a fatal error.

void **PyGILState_Release**(PyGILState_STATE)
Release any resources previously acquired. After this call, Python's state will be the same as it was prior to the corresponding *PyGILState_Ensure()* call (but generally this state will be unknown to the caller, hence the use of the GILState API).

Every call to *PyGILState_Ensure()* must be matched by a call to *PyGILState_Release()* on the same thread.

*PyThreadState** **PyGILState_GetThisThreadState()**
Get the current thread state for this thread. May return `NULL` if no GILState API has been used on the current thread. Note that the main thread always has such a thread-state, even if no auto-thread-state call has been made on the main thread. This is mainly a helper/diagnostic function.

int **PyGILState_Check()**
Return `1` if the current thread is holding the GIL and `0` otherwise. This function can be called from any thread at any time. Only if it has had its Python thread state initialized and currently is holding the GIL will it return `1`. This is mainly a helper/diagnostic function. It can be useful for example in callback contexts or memory allocation functions when knowing that the GIL is locked can allow the caller to perform sensitive actions or otherwise behave differently.

New in version 3.4.

The following macros are normally used without a trailing semicolon; look for example usage in the Python source distribution.

Py_BEGIN_ALLOW_THREADS
This macro expands to `{ PyThreadState *_save; _save = PyEval_SaveThread();`. Note that it contains an opening brace; it must be matched with a following *Py_END_ALLOW_THREADS* macro. See above for further discussion of this macro.

Py_END_ALLOW_THREADS
This macro expands to `PyEval_RestoreThread(_save); }`. Note that it contains a closing brace; it must be matched with an earlier *Py_BEGIN_ALLOW_THREADS* macro. See above for further discussion of this macro.

Py_BLOCK_THREADS
This macro expands to `PyEval_RestoreThread(_save);`: it is equivalent to *Py_END_ALLOW_THREADS* without the closing brace.

Py_UNBLOCK_THREADS
This macro expands to `_save = PyEval_SaveThread();`: it is equivalent to *Py_BEGIN_ALLOW_THREADS* without the opening brace and variable declaration.

9.5.4 Low-level API

All of the following functions must be called after *Py_Initialize()*.

Changed in version 3.7: *Py_Initialize()* now initializes the *GIL*.

*PyInterpreterState** **PyInterpreterState_New()**
Create a new interpreter state object. The global interpreter lock need not be held, but may be held if it is necessary to serialize calls to this function.

void **PyInterpreterState_Clear**(*PyInterpreterState *interp*)
Reset all information in an interpreter state object. The global interpreter lock must be held.

void **PyInterpreterState_Delete**(*PyInterpreterState *interp*)
Destroy an interpreter state object. The global interpreter lock need not be held. The interpreter state must have been reset with a previous call to *PyInterpreterState_Clear()*.

*PyThreadState** **PyThreadState_New**(*PyInterpreterState *interp*)
Create a new thread state object belonging to the given interpreter object. The global interpreter lock need not be held, but may be held if it is necessary to serialize calls to this function.

void **PyThreadState_Clear**(*PyThreadState *tstate*)
Reset all information in a thread state object. The global interpreter lock must be held.

void **PyThreadState_Delete**(*PyThreadState* **tstate*)
Destroy a thread state object. The global interpreter lock need not be held. The thread state must have been reset with a previous call to *PyThreadState_Clear()*.

PY_INT64_T **PyInterpreterState_GetID**(*PyInterpreterState* **interp*)
Return the interpreter's unique ID. If there was any error in doing so then `-1` is returned and an error is set.

New in version 3.7.

*PyObject** **PyThreadState_GetDict**()
Return value: Borrowed reference. Return a dictionary in which extensions can store thread-specific state information. Each extension should use a unique key to use to store state in the dictionary. It is okay to call this function when no current thread state is available. If this function returns *NULL*, no exception has been raised and the caller should assume no current thread state is available.

int **PyThreadState_SetAsyncExc**(unsigned long *id*, *PyObject* **exc*)
Asynchronously raise an exception in a thread. The *id* argument is the thread id of the target thread; *exc* is the exception object to be raised. This function does not steal any references to *exc*. To prevent naive misuse, you must write your own C extension to call this. Must be called with the GIL held. Returns the number of thread states modified; this is normally one, but will be zero if the thread id isn't found. If *exc* is `NULL`, the pending exception (if any) for the thread is cleared. This raises no exceptions.

Changed in version 3.7: The type of the *id* parameter changed from `long` to `unsigned long`.

void **PyEval_AcquireThread**(*PyThreadState* **tstate*)
Acquire the global interpreter lock and set the current thread state to *tstate*, which should not be *NULL*. The lock must have been created earlier. If this thread already has the lock, deadlock ensues.

PyEval_RestoreThread() is a higher-level function which is always available (even when threads have not been initialized).

void **PyEval_ReleaseThread**(*PyThreadState* **tstate*)
Reset the current thread state to *NULL* and release the global interpreter lock. The lock must have been created earlier and must be held by the current thread. The *tstate* argument, which must not be *NULL*, is only used to check that it represents the current thread state — if it isn't, a fatal error is reported.

PyEval_SaveThread() is a higher-level function which is always available (even when threads have not been initialized).

void **PyEval_AcquireLock**()
Acquire the global interpreter lock. The lock must have been created earlier. If this thread already has the lock, a deadlock ensues.

Deprecated since version 3.2: This function does not update the current thread state. Please use *PyEval_RestoreThread()* or *PyEval_AcquireThread()* instead.

void **PyEval_ReleaseLock**()
Release the global interpreter lock. The lock must have been created earlier.

Deprecated since version 3.2: This function does not update the current thread state. Please use *PyEval_SaveThread()* or *PyEval_ReleaseThread()* instead.

9.6 Sub-interpreter support

While in most uses, you will only embed a single Python interpreter, there are cases where you need to create several independent interpreters in the same process and perhaps even in the same thread. Sub-interpreters

allow you to do that. You can switch between sub-interpreters using the *PyThreadState_Swap()* function. You can create and destroy them using the following functions:

*PyThreadState** **Py_NewInterpreter()**

Create a new sub-interpreter. This is an (almost) totally separate environment for the execution of Python code. In particular, the new interpreter has separate, independent versions of all imported modules, including the fundamental modules `builtins`, `__main__` and `sys`. The table of loaded modules (`sys.modules`) and the module search path (`sys.path`) are also separate. The new environment has no `sys.argv` variable. It has new standard I/O stream file objects `sys.stdin`, `sys.stdout` and `sys.stderr` (however these refer to the same underlying file descriptors).

The return value points to the first thread state created in the new sub-interpreter. This thread state is made in the current thread state. Note that no actual thread is created; see the discussion of thread states below. If creation of the new interpreter is unsuccessful, *NULL* is returned; no exception is set since the exception state is stored in the current thread state and there may not be a current thread state. (Like all other Python/C API functions, the global interpreter lock must be held before calling this function and is still held when it returns; however, unlike most other Python/C API functions, there needn't be a current thread state on entry.)

Extension modules are shared between (sub-)interpreters as follows: the first time a particular extension is imported, it is initialized normally, and a (shallow) copy of its module's dictionary is squirreled away. When the same extension is imported by another (sub-)interpreter, a new module is initialized and filled with the contents of this copy; the extension's `init` function is not called. Note that this is different from what happens when an extension is imported after the interpreter has been completely re-initialized by calling *Py_FinalizeEx()* and *Py_Initialize()*; in that case, the extension's `initmodule` function *is* called again.

void **Py_EndInterpreter**(*PyThreadState* **tstate*)

Destroy the (sub-)interpreter represented by the given thread state. The given thread state must be the current thread state. See the discussion of thread states below. When the call returns, the current thread state is *NULL*. All thread states associated with this interpreter are destroyed. (The global interpreter lock must be held before calling this function and is still held when it returns.) *Py_FinalizeEx()* will destroy all sub-interpreters that haven't been explicitly destroyed at that point.

9.6.1 Bugs and caveats

Because sub-interpreters (and the main interpreter) are part of the same process, the insulation between them isn't perfect — for example, using low-level file operations like `os.close()` they can (accidentally or maliciously) affect each other's open files. Because of the way extensions are shared between (sub-)interpreters, some extensions may not work properly; this is especially likely when the extension makes use of (static) global variables, or when the extension manipulates its module's dictionary after its initialization. It is possible to insert objects created in one sub-interpreter into a namespace of another sub-interpreter; this should be done with great care to avoid sharing user-defined functions, methods, instances or classes between sub-interpreters, since import operations executed by such objects may affect the wrong (sub-)interpreter's dictionary of loaded modules.

Also note that combining this functionality with `PyGILState_*()` APIs is delicate, because these APIs assume a bijection between Python thread states and OS-level threads, an assumption broken by the presence of sub-interpreters. It is highly recommended that you don't switch sub-interpreters between a pair of matching *PyGILState_Ensure()* and *PyGILState_Release()* calls. Furthermore, extensions (such as `ctypes`) using these APIs to allow calling of Python code from non-Python created threads will probably be broken when using sub-interpreters.

9.7 Asynchronous Notifications

A mechanism is provided to make asynchronous notifications to the main interpreter thread. These notifications take the form of a function pointer and a void pointer argument.

int **Py_AddPendingCall**(int (**func*)(void *), void **arg*)
Schedule a function to be called from the main interpreter thread. On success, `0` is returned and *func* is queued for being called in the main thread. On failure, `-1` is returned without setting any exception.

When successfully queued, *func* will be *eventually* called from the main interpreter thread with the argument *arg*. It will be called asynchronously with respect to normally running Python code, but with both these conditions met:

- on a *bytecode* boundary;
- with the main thread holding the *global interpreter lock* (*func* can therefore use the full C API).

func must return `0` on success, or `-1` on failure with an exception set. *func* won't be interrupted to perform another asynchronous notification recursively, but it can still be interrupted to switch threads if the global interpreter lock is released.

This function doesn't need a current thread state to run, and it doesn't need the global interpreter lock.

> **Warning:** This is a low-level function, only useful for very special cases. There is no guarantee that *func* will be called as quick as possible. If the main thread is busy executing a system call, *func* won't be called before the system call returns. This function is generally **not** suitable for calling Python code from arbitrary C threads. Instead, use the *PyGILState API*.

New in version 3.1.

9.8 Profiling and Tracing

The Python interpreter provides some low-level support for attaching profiling and execution tracing facilities. These are used for profiling, debugging, and coverage analysis tools.

This C interface allows the profiling or tracing code to avoid the overhead of calling through Python-level callable objects, making a direct C function call instead. The essential attributes of the facility have not changed; the interface allows trace functions to be installed per-thread, and the basic events reported to the trace function are the same as had been reported to the Python-level trace functions in previous versions.

int **(*Py_tracefunc)**(*PyObject *obj*, *PyFrameObject *frame*, int *what*, *PyObject *arg*)
The type of the trace function registered using *PyEval_SetProfile()* and *PyEval_SetTrace()*. The first parameter is the object passed to the registration function as *obj*, *frame* is the frame object to which the event pertains, *what* is one of the constants `PyTrace_CALL`, `PyTrace_EXCEPTION`, `PyTrace_LINE`, `PyTrace_RETURN`, `PyTrace_C_CALL`, `PyTrace_C_EXCEPTION`, `PyTrace_C_RETURN`, or `PyTrace_OPCODE`, and *arg* depends on the value of *what*:

Value of *what*	Meaning of *arg*
`PyTrace_CALL`	Always *Py_None*.
`PyTrace_EXCEPTION`	Exception information as returned by `sys.exc_info()`.
`PyTrace_LINE`	Always *Py_None*.
`PyTrace_RETURN`	Value being returned to the caller, or *NULL* if caused by an exception.
`PyTrace_C_CALL`	Function object being called.
`PyTrace_C_EXCEPTION`	Function object being called.
`PyTrace_C_RETURN`	Function object being called.
`PyTrace_OPCODE`	Always *Py_None*.

int **PyTrace_CALL**
The value of the *what* parameter to a *Py_tracefunc* function when a new call to a function or method is being reported, or a new entry into a generator. Note that the creation of the iterator for a generator function is not reported as there is no control transfer to the Python bytecode in the corresponding frame.

int **PyTrace_EXCEPTION**
The value of the *what* parameter to a *Py_tracefunc* function when an exception has been raised. The callback function is called with this value for *what* when after any bytecode is processed after which the exception becomes set within the frame being executed. The effect of this is that as exception propagation causes the Python stack to unwind, the callback is called upon return to each frame as the exception propagates. Only trace functions receives these events; they are not needed by the profiler.

int **PyTrace_LINE**
The value passed as the *what* parameter to a *Py_tracefunc* function (but not a profiling function) when a line-number event is being reported. It may be disabled for a frame by setting `f_trace_lines` to *0* on that frame.

int **PyTrace_RETURN**
The value for the *what* parameter to *Py_tracefunc* functions when a call is about to return.

int **PyTrace_C_CALL**
The value for the *what* parameter to *Py_tracefunc* functions when a C function is about to be called.

int **PyTrace_C_EXCEPTION**
The value for the *what* parameter to *Py_tracefunc* functions when a C function has raised an exception.

int **PyTrace_C_RETURN**
The value for the *what* parameter to *Py_tracefunc* functions when a C function has returned.

int **PyTrace_OPCODE**
The value for the *what* parameter to *Py_tracefunc* functions (but not profiling functions) when a new opcode is about to be executed. This event is not emitted by default: it must be explicitly requested by setting `f_trace_opcodes` to *1* on the frame.

void **PyEval_SetProfile**(*Py_tracefunc func*, *PyObject *obj*)
Set the profiler function to *func*. The *obj* parameter is passed to the function as its first parameter, and may be any Python object, or *NULL*. If the profile function needs to maintain state, using a different value for *obj* for each thread provides a convenient and thread-safe place to store it. The profile function is called for all monitored events except `PyTrace_LINE` `PyTrace_OPCODE` and `PyTrace_EXCEPTION`.

void **PyEval_SetTrace**(*Py_tracefunc func*, *PyObject *obj*)
Set the tracing function to *func*. This is similar to *PyEval_SetProfile()*, except the tracing function does receive line-number events and per-opcode events, but does not receive any event related to C function objects being called. Any trace function registered using *PyEval_SetTrace()* will not receive `PyTrace_C_CALL`, `PyTrace_C_EXCEPTION` or `PyTrace_C_RETURN` as a value for the *what* parameter.

9.9 Advanced Debugger Support

These functions are only intended to be used by advanced debugging tools.

*PyInterpreterState** **PyInterpreterState_Head()**
Return the interpreter state object at the head of the list of all such objects.

*PyInterpreterState** **PyInterpreterState_Next(***PyInterpreterState* ***interp*)
Return the next interpreter state object after *interp* from the list of all such objects.

PyThreadState * **PyInterpreterState_ThreadHead(***PyInterpreterState* ***interp*)
Return the pointer to the first *PyThreadState* object in the list of threads associated with the interpreter *interp*.

*PyThreadState** **PyThreadState_Next(***PyThreadState* ***tstate*)
Return the next thread state object after *tstate* from the list of all such objects belonging to the same *PyInterpreterState* object.

9.10 Thread Local Storage Support

The Python interpreter provides low-level support for thread-local storage (TLS) which wraps the underlying native TLS implementation to support the Python-level thread local storage API (`threading.local`). The CPython C level APIs are similar to those offered by pthreads and Windows: use a thread key and functions to associate a `void*` value per thread.

The GIL does *not* need to be held when calling these functions; they supply their own locking.

Note that `Python.h` does not include the declaration of the TLS APIs, you need to include `pythread.h` to use thread-local storage.

Note: None of these API functions handle memory management on behalf of the `void*` values. You need to allocate and deallocate them yourself. If the `void*` values happen to be *PyObject**, these functions don't do refcount operations on them either.

9.10.1 Thread Specific Storage (TSS) API

TSS API is introduced to supersede the use of the existing TLS API within the CPython interpreter. This API uses a new type *Py_tss_t* instead of `int` to represent thread keys.

New in version 3.7.

See also:

"A New C-API for Thread-Local Storage in CPython" (**PEP 539**)

Py_tss_t
This data structure represents the state of a thread key, the definition of which may depend on the underlying TLS implementation, and it has an internal field representing the key's initialization state. There are no public members in this structure.

When *Py_LIMITED_API* is not defined, static allocation of this type by *Py_tss_NEEDS_INIT* is allowed.

Py_tss_NEEDS_INIT
This macro expands to the initializer for *Py_tss_t* variables. Note that this macro won't be defined with *Py_LIMITED_API*.

Dynamic Allocation

Dynamic allocation of the *Py_tss_t*, required in extension modules built with *Py_LIMITED_API*, where static allocation of this type is not possible due to its implementation being opaque at build time.

*Py_tss_t** **PyThread_tss_alloc**()
Return a value which is the same state as a value initialized with *Py_tss_NEEDS_INIT*, or *NULL* in the case of dynamic allocation failure.

void **PyThread_tss_free**(*Py_tss_t *key*)
Free the given *key* allocated by *PyThread_tss_alloc()*, after first calling *PyThread_tss_delete()* to ensure any associated thread locals have been unassigned. This is a no-op if the *key* argument is *NULL*.

Note: A freed key becomes a dangling pointer, you should reset the key to *NULL*.

Methods

The parameter *key* of these functions must not be *NULL*. Moreover, the behaviors of *PyThread_tss_set()* and *PyThread_tss_get()* are undefined if the given *Py_tss_t* has not been initialized by *PyThread_tss_create()*.

int **PyThread_tss_is_created**(*Py_tss_t *key*)
Return a non-zero value if the given *Py_tss_t* has been initialized by *PyThread_tss_create()*.

int **PyThread_tss_create**(*Py_tss_t *key*)
Return a zero value on successful initialization of a TSS key. The behavior is undefined if the value pointed to by the *key* argument is not initialized by *Py_tss_NEEDS_INIT*. This function can be called repeatedly on the same key – calling it on an already initialized key is a no-op and immediately returns success.

void **PyThread_tss_delete**(*Py_tss_t *key*)
Destroy a TSS key to forget the values associated with the key across all threads, and change the key's initialization state to uninitialized. A destroyed key is able to be initialized again by *PyThread_tss_create()*. This function can be called repeatedly on the same key – calling it on an already destroyed key is a no-op.

int **PyThread_tss_set**(*Py_tss_t *key*, void *value*)
Return a zero value to indicate successfully associating a `void*` value with a TSS key in the current thread. Each thread has a distinct mapping of the key to a `void*` value.

void* **PyThread_tss_get**(*Py_tss_t *key*)
Return the `void*` value associated with a TSS key in the current thread. This returns *NULL* if no value is associated with the key in the current thread.

9.10.2 Thread Local Storage (TLS) API

Deprecated since version 3.7: This API is superseded by *Thread Specific Storage (TSS) API*.

Note: This version of the API does not support platforms where the native TLS key is defined in a way that cannot be safely cast to `int`. On such platforms, *PyThread_create_key()* will return immediately with a failure status, and the other TLS functions will all be no-ops on such platforms.

Due to the compatibility problem noted above, this version of the API should not be used in new code.

int **PyThread_create_key**()

void **PyThread_delete_key**(int *key*)

int **PyThread_set_key_value**(int *key*, void **value*)

void* **PyThread_get_key_value**(int *key*)

void **PyThread_delete_key_value**(int *key*)

void **PyThread_ReInitTLS**()

CHAPTER

TEN

MEMORY MANAGEMENT

10.1 Overview

Memory management in Python involves a private heap containing all Python objects and data structures. The management of this private heap is ensured internally by the *Python memory manager*. The Python memory manager has different components which deal with various dynamic storage management aspects, like sharing, segmentation, preallocation or caching.

At the lowest level, a raw memory allocator ensures that there is enough room in the private heap for storing all Python-related data by interacting with the memory manager of the operating system. On top of the raw memory allocator, several object-specific allocators operate on the same heap and implement distinct memory management policies adapted to the peculiarities of every object type. For example, integer objects are managed differently within the heap than strings, tuples or dictionaries because integers imply different storage requirements and speed/space tradeoffs. The Python memory manager thus delegates some of the work to the object-specific allocators, but ensures that the latter operate within the bounds of the private heap.

It is important to understand that the management of the Python heap is performed by the interpreter itself and that the user has no control over it, even if they regularly manipulate object pointers to memory blocks inside that heap. The allocation of heap space for Python objects and other internal buffers is performed on demand by the Python memory manager through the Python/C API functions listed in this document.

To avoid memory corruption, extension writers should never try to operate on Python objects with the functions exported by the C library: `malloc()`, `calloc()`, `realloc()` and `free()`. This will result in mixed calls between the C allocator and the Python memory manager with fatal consequences, because they implement different algorithms and operate on different heaps. However, one may safely allocate and release memory blocks with the C library allocator for individual purposes, as shown in the following example:

```
PyObject *res;
char *buf = (char *) malloc(BUFSIZ); /* for I/O */

if (buf == NULL)
    return PyErr_NoMemory();
...Do some I/O operation involving buf...
res = PyBytes_FromString(buf);
free(buf); /* malloc'ed */
return res;
```

In this example, the memory request for the I/O buffer is handled by the C library allocator. The Python memory manager is involved only in the allocation of the string object returned as a result.

In most situations, however, it is recommended to allocate memory from the Python heap specifically because the latter is under control of the Python memory manager. For example, this is required when the interpreter is extended with new object types written in C. Another reason for using the Python heap is the desire to *inform* the Python memory manager about the memory needs of the extension module. Even when the

requested memory is used exclusively for internal, highly-specific purposes, delegating all memory requests to the Python memory manager causes the interpreter to have a more accurate image of its memory footprint as a whole. Consequently, under certain circumstances, the Python memory manager may or may not trigger appropriate actions, like garbage collection, memory compaction or other preventive procedures. Note that by using the C library allocator as shown in the previous example, the allocated memory for the I/O buffer escapes completely the Python memory manager.

See also:

The `PYTHONMALLOC` environment variable can be used to configure the memory allocators used by Python.

The `PYTHONMALLOCSTATS` environment variable can be used to print statistics of the *pymalloc memory allocator* every time a new pymalloc object arena is created, and on shutdown.

10.2 Raw Memory Interface

The following function sets are wrappers to the system allocator. These functions are thread-safe, the *GIL* does not need to be held.

The *default raw memory allocator* uses the following functions: `malloc()`, `calloc()`, `realloc()` and `free()`; call `malloc(1)` (or `calloc(1, 1)`) when requesting zero bytes.

New in version 3.4.

void* **PyMem_RawMalloc**(size_t *n*)
Allocates *n* bytes and returns a pointer of type `void*` to the allocated memory, or *NULL* if the request fails.

Requesting zero bytes returns a distinct non-*NULL* pointer if possible, as if `PyMem_RawMalloc(1)` had been called instead. The memory will not have been initialized in any way.

void* **PyMem_RawCalloc**(size_t *nelem*, size_t *elsize*)
Allocates *nelem* elements each whose size in bytes is *elsize* and returns a pointer of type `void*` to the allocated memory, or *NULL* if the request fails. The memory is initialized to zeros.

Requesting zero elements or elements of size zero bytes returns a distinct non-*NULL* pointer if possible, as if `PyMem_RawCalloc(1, 1)` had been called instead.

New in version 3.5.

void* **PyMem_RawRealloc**(void **p*, size_t *n*)
Resizes the memory block pointed to by *p* to *n* bytes. The contents will be unchanged to the minimum of the old and the new sizes.

If *p* is *NULL*, the call is equivalent to `PyMem_RawMalloc(n)`; else if *n* is equal to zero, the memory block is resized but is not freed, and the returned pointer is non-*NULL*.

Unless *p* is *NULL*, it must have been returned by a previous call to *PyMem_RawMalloc()*, *PyMem_RawRealloc()* or *PyMem_RawCalloc()*.

If the request fails, *PyMem_RawRealloc()* returns *NULL* and *p* remains a valid pointer to the previous memory area.

void **PyMem_RawFree**(void **p*)
Frees the memory block pointed to by *p*, which must have been returned by a previous call to *PyMem_RawMalloc()*, *PyMem_RawRealloc()* or *PyMem_RawCalloc()*. Otherwise, or if `PyMem_RawFree(p)` has been called before, undefined behavior occurs.

If *p* is *NULL*, no operation is performed.

10.3 Memory Interface

The following function sets, modeled after the ANSI C standard, but specifying behavior when requesting zero bytes, are available for allocating and releasing memory from the Python heap.

The *default memory allocator* uses the *pymalloc memory allocator*.

Warning: The *GIL* must be held when using these functions.

Changed in version 3.6: The default allocator is now pymalloc instead of system `malloc()`.

void* **PyMem_Malloc**(size_t *n*)
Allocates *n* bytes and returns a pointer of type `void*` to the allocated memory, or *NULL* if the request fails.

Requesting zero bytes returns a distinct non-*NULL* pointer if possible, as if `PyMem_Malloc(1)` had been called instead. The memory will not have been initialized in any way.

void* **PyMem_Calloc**(size_t *nelem*, size_t *elsize*)
Allocates *nelem* elements each whose size in bytes is *elsize* and returns a pointer of type `void*` to the allocated memory, or *NULL* if the request fails. The memory is initialized to zeros.

Requesting zero elements or elements of size zero bytes returns a distinct non-*NULL* pointer if possible, as if `PyMem_Calloc(1, 1)` had been called instead.

New in version 3.5.

void* **PyMem_Realloc**(void **p*, size_t *n*)
Resizes the memory block pointed to by *p* to *n* bytes. The contents will be unchanged to the minimum of the old and the new sizes.

If *p* is *NULL*, the call is equivalent to `PyMem_Malloc(n)`; else if *n* is equal to zero, the memory block is resized but is not freed, and the returned pointer is non-*NULL*.

Unless *p* is *NULL*, it must have been returned by a previous call to *PyMem_Malloc()*, *PyMem_Realloc()* or *PyMem_Calloc()*.

If the request fails, *PyMem_Realloc()* returns *NULL* and *p* remains a valid pointer to the previous memory area.

void **PyMem_Free**(void **p*)
Frees the memory block pointed to by *p*, which must have been returned by a previous call to *PyMem_Malloc()*, *PyMem_Realloc()* or *PyMem_Calloc()*. Otherwise, or if `PyMem_Free(p)` has been called before, undefined behavior occurs.

If *p* is *NULL*, no operation is performed.

The following type-oriented macros are provided for convenience. Note that *TYPE* refers to any C type.

TYPE* **PyMem_New**(TYPE, size_t *n*)
Same as *PyMem_Malloc()*, but allocates `(n * sizeof(TYPE))` bytes of memory. Returns a pointer cast to `TYPE*`. The memory will not have been initialized in any way.

TYPE* **PyMem_Resize**(void **p*, TYPE, size_t *n*)
Same as *PyMem_Realloc()*, but the memory block is resized to `(n * sizeof(TYPE))` bytes. Returns a pointer cast to `TYPE*`. On return, *p* will be a pointer to the new memory area, or *NULL* in the event of failure.

This is a C preprocessor macro; *p* is always reassigned. Save the original value of *p* to avoid losing memory when handling errors.

void **PyMem_Del**(void **p*)
Same as *PyMem_Free()*.

In addition, the following macro sets are provided for calling the Python memory allocator directly, without involving the C API functions listed above. However, note that their use does not preserve binary compatibility across Python versions and is therefore deprecated in extension modules.

- `PyMem_MALLOC(size)`
- `PyMem_NEW(type, size)`
- `PyMem_REALLOC(ptr, size)`
- `PyMem_RESIZE(ptr, type, size)`
- `PyMem_FREE(ptr)`
- `PyMem_DEL(ptr)`

10.4 Object allocators

The following function sets, modeled after the ANSI C standard, but specifying behavior when requesting zero bytes, are available for allocating and releasing memory from the Python heap.

The *default object allocator* uses the *pymalloc memory allocator*.

Warning: The *GIL* must be held when using these functions.

void* **PyObject_Malloc**(size_t *n*)
Allocates *n* bytes and returns a pointer of type `void*` to the allocated memory, or *NULL* if the request fails.

Requesting zero bytes returns a distinct non-*NULL* pointer if possible, as if `PyObject_Malloc(1)` had been called instead. The memory will not have been initialized in any way.

void* **PyObject_Calloc**(size_t *nelem*, size_t *elsize*)
Allocates *nelem* elements each whose size in bytes is *elsize* and returns a pointer of type `void*` to the allocated memory, or *NULL* if the request fails. The memory is initialized to zeros.

Requesting zero elements or elements of size zero bytes returns a distinct non-*NULL* pointer if possible, as if `PyObject_Calloc(1, 1)` had been called instead.

New in version 3.5.

void* **PyObject_Realloc**(void **p*, size_t *n*)
Resizes the memory block pointed to by *p* to *n* bytes. The contents will be unchanged to the minimum of the old and the new sizes.

If *p* is *NULL*, the call is equivalent to `PyObject_Malloc(n)`; else if *n* is equal to zero, the memory block is resized but is not freed, and the returned pointer is non-*NULL*.

Unless *p* is *NULL*, it must have been returned by a previous call to *PyObject_Malloc()*, *PyObject_Realloc()* or *PyObject_Calloc()*.

If the request fails, *PyObject_Realloc()* returns *NULL* and *p* remains a valid pointer to the previous memory area.

void **PyObject_Free**(void **p*)
Frees the memory block pointed to by *p*, which must have been returned by a previous call to *PyObject_Malloc()*, *PyObject_Realloc()* or *PyObject_Calloc()*. Otherwise, or if `PyObject_Free(p)` has been called before, undefined behavior occurs.

If *p* is *NULL*, no operation is performed.

10.5 Default Memory Allocators

Default memory allocators:

Configuration	Name	PyMem_RawMalloc	PyMem_Malloc	PyObject_Malloc
Release build	`"pymalloc"`	`malloc`	`pymalloc`	`pymalloc`
Debug build	`"pymalloc_debug"`	`malloc` + debug	`pymalloc` + debug	`pymalloc` + debug
Release build, without pymalloc	`"malloc"`	`malloc`	`malloc`	`malloc`
Release build, without pymalloc	`"malloc_debug"`	`malloc` + debug	`malloc` + debug	`malloc` + debug

Legend:

- Name: value for `PYTHONMALLOC` environment variable
- `malloc`: system allocators from the standard C library, C functions: `malloc()`, `calloc()`, `realloc()` and `free()`
- `pymalloc`: *pymalloc memory allocator*
- "+ debug": with debug hooks installed by *PyMem_SetupDebugHooks()*

10.6 Customize Memory Allocators

New in version 3.4.

PyMemAllocatorEx

Structure used to describe a memory block allocator. The structure has four fields:

Field	Meaning
`void *ctx`	user context passed as first argument
`void* malloc(void *ctx, size_t size)`	allocate a memory block
`void* calloc(void *ctx, size_t nelem, size_t elsize)`	allocate a memory block initialized with zeros
`void* realloc(void *ctx, void *ptr, size_t new_size)`	allocate or resize a memory block
`void free(void *ctx, void *ptr)`	free a memory block

Changed in version 3.5: The `PyMemAllocator` structure was renamed to *PyMemAllocatorEx* and a new `calloc` field was added.

PyMemAllocatorDomain

Enum used to identify an allocator domain. Domains:

PYMEM_DOMAIN_RAW

Functions:

- *PyMem_RawMalloc()*
- *PyMem_RawRealloc()*

- *PyMem_RawCalloc()*
- *PyMem_RawFree()*

PYMEM_DOMAIN_MEM
Functions:

- *PyMem_Malloc()*,
- *PyMem_Realloc()*
- *PyMem_Calloc()*
- *PyMem_Free()*

PYMEM_DOMAIN_OBJ
Functions:

- *PyObject_Malloc()*
- *PyObject_Realloc()*
- *PyObject_Calloc()*
- *PyObject_Free()*

void **PyMem_GetAllocator**(*PyMemAllocatorDomain domain*, *PyMemAllocatorEx *allocator*)
Get the memory block allocator of the specified domain.

void **PyMem_SetAllocator**(*PyMemAllocatorDomain domain*, *PyMemAllocatorEx *allocator*)
Set the memory block allocator of the specified domain.

The new allocator must return a distinct non-NULL pointer when requesting zero bytes.

For the *PYMEM_DOMAIN_RAW* domain, the allocator must be thread-safe: the *GIL* is not held when the allocator is called.

If the new allocator is not a hook (does not call the previous allocator), the *PyMem_SetupDebugHooks()* function must be called to reinstall the debug hooks on top on the new allocator.

void **PyMem_SetupDebugHooks**(void)
Setup hooks to detect bugs in the Python memory allocator functions.

Newly allocated memory is filled with the byte `0xCB`, freed memory is filled with the byte `0xDB`.

Runtime checks:

- Detect API violations, ex: *PyObject_Free()* called on a buffer allocated by *PyMem_Malloc()*
- Detect write before the start of the buffer (buffer underflow)
- Detect write after the end of the buffer (buffer overflow)
- Check that the *GIL* is held when allocator functions of *PYMEM_DOMAIN_OBJ* (ex: *PyObject_Malloc()*) and *PYMEM_DOMAIN_MEM* (ex: *PyMem_Malloc()*) domains are called

On error, the debug hooks use the `tracemalloc` module to get the traceback where a memory block was allocated. The traceback is only displayed if `tracemalloc` is tracing Python memory allocations and the memory block was traced.

These hooks are *installed by default* if Python is compiled in debug mode. The `PYTHONMALLOC` environment variable can be used to install debug hooks on a Python compiled in release mode.

Changed in version 3.6: This function now also works on Python compiled in release mode. On error, the debug hooks now use `tracemalloc` to get the traceback where a memory block was allocated. The debug hooks now also check if the GIL is held when functions of *PYMEM_DOMAIN_OBJ* and *PYMEM_DOMAIN_MEM* domains are called.

10.7 The pymalloc allocator

Python has a *pymalloc* allocator optimized for small objects (smaller or equal to 512 bytes) with a short lifetime. It uses memory mappings called "arenas" with a fixed size of 256 KiB. It falls back to *PyMem_RawMalloc()* and *PyMem_RawRealloc()* for allocations larger than 512 bytes.

pymalloc is the *default allocator* of the *PYMEM_DOMAIN_MEM* (ex: *PyMem_Malloc()*) and *PYMEM_DOMAIN_OBJ* (ex: *PyObject_Malloc()*) domains.

The arena allocator uses the following functions:

- `VirtualAlloc()` and `VirtualFree()` on Windows,
- `mmap()` and `munmap()` if available,
- `malloc()` and `free()` otherwise.

10.7.1 Customize pymalloc Arena Allocator

New in version 3.4.

PyObjectArenaAllocator
Structure used to describe an arena allocator. The structure has three fields:

Field	Meaning
`void *ctx`	user context passed as first argument
`void* alloc(void *ctx, size_t size)`	allocate an arena of size bytes
`void free(void *ctx, size_t size, void *ptr)`	free an arena

PyObject_GetArenaAllocator(*PyObjectArenaAllocator *allocator*)
Get the arena allocator.

PyObject_SetArenaAllocator(*PyObjectArenaAllocator *allocator*)
Set the arena allocator.

10.8 tracemalloc C API

New in version 3.7.

10.9 Examples

Here is the example from section *Overview*, rewritten so that the I/O buffer is allocated from the Python heap by using the first function set:

```
PyObject *res;
char *buf = (char *) PyMem_Malloc(BUFSIZ); /* for I/O */

if (buf == NULL)
    return PyErr_NoMemory();
/* ...Do some I/O operation involving buf... */
res = PyBytes_FromString(buf);
PyMem_Free(buf); /* allocated with PyMem_Malloc */
return res;
```

The same code using the type-oriented function set:

```
PyObject *res;
char *buf = PyMem_New(char, BUFSIZ); /* for I/O */

if (buf == NULL)
    return PyErr_NoMemory();
/* ...Do some I/O operation involving buf... */
res = PyBytes_FromString(buf);
PyMem_Del(buf); /* allocated with PyMem_New */
return res;
```

Note that in the two examples above, the buffer is always manipulated via functions belonging to the same set. Indeed, it is required to use the same memory API family for a given memory block, so that the risk of mixing different allocators is reduced to a minimum. The following code sequence contains two errors, one of which is labeled as *fatal* because it mixes two different allocators operating on different heaps.

```
char *buf1 = PyMem_New(char, BUFSIZ);
char *buf2 = (char *) malloc(BUFSIZ);
char *buf3 = (char *) PyMem_Malloc(BUFSIZ);
...
PyMem_Del(buf3);  /* Wrong -- should be PyMem_Free() */
free(buf2);       /* Right -- allocated via malloc() */
free(buf1);       /* Fatal -- should be PyMem_Del()  */
```

In addition to the functions aimed at handling raw memory blocks from the Python heap, objects in Python are allocated and released with *PyObject_New()*, *PyObject_NewVar()* and *PyObject_Del()*.

These will be explained in the next chapter on defining and implementing new object types in C.

CHAPTER

ELEVEN

OBJECT IMPLEMENTATION SUPPORT

This chapter describes the functions, types, and macros used when defining new object types.

11.1 Allocating Objects on the Heap

*PyObject** **_PyObject_New**(*PyTypeObject* **type*)
Return value: New reference.

*PyVarObject** **_PyObject_NewVar**(*PyTypeObject* **type*, Py_ssize_t *size*)
Return value: New reference.

*PyObject** **PyObject_Init**(*PyObject* **op*, *PyTypeObject* **type*)
Return value: Borrowed reference. Initialize a newly-allocated object *op* with its type and initial reference. Returns the initialized object. If *type* indicates that the object participates in the cyclic garbage detector, it is added to the detector's set of observed objects. Other fields of the object are not affected.

*PyVarObject** **PyObject_InitVar**(*PyVarObject* **op*, *PyTypeObject* **type*, Py_ssize_t *size*)
Return value: Borrowed reference. This does everything *PyObject_Init()* does, and also initializes the length information for a variable-size object.

TYPE* **PyObject_New**(TYPE, *PyTypeObject* **type*)
Return value: New reference. Allocate a new Python object using the C structure type *TYPE* and the Python type object *type*. Fields not defined by the Python object header are not initialized; the object's reference count will be one. The size of the memory allocation is determined from the *tp_basicsize* field of the type object.

TYPE* **PyObject_NewVar**(TYPE, *PyTypeObject* **type*, Py_ssize_t *size*)
Return value: New reference. Allocate a new Python object using the C structure type *TYPE* and the Python type object *type*. Fields not defined by the Python object header are not initialized. The allocated memory allows for the *TYPE* structure plus *size* fields of the size given by the *tp_itemsize* field of *type*. This is useful for implementing objects like tuples, which are able to determine their size at construction time. Embedding the array of fields into the same allocation decreases the number of allocations, improving the memory management efficiency.

void **PyObject_Del**(*PyObject* **op*)
Releases memory allocated to an object using *PyObject_New()* or *PyObject_NewVar()*. This is normally called from the *tp_dealloc* handler specified in the object's type. The fields of the object should not be accessed after this call as the memory is no longer a valid Python object.

PyObject **_Py_NoneStruct**
Object which is visible in Python as `None`. This should only be accessed using the *Py_None* macro, which evaluates to a pointer to this object.

See also:

PyModule_Create() To allocate and create extension modules.

11.2 Common Object Structures

There are a large number of structures which are used in the definition of object types for Python. This section describes these structures and how they are used.

All Python objects ultimately share a small number of fields at the beginning of the object's representation in memory. These are represented by the *PyObject* and *PyVarObject* types, which are defined, in turn, by the expansions of some macros also used, whether directly or indirectly, in the definition of all other Python objects.

PyObject
All object types are extensions of this type. This is a type which contains the information Python needs to treat a pointer to an object as an object. In a normal "release" build, it contains only the object's reference count and a pointer to the corresponding type object. Nothing is actually declared to be a *PyObject*, but every pointer to a Python object can be cast to a *PyObject**. Access to the members must be done by using the macros *Py_REFCNT* and *Py_TYPE*.

PyVarObject
This is an extension of *PyObject* that adds the `ob_size` field. This is only used for objects that have some notion of *length*. This type does not often appear in the Python/C API. Access to the members must be done by using the macros *Py_REFCNT*, *Py_TYPE*, and *Py_SIZE*.

PyObject_HEAD
This is a macro used when declaring new types which represent objects without a varying length. The PyObject_HEAD macro expands to:

```
PyObject ob_base;
```

See documentation of *PyObject* above.

PyObject_VAR_HEAD
This is a macro used when declaring new types which represent objects with a length that varies from instance to instance. The PyObject_VAR_HEAD macro expands to:

```
PyVarObject ob_base;
```

See documentation of *PyVarObject* above.

Py_TYPE(o)
This macro is used to access the `ob_type` member of a Python object. It expands to:

```
(((PyObject*)(o))->ob_type)
```

Py_REFCNT(o)
This macro is used to access the `ob_refcnt` member of a Python object. It expands to:

```
(((PyObject*)(o))->ob_refcnt)
```

Py_SIZE(o)
This macro is used to access the `ob_size` member of a Python object. It expands to:

```
(((PyVarObject*)(o))->ob_size)
```

PyObject_HEAD_INIT(type)
This is a macro which expands to initialization values for a new *PyObject* type. This macro expands to:

```
_PyObject_EXTRA_INIT
1, type,
```

PyVarObject_HEAD_INIT(type, size)
This is a macro which expands to initialization values for a new *PyVarObject* type, including the ob_size field. This macro expands to:

```
_PyObject_EXTRA_INIT
1, type, size,
```

PyCFunction
Type of the functions used to implement most Python callables in C. Functions of this type take two *PyObject** parameters and return one such value. If the return value is *NULL*, an exception shall have been set. If not *NULL*, the return value is interpreted as the return value of the function as exposed in Python. The function must return a new reference.

PyCFunctionWithKeywords
Type of the functions used to implement Python callables in C that take keyword arguments: they take three *PyObject** parameters and return one such value. See *PyCFunction* above for the meaning of the return value.

PyMethodDef
Structure used to describe a method of an extension type. This structure has four fields:

Field	C Type	Meaning
ml_name	const char *	name of the method
ml_meth	PyCFunction	pointer to the C implementation
ml_flags	int	flag bits indicating how the call should be constructed
ml_doc	const char *	points to the contents of the docstring

The ml_meth is a C function pointer. The functions may be of different types, but they always return *PyObject**. If the function is not of the *PyCFunction*, the compiler will require a cast in the method table. Even though *PyCFunction* defines the first parameter as *PyObject**, it is common that the method implementation uses the specific C type of the *self* object.

The ml_flags field is a bitfield which can include the following flags. The individual flags indicate either a calling convention or a binding convention. Of the calling convention flags, only *METH_VARARGS* and *METH_KEYWORDS* can be combined. Any of the calling convention flags can be combined with a binding flag.

METH_VARARGS
This is the typical calling convention, where the methods have the type *PyCFunction*. The function expects two *PyObject** values. The first one is the *self* object for methods; for module functions, it is the module object. The second parameter (often called *args*) is a tuple object representing all arguments. This parameter is typically processed using *PyArg_ParseTuple()* or *PyArg_UnpackTuple()*.

METH_KEYWORDS
Methods with these flags must be of type *PyCFunctionWithKeywords*. The function expects three parameters: *self*, *args*, and a dictionary of all the keyword arguments. The flag must be combined with *METH_VARARGS*, and the parameters are typically processed using *PyArg_ParseTupleAndKeywords()*.

METH_NOARGS
Methods without parameters don't need to check whether arguments are given if they are listed with the *METH_NOARGS* flag. They need to be of type *PyCFunction*. The first parameter is typically named *self* and will hold a reference to the module or object instance. In all cases the second parameter will be *NULL*.

METH_O
Methods with a single object argument can be listed with the *METH_O* flag, instead of invoking

PyArg_ParseTuple() with a "O" argument. They have the type *PyCFunction*, with the *self* parameter, and a *PyObject** parameter representing the single argument.

These two constants are not used to indicate the calling convention but the binding when use with methods of classes. These may not be used for functions defined for modules. At most one of these flags may be set for any given method.

METH_CLASS
: The method will be passed the type object as the first parameter rather than an instance of the type. This is used to create *class methods*, similar to what is created when using the `classmethod()` built-in function.

METH_STATIC
: The method will be passed *NULL* as the first parameter rather than an instance of the type. This is used to create *static methods*, similar to what is created when using the `staticmethod()` built-in function.

One other constant controls whether a method is loaded in place of another definition with the same method name.

METH_COEXIST
: The method will be loaded in place of existing definitions. Without *METH_COEXIST*, the default is to skip repeated definitions. Since slot wrappers are loaded before the method table, the existence of a *sq_contains* slot, for example, would generate a wrapped method named `__contains__()` and preclude the loading of a corresponding PyCFunction with the same name. With the flag defined, the PyCFunction will be loaded in place of the wrapper object and will co-exist with the slot. This is helpful because calls to PyCFunctions are optimized more than wrapper object calls.

PyMemberDef
: Structure which describes an attribute of a type which corresponds to a C struct member. Its fields are:

Field	C Type	Meaning
`name`	const char *	name of the member
`type`	int	the type of the member in the C struct
`offset`	Py_ssize_t	the offset in bytes that the member is located on the type's object struct
`flags`	int	flag bits indicating if the field should be read-only or writable
`doc`	const char *	points to the contents of the docstring

`type` can be one of many `T_` macros corresponding to various C types. When the member is accessed in Python, it will be converted to the equivalent Python type.

Macro name	C type
T_SHORT	short
T_INT	int
T_LONG	long
T_FLOAT	float
T_DOUBLE	double
T_STRING	const char *
T_OBJECT	PyObject *
T_OBJECT_EX	PyObject *
T_CHAR	char
T_BYTE	char
T_UBYTE	unsigned char
T_UINT	unsigned int
T_USHORT	unsigned short
T_ULONG	unsigned long
T_BOOL	char
T_LONGLONG	long long
T_ULONGLONG	unsigned long long
T_PYSSIZET	Py_ssize_t

`T_OBJECT` and `T_OBJECT_EX` differ in that `T_OBJECT` returns `None` if the member is *NULL* and `T_OBJECT_EX` raises an `AttributeError`. Try to use `T_OBJECT_EX` over `T_OBJECT` because `T_OBJECT_EX` handles use of the `del` statement on that attribute more correctly than `T_OBJECT`.

`flags` can be `0` for write and read access or `READONLY` for read-only access. Using `T_STRING` for `type` implies `READONLY`. Only `T_OBJECT` and `T_OBJECT_EX` members can be deleted. (They are set to *NULL*).

PyGetSetDef

Structure to define property-like access for a type. See also description of the *PyTypeObject.tp_getset* slot.

Field	C Type	Meaning
name	const char *	attribute name
get	getter	C Function to get the attribute
set	setter	optional C function to set or delete the attribute, if omitted the attribute is readonly
doc	const char *	optional docstring
closure	void *	optional function pointer, providing additional data for getter and setter

The `get` function takes one *PyObject** parameter (the instance) and a function pointer (the associated `closure`):

```
typedef PyObject *(*getter)(PyObject *, void *);
```

It should return a new reference on success or *NULL* with a set exception on failure.

`set` functions take two *PyObject** parameters (the instance and the value to be set) and a function pointer (the associated `closure`):

```
typedef int (*setter)(PyObject *, PyObject *, void *);
```

In case the attribute should be deleted the second parameter is *NULL*. Should return `0` on success or `-1` with a set exception on failure.

11.3 Type Objects

Perhaps one of the most important structures of the Python object system is the structure that defines a new type: the *PyTypeObject* structure. Type objects can be handled using any of the `PyObject_*()` or `PyType_*()` functions, but do not offer much that's interesting to most Python applications. These objects are fundamental to how objects behave, so they are very important to the interpreter itself and to any extension module that implements new types.

Type objects are fairly large compared to most of the standard types. The reason for the size is that each type object stores a large number of values, mostly C function pointers, each of which implements a small part of the type's functionality. The fields of the type object are examined in detail in this section. The fields will be described in the order in which they occur in the structure.

Typedefs: unaryfunc, binaryfunc, ternaryfunc, inquiry, intargfunc, intintargfunc, intobjargproc, intintobjargproc, objobjargproc, destructor, freefunc, printfunc, getattrfunc, getattrofunc, setattrfunc, setattrofunc, reprfunc, hashfunc

The structure definition for *PyTypeObject* can be found in `Include/object.h`. For convenience of reference, this repeats the definition found there:

```
typedef struct _typeobject {
    PyObject_VAR_HEAD
    const char *tp_name; /* For printing, in format "<module>.<name>" */
    Py_ssize_t tp_basicsize, tp_itemsize; /* For allocation */

    /* Methods to implement standard operations */

    destructor tp_dealloc;
    printfunc tp_print;
    getattrfunc tp_getattr;
    setattrfunc tp_setattr;
    PyAsyncMethods *tp_as_async; /* formerly known as tp_compare (Python 2)
                                    or tp_reserved (Python 3) */
    reprfunc tp_repr;

    /* Method suites for standard classes */

    PyNumberMethods *tp_as_number;
    PySequenceMethods *tp_as_sequence;
    PyMappingMethods *tp_as_mapping;

    /* More standard operations (here for binary compatibility) */

    hashfunc tp_hash;
    ternaryfunc tp_call;
    reprfunc tp_str;
    getattrofunc tp_getattro;
    setattrofunc tp_setattro;

    /* Functions to access object as input/output buffer */
    PyBufferProcs *tp_as_buffer;

    /* Flags to define presence of optional/expanded features */
```

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```
    unsigned long tp_flags;

    const char *tp_doc; /* Documentation string */

    /* call function for all accessible objects */
    traverseproc tp_traverse;

    /* delete references to contained objects */
    inquiry tp_clear;

    /* rich comparisons */
    richcmpfunc tp_richcompare;

    /* weak reference enabler */
    Py_ssize_t tp_weaklistoffset;

    /* Iterators */
    getiterfunc tp_iter;
    iternextfunc tp_iternext;

    /* Attribute descriptor and subclassing stuff */
    struct PyMethodDef *tp_methods;
    struct PyMemberDef *tp_members;
    struct PyGetSetDef *tp_getset;
    struct _typeobject *tp_base;
    PyObject *tp_dict;
    descrgetfunc tp_descr_get;
    descrsetfunc tp_descr_set;
    Py_ssize_t tp_dictoffset;
    initproc tp_init;
    allocfunc tp_alloc;
    newfunc tp_new;
    freefunc tp_free; /* Low-level free-memory routine */
    inquiry tp_is_gc; /* For PyObject_IS_GC */
    PyObject *tp_bases;
    PyObject *tp_mro; /* method resolution order */
    PyObject *tp_cache;
    PyObject *tp_subclasses;
    PyObject *tp_weaklist;
    destructor tp_del;

    /* Type attribute cache version tag. Added in version 2.6 */
    unsigned int tp_version_tag;

    destructor tp_finalize;

} PyTypeObject;
```

The type object structure extends the *PyVarObject* structure. The `ob_size` field is used for dynamic types (created by `type_new()`, usually called from a class statement). Note that *PyType_Type* (the metatype) initializes *tp_itemsize*, which means that its instances (i.e. type objects) *must* have the `ob_size` field.

*PyObject** **PyObject._ob_next**
*PyObject** **PyObject._ob_prev**
These fields are only present when the macro `Py_TRACE_REFS` is defined. Their initialization to *NULL* is taken care of by the `PyObject_HEAD_INIT` macro. For statically allocated objects, these fields always remain *NULL*. For dynamically allocated objects, these two fields are used to link the object into a

doubly-linked list of *all* live objects on the heap. This could be used for various debugging purposes; currently the only use is to print the objects that are still alive at the end of a run when the environment variable `PYTHONDUMPREFS` is set.

These fields are not inherited by subtypes.

Py_ssize_t **PyObject.ob_refcnt**
This is the type object's reference count, initialized to `1` by the `PyObject_HEAD_INIT` macro. Note that for statically allocated type objects, the type's instances (objects whose `ob_type` points back to the type) do *not* count as references. But for dynamically allocated type objects, the instances *do* count as references.

This field is not inherited by subtypes.

*PyTypeObject** **PyObject.ob_type**
This is the type's type, in other words its metatype. It is initialized by the argument to the `PyObject_HEAD_INIT` macro, and its value should normally be `&PyType_Type`. However, for dynamically loadable extension modules that must be usable on Windows (at least), the compiler complains that this is not a valid initializer. Therefore, the convention is to pass *NULL* to the `PyObject_HEAD_INIT` macro and to initialize this field explicitly at the start of the module's initialization function, before doing anything else. This is typically done like this:

```
Foo_Type.ob_type = &PyType_Type;
```

This should be done before any instances of the type are created. *PyType_Ready()* checks if `ob_type` is *NULL*, and if so, initializes it to the `ob_type` field of the base class. *PyType_Ready()* will not change this field if it is non-zero.

This field is inherited by subtypes.

Py_ssize_t **PyVarObject.ob_size**
For statically allocated type objects, this should be initialized to zero. For dynamically allocated type objects, this field has a special internal meaning.

This field is not inherited by subtypes.

const char* **PyTypeObject.tp_name**
Pointer to a NUL-terminated string containing the name of the type. For types that are accessible as module globals, the string should be the full module name, followed by a dot, followed by the type name; for built-in types, it should be just the type name. If the module is a submodule of a package, the full package name is part of the full module name. For example, a type named `T` defined in module `M` in subpackage `Q` in package `P` should have the *tp_name* initializer `"P.Q.M.T"`.

For dynamically allocated type objects, this should just be the type name, and the module name explicitly stored in the type dict as the value for key `'__module__'`.

For statically allocated type objects, the tp_name field should contain a dot. Everything before the last dot is made accessible as the `__module__` attribute, and everything after the last dot is made accessible as the `__name__` attribute.

If no dot is present, the entire *tp_name* field is made accessible as the `__name__` attribute, and the `__module__` attribute is undefined (unless explicitly set in the dictionary, as explained above). This means your type will be impossible to pickle. Additionally, it will not be listed in module documentations created with pydoc.

This field is not inherited by subtypes.

Py_ssize_t **PyTypeObject.tp_basicsize**
Py_ssize_t **PyTypeObject.tp_itemsize**
These fields allow calculating the size in bytes of instances of the type.

There are two kinds of types: types with fixed-length instances have a zero *tp_itemsize* field, types with variable-length instances have a non-zero *tp_itemsize* field. For a type with fixed-length instances, all instances have the same size, given in *tp_basicsize*.

For a type with variable-length instances, the instances must have an `ob_size` field, and the instance size is *tp_basicsize* plus N times *tp_itemsize*, where N is the "length" of the object. The value of N is typically stored in the instance's `ob_size` field. There are exceptions: for example, ints use a negative `ob_size` to indicate a negative number, and N is `abs(ob_size)` there. Also, the presence of an `ob_size` field in the instance layout doesn't mean that the instance structure is variable-length (for example, the structure for the list type has fixed-length instances, yet those instances have a meaningful `ob_size` field).

The basic size includes the fields in the instance declared by the macro *PyObject_HEAD* or *PyObject_VAR_HEAD* (whichever is used to declare the instance struct) and this in turn includes the `_ob_prev` and `_ob_next` fields if they are present. This means that the only correct way to get an initializer for the *tp_basicsize* is to use the `sizeof` operator on the struct used to declare the instance layout. The basic size does not include the GC header size.

These fields are inherited separately by subtypes. If the base type has a non-zero *tp_itemsize*, it is generally not safe to set *tp_itemsize* to a different non-zero value in a subtype (though this depends on the implementation of the base type).

A note about alignment: if the variable items require a particular alignment, this should be taken care of by the value of *tp_basicsize*. Example: suppose a type implements an array of `double`. *tp_itemsize* is `sizeof(double)`. It is the programmer's responsibility that *tp_basicsize* is a multiple of `sizeof(double)` (assuming this is the alignment requirement for `double`).

destructor **PyTypeObject.tp_dealloc**
A pointer to the instance destructor function. This function must be defined unless the type guarantees that its instances will never be deallocated (as is the case for the singletons `None` and `Ellipsis`).

The destructor function is called by the *Py_DECREF()* and *Py_XDECREF()* macros when the new reference count is zero. At this point, the instance is still in existence, but there are no references to it. The destructor function should free all references which the instance owns, free all memory buffers owned by the instance (using the freeing function corresponding to the allocation function used to allocate the buffer), and finally (as its last action) call the type's *tp_free* function. If the type is not subtypable (doesn't have the *Py_TPFLAGS_BASETYPE* flag bit set), it is permissible to call the object deallocator directly instead of via *tp_free*. The object deallocator should be the one used to allocate the instance; this is normally *PyObject_Del()* if the instance was allocated using *PyObject_New()* or `PyObject_VarNew()`, or *PyObject_GC_Del()* if the instance was allocated using *PyObject_GC_New()* or *PyObject_GC_NewVar()*.

This field is inherited by subtypes.

printfunc **PyTypeObject.tp_print**
Reserved slot, formerly used for print formatting in Python 2.x.

getattrfunc **PyTypeObject.tp_getattr**
An optional pointer to the get-attribute-string function.

This field is deprecated. When it is defined, it should point to a function that acts the same as the *tp_getattro* function, but taking a C string instead of a Python string object to give the attribute name. The signature is

```
PyObject * tp_getattr(PyObject *o, char *attr_name);
```

This field is inherited by subtypes together with *tp_getattro*: a subtype inherits both *tp_getattr* and *tp_getattro* from its base type when the subtype's *tp_getattr* and *tp_getattro* are both *NULL*.

setattrfunc **PyTypeObject.tp_setattr**
An optional pointer to the function for setting and deleting attributes.

This field is deprecated. When it is defined, it should point to a function that acts the same as the *tp_setattro* function, but taking a C string instead of a Python string object to give the attribute name. The signature is

```
PyObject * tp_setattr(PyObject *o, char *attr_name, PyObject *v);
```

The *v* argument is set to *NULL* to delete the attribute. This field is inherited by subtypes together with *tp_setattro*: a subtype inherits both *tp_setattr* and *tp_setattro* from its base type when the subtype's *tp_setattr* and *tp_setattro* are both *NULL*.

*PyAsyncMethods** **tp_as_async**
Pointer to an additional structure that contains fields relevant only to objects which implement *awaitable* and *asynchronous iterator* protocols at the C-level. See *Async Object Structures* for details.

New in version 3.5: Formerly known as `tp_compare` and `tp_reserved`.

reprfunc **PyTypeObject.tp_repr**
An optional pointer to a function that implements the built-in function `repr()`.

The signature is the same as for *PyObject_Repr()*; it must return a string or a Unicode object. Ideally, this function should return a string that, when passed to `eval()`, given a suitable environment, returns an object with the same value. If this is not feasible, it should return a string starting with `'<'` and ending with `'>'` from which both the type and the value of the object can be deduced.

When this field is not set, a string of the form `<%s object at %p>` is returned, where `%s` is replaced by the type name, and `%p` by the object's memory address.

This field is inherited by subtypes.

*PyNumberMethods** **tp_as_number**
Pointer to an additional structure that contains fields relevant only to objects which implement the number protocol. These fields are documented in *Number Object Structures*.

The `tp_as_number` field is not inherited, but the contained fields are inherited individually.

*PySequenceMethods** **tp_as_sequence**
Pointer to an additional structure that contains fields relevant only to objects which implement the sequence protocol. These fields are documented in *Sequence Object Structures*.

The `tp_as_sequence` field is not inherited, but the contained fields are inherited individually.

*PyMappingMethods** **tp_as_mapping**
Pointer to an additional structure that contains fields relevant only to objects which implement the mapping protocol. These fields are documented in *Mapping Object Structures*.

The `tp_as_mapping` field is not inherited, but the contained fields are inherited individually.

hashfunc **PyTypeObject.tp_hash**
An optional pointer to a function that implements the built-in function `hash()`.

The signature is the same as for *PyObject_Hash()*; it must return a value of the type Py_hash_t. The value `-1` should not be returned as a normal return value; when an error occurs during the computation of the hash value, the function should set an exception and return `-1`.

This field can be set explicitly to *PyObject_HashNotImplemented()* to block inheritance of the hash method from a parent type. This is interpreted as the equivalent of `__hash__ = None` at the Python level, causing `isinstance(o, collections.Hashable)` to correctly return `False`. Note that the converse is also true - setting `__hash__ = None` on a class at the Python level will result in the `tp_hash` slot being set to *PyObject_HashNotImplemented()*.

When this field is not set, an attempt to take the hash of the object raises `TypeError`.

This field is inherited by subtypes together with *tp_richcompare*: a subtype inherits both of *tp_richcompare* and *tp_hash*, when the subtype's *tp_richcompare* and *tp_hash* are both *NULL*.

ternaryfunc **PyTypeObject.tp_call**
An optional pointer to a function that implements calling the object. This should be *NULL* if the object is not callable. The signature is the same as for *PyObject_Call()*.

This field is inherited by subtypes.

reprfunc **PyTypeObject.tp_str**
An optional pointer to a function that implements the built-in operation `str()`. (Note that `str` is a type now, and `str()` calls the constructor for that type. This constructor calls *PyObject_Str()* to do the actual work, and *PyObject_Str()* will call this handler.)

The signature is the same as for *PyObject_Str()*; it must return a string or a Unicode object. This function should return a "friendly" string representation of the object, as this is the representation that will be used, among other things, by the `print()` function.

When this field is not set, *PyObject_Repr()* is called to return a string representation.

This field is inherited by subtypes.

getattrofunc **PyTypeObject.tp_getattro**
An optional pointer to the get-attribute function.

The signature is the same as for *PyObject_GetAttr()*. It is usually convenient to set this field to *PyObject_GenericGetAttr()*, which implements the normal way of looking for object attributes.

This field is inherited by subtypes together with *tp_getattr*: a subtype inherits both *tp_getattr* and *tp_getattro* from its base type when the subtype's *tp_getattr* and *tp_getattro* are both *NULL*.

setattrofunc **PyTypeObject.tp_setattro**
An optional pointer to the function for setting and deleting attributes.

The signature is the same as for *PyObject_SetAttr()*, but setting *v* to *NULL* to delete an attribute must be supported. It is usually convenient to set this field to *PyObject_GenericSetAttr()*, which implements the normal way of setting object attributes.

This field is inherited by subtypes together with *tp_setattr*: a subtype inherits both *tp_setattr* and *tp_setattro* from its base type when the subtype's *tp_setattr* and *tp_setattro* are both *NULL*.

*PyBufferProcs** **PyTypeObject.tp_as_buffer**
Pointer to an additional structure that contains fields relevant only to objects which implement the buffer interface. These fields are documented in *Buffer Object Structures*.

The *tp_as_buffer* field is not inherited, but the contained fields are inherited individually.

unsigned long **PyTypeObject.tp_flags**
This field is a bit mask of various flags. Some flags indicate variant semantics for certain situations; others are used to indicate that certain fields in the type object (or in the extension structures referenced via `tp_as_number`, `tp_as_sequence`, `tp_as_mapping`, and *tp_as_buffer*) that were historically not always present are valid; if such a flag bit is clear, the type fields it guards must not be accessed and must be considered to have a zero or *NULL* value instead.

Inheritance of this field is complicated. Most flag bits are inherited individually, i.e. if the base type has a flag bit set, the subtype inherits this flag bit. The flag bits that pertain to extension structures are strictly inherited if the extension structure is inherited, i.e. the base type's value of the flag bit is copied into the subtype together with a pointer to the extension structure. The *Py_TPFLAGS_HAVE_GC* flag bit is inherited together with the *tp_traverse* and *tp_clear* fields, i.e. if the *Py_TPFLAGS_HAVE_GC* flag bit is clear in the subtype and the *tp_traverse* and *tp_clear* fields in the subtype exist and have *NULL* values.

The following bit masks are currently defined; these can be ORed together using the `|` operator to form the value of the *tp_flags* field. The macro *PyType_HasFeature()* takes a type and a flags value, *tp* and *f*, and checks whether `tp->tp_flags & f` is non-zero.

Py_TPFLAGS_HEAPTYPE
This bit is set when the type object itself is allocated on the heap. In this case, the `ob_type` field of its instances is considered a reference to the type, and the type object is INCREF'ed when a new instance is created, and DECREF'ed when an instance is destroyed (this does not apply to instances of subtypes; only the type referenced by the instance's ob_type gets INCREF'ed or DECREF'ed).

Py_TPFLAGS_BASETYPE
This bit is set when the type can be used as the base type of another type. If this bit is clear, the type cannot be subtyped (similar to a "final" class in Java).

Py_TPFLAGS_READY
This bit is set when the type object has been fully initialized by *PyType_Ready()*.

Py_TPFLAGS_READYING
This bit is set while *PyType_Ready()* is in the process of initializing the type object.

Py_TPFLAGS_HAVE_GC
This bit is set when the object supports garbage collection. If this bit is set, instances must be created using *PyObject_GC_New()* and destroyed using *PyObject_GC_Del()*. More information in section *Supporting Cyclic Garbage Collection*. This bit also implies that the GC-related fields *tp_traverse* and *tp_clear* are present in the type object.

Py_TPFLAGS_DEFAULT
This is a bitmask of all the bits that pertain to the existence of certain fields in the type object and its extension structures. Currently, it includes the following bits: `Py_TPFLAGS_HAVE_STACKLESS_EXTENSION`, `Py_TPFLAGS_HAVE_VERSION_TAG`.

Py_TPFLAGS_LONG_SUBCLASS

Py_TPFLAGS_LIST_SUBCLASS

Py_TPFLAGS_TUPLE_SUBCLASS

Py_TPFLAGS_BYTES_SUBCLASS

Py_TPFLAGS_UNICODE_SUBCLASS

Py_TPFLAGS_DICT_SUBCLASS

Py_TPFLAGS_BASE_EXC_SUBCLASS

Py_TPFLAGS_TYPE_SUBCLASS
These flags are used by functions such as *PyLong_Check()* to quickly determine if a type is a subclass of a built-in type; such specific checks are faster than a generic check, like *PyObject_IsInstance()*. Custom types that inherit from built-ins should have their *tp_flags* set appropriately, or the code that interacts with such types will behave differently depending on what kind of check is used.

Py_TPFLAGS_HAVE_FINALIZE
This bit is set when the *tp_finalize* slot is present in the type structure.

New in version 3.4.

const char* **PyTypeObject.tp_doc**
An optional pointer to a NUL-terminated C string giving the docstring for this type object. This is exposed as the `__doc__` attribute on the type and instances of the type.

This field is *not* inherited by subtypes.

traverseproc **PyTypeObject.tp_traverse**
An optional pointer to a traversal function for the garbage collector. This is only used if the *Py_TPFLAGS_HAVE_GC* flag bit is set. More information about Python's garbage collection scheme can be found in section *Supporting Cyclic Garbage Collection*.

The *tp_traverse* pointer is used by the garbage collector to detect reference cycles. A typical implementation of a *tp_traverse* function simply calls *Py_VISIT()* on each of the instance's members that are Python objects. For example, this is function `local_traverse()` from the `_thread` extension module:

```
static int
local_traverse(localobject *self, visitproc visit, void *arg)
{
    Py_VISIT(self->args);
    Py_VISIT(self->kw);
    Py_VISIT(self->dict);
    return 0;
}
```

Note that *Py_VISIT()* is called only on those members that can participate in reference cycles. Although there is also a `self->key` member, it can only be *NULL* or a Python string and therefore cannot be part of a reference cycle.

On the other hand, even if you know a member can never be part of a cycle, as a debugging aid you may want to visit it anyway just so the `gc` module's `get_referents()` function will include it.

Note that *Py_VISIT()* requires the *visit* and *arg* parameters to `local_traverse()` to have these specific names; don't name them just anything.

This field is inherited by subtypes together with *tp_clear* and the *Py_TPFLAGS_HAVE_GC* flag bit: the flag bit, *tp_traverse*, and *tp_clear* are all inherited from the base type if they are all zero in the subtype.

inquiry **PyTypeObject.tp_clear**

An optional pointer to a clear function for the garbage collector. This is only used if the *Py_TPFLAGS_HAVE_GC* flag bit is set.

The *tp_clear* member function is used to break reference cycles in cyclic garbage detected by the garbage collector. Taken together, all *tp_clear* functions in the system must combine to break all reference cycles. This is subtle, and if in any doubt supply a *tp_clear* function. For example, the tuple type does not implement a *tp_clear* function, because it's possible to prove that no reference cycle can be composed entirely of tuples. Therefore the *tp_clear* functions of other types must be sufficient to break any cycle containing a tuple. This isn't immediately obvious, and there's rarely a good reason to avoid implementing *tp_clear*.

Implementations of *tp_clear* should drop the instance's references to those of its members that may be Python objects, and set its pointers to those members to *NULL*, as in the following example:

```
static int
local_clear(localobject *self)
{
    Py_CLEAR(self->key);
    Py_CLEAR(self->args);
    Py_CLEAR(self->kw);
    Py_CLEAR(self->dict);
    return 0;
}
```

The *Py_CLEAR()* macro should be used, because clearing references is delicate: the reference to the contained object must not be decremented until after the pointer to the contained object is set to *NULL*. This is because decrementing the reference count may cause the contained object to become trash, triggering a chain of reclamation activity that may include invoking arbitrary Python code (due to finalizers, or weakref callbacks, associated with the contained object). If it's possible for such code to reference *self* again, it's important that the pointer to the contained object be *NULL* at that time,

so that *self* knows the contained object can no longer be used. The *Py_CLEAR()* macro performs the operations in a safe order.

Because the goal of *tp_clear* functions is to break reference cycles, it's not necessary to clear contained objects like Python strings or Python integers, which can't participate in reference cycles. On the other hand, it may be convenient to clear all contained Python objects, and write the type's *tp_dealloc* function to invoke *tp_clear*.

More information about Python's garbage collection scheme can be found in section *Supporting Cyclic Garbage Collection*.

This field is inherited by subtypes together with *tp_traverse* and the *Py_TPFLAGS_HAVE_GC* flag bit: the flag bit, *tp_traverse*, and *tp_clear* are all inherited from the base type if they are all zero in the subtype.

richcmpfunc **PyTypeObject.tp_richcompare**

An optional pointer to the rich comparison function, whose signature is `PyObject *tp_richcompare(PyObject *a, PyObject *b, int op)`. The first parameter is guaranteed to be an instance of the type that is defined by *PyTypeObject*.

The function should return the result of the comparison (usually `Py_True` or `Py_False`). If the comparison is undefined, it must return `Py_NotImplemented`, if another error occurred it must return `NULL` and set an exception condition.

Note: If you want to implement a type for which only a limited set of comparisons makes sense (e.g. `==` and `!=`, but not `<` and friends), directly raise `TypeError` in the rich comparison function.

This field is inherited by subtypes together with *tp_hash*: a subtype inherits *tp_richcompare* and *tp_hash* when the subtype's *tp_richcompare* and *tp_hash* are both *NULL*.

The following constants are defined to be used as the third argument for *tp_richcompare* and for *PyObject_RichCompare()*:

Constant	Comparison
Py_LT	<
Py_LE	<=
Py_EQ	==
Py_NE	!=
Py_GT	>
Py_GE	>=

The following macro is defined to ease writing rich comparison functions:

PyObject ***Py_RETURN_RICHCOMPARE**(VAL_A, VAL_B, int *op*)

Return `Py_True` or `Py_False` from the function, depending on the result of a comparison. VAL_A and VAL_B must be orderable by C comparison operators (for example, they may be C ints or floats). The third argument specifies the requested operation, as for *PyObject_RichCompare()*.

The return value's reference count is properly incremented.

On error, sets an exception and returns NULL from the function.

New in version 3.7.

Py_ssize_t **PyTypeObject.tp_weaklistoffset**

If the instances of this type are weakly referenceable, this field is greater than zero and contains the offset in the instance structure of the weak reference list head (ignoring the GC header, if present); this offset is used by `PyObject_ClearWeakRefs()` and the `PyWeakref_*()` functions. The instance structure needs to include a field of type *PyObject** which is initialized to *NULL*.

Do not confuse this field with *tp_weaklist*; that is the list head for weak references to the type object itself.

This field is inherited by subtypes, but see the rules listed below. A subtype may override this offset; this means that the subtype uses a different weak reference list head than the base type. Since the list head is always found via *tp_weaklistoffset*, this should not be a problem.

When a type defined by a class statement has no `__slots__` declaration, and none of its base types are weakly referenceable, the type is made weakly referenceable by adding a weak reference list head slot to the instance layout and setting the *tp_weaklistoffset* of that slot's offset.

When a type's `__slots__` declaration contains a slot named `__weakref__`, that slot becomes the weak reference list head for instances of the type, and the slot's offset is stored in the type's *tp_weaklistoffset*.

When a type's `__slots__` declaration does not contain a slot named `__weakref__`, the type inherits its *tp_weaklistoffset* from its base type.

getiterfunc **PyTypeObject.tp_iter**
An optional pointer to a function that returns an iterator for the object. Its presence normally signals that the instances of this type are iterable (although sequences may be iterable without this function).

This function has the same signature as *PyObject_GetIter()*.

This field is inherited by subtypes.

iternextfunc **PyTypeObject.tp_iternext**
An optional pointer to a function that returns the next item in an iterator. When the iterator is exhausted, it must return *NULL*; a `StopIteration` exception may or may not be set. When another error occurs, it must return *NULL* too. Its presence signals that the instances of this type are iterators.

Iterator types should also define the *tp_iter* function, and that function should return the iterator instance itself (not a new iterator instance).

This function has the same signature as *PyIter_Next()*.

This field is inherited by subtypes.

struct *PyMethodDef** **PyTypeObject.tp_methods**
An optional pointer to a static *NULL*-terminated array of *PyMethodDef* structures, declaring regular methods of this type.

For each entry in the array, an entry is added to the type's dictionary (see *tp_dict* below) containing a method descriptor.

This field is not inherited by subtypes (methods are inherited through a different mechanism).

struct *PyMemberDef** **PyTypeObject.tp_members**
An optional pointer to a static *NULL*-terminated array of *PyMemberDef* structures, declaring regular data members (fields or slots) of instances of this type.

For each entry in the array, an entry is added to the type's dictionary (see *tp_dict* below) containing a member descriptor.

This field is not inherited by subtypes (members are inherited through a different mechanism).

struct *PyGetSetDef** **PyTypeObject.tp_getset**
An optional pointer to a static *NULL*-terminated array of *PyGetSetDef* structures, declaring computed attributes of instances of this type.

For each entry in the array, an entry is added to the type's dictionary (see *tp_dict* below) containing a getset descriptor.

This field is not inherited by subtypes (computed attributes are inherited through a different mechanism).

*PyTypeObject** **PyTypeObject.tp_base**
An optional pointer to a base type from which type properties are inherited. At this level, only single inheritance is supported; multiple inheritance require dynamically creating a type object by calling the metatype.

This field is not inherited by subtypes (obviously), but it defaults to `&PyBaseObject_Type` (which to Python programmers is known as the type `object`).

*PyObject** **PyTypeObject.tp_dict**
The type's dictionary is stored here by *PyType_Ready()*.

This field should normally be initialized to *NULL* before PyType_Ready is called; it may also be initialized to a dictionary containing initial attributes for the type. Once *PyType_Ready()* has initialized the type, extra attributes for the type may be added to this dictionary only if they don't correspond to overloaded operations (like `__add__()`).

This field is not inherited by subtypes (though the attributes defined in here are inherited through a different mechanism).

> **Warning:** It is not safe to use *PyDict_SetItem()* on or otherwise modify *tp_dict* with the dictionary C-API.

descrgetfunc **PyTypeObject.tp_descr_get**
An optional pointer to a "descriptor get" function.

The function signature is

```
PyObject * tp_descr_get(PyObject *self, PyObject *obj, PyObject *type);
```

This field is inherited by subtypes.

descrsetfunc **PyTypeObject.tp_descr_set**
An optional pointer to a function for setting and deleting a descriptor's value.

The function signature is

```
int tp_descr_set(PyObject *self, PyObject *obj, PyObject *value);
```

The *value* argument is set to *NULL* to delete the value. This field is inherited by subtypes.

Py_ssize_t **PyTypeObject.tp_dictoffset**
If the instances of this type have a dictionary containing instance variables, this field is non-zero and contains the offset in the instances of the type of the instance variable dictionary; this offset is used by *PyObject_GenericGetAttr()*.

Do not confuse this field with *tp_dict*; that is the dictionary for attributes of the type object itself.

If the value of this field is greater than zero, it specifies the offset from the start of the instance structure. If the value is less than zero, it specifies the offset from the *end* of the instance structure. A negative offset is more expensive to use, and should only be used when the instance structure contains a variable-length part. This is used for example to add an instance variable dictionary to subtypes of `str` or `tuple`. Note that the *tp_basicsize* field should account for the dictionary added to the end in that case, even though the dictionary is not included in the basic object layout. On a system with a pointer size of 4 bytes, *tp_dictoffset* should be set to `-4` to indicate that the dictionary is at the very end of the structure.

The real dictionary offset in an instance can be computed from a negative *tp_dictoffset* as follows:

```
dictoffset = tp_basicsize + abs(ob_size)*tp_itemsize + tp_dictoffset
if dictoffset is not aligned on sizeof(void*):
    round up to sizeof(void*)
```

where *tp_basicsize*, *tp_itemsize* and *tp_dictoffset* are taken from the type object, and `ob_size` is taken from the instance. The absolute value is taken because ints use the sign of `ob_size` to store the sign of the number. (There's never a need to do this calculation yourself; it is done for you by `_PyObject_GetDictPtr()`.)

This field is inherited by subtypes, but see the rules listed below. A subtype may override this offset; this means that the subtype instances store the dictionary at a difference offset than the base type. Since the dictionary is always found via *tp_dictoffset*, this should not be a problem.

When a type defined by a class statement has no `__slots__` declaration, and none of its base types has an instance variable dictionary, a dictionary slot is added to the instance layout and the *tp_dictoffset* is set to that slot's offset.

When a type defined by a class statement has a `__slots__` declaration, the type inherits its *tp_dictoffset* from its base type.

(Adding a slot named `__dict__` to the `__slots__` declaration does not have the expected effect, it just causes confusion. Maybe this should be added as a feature just like `__weakref__` though.)

initproc **PyTypeObject.tp_init**

An optional pointer to an instance initialization function.

This function corresponds to the `__init__()` method of classes. Like `__init__()`, it is possible to create an instance without calling `__init__()`, and it is possible to reinitialize an instance by calling its `__init__()` method again.

The function signature is

```
int tp_init(PyObject *self, PyObject *args, PyObject *kwds)
```

The self argument is the instance to be initialized; the *args* and *kwds* arguments represent positional and keyword arguments of the call to `__init__()`.

The *tp_init* function, if not *NULL*, is called when an instance is created normally by calling its type, after the type's *tp_new* function has returned an instance of the type. If the *tp_new* function returns an instance of some other type that is not a subtype of the original type, no *tp_init* function is called; if *tp_new* returns an instance of a subtype of the original type, the subtype's *tp_init* is called.

This field is inherited by subtypes.

allocfunc **PyTypeObject.tp_alloc**

An optional pointer to an instance allocation function.

The function signature is

```
PyObject *tp_alloc(PyTypeObject *self, Py_ssize_t nitems)
```

The purpose of this function is to separate memory allocation from memory initialization. It should return a pointer to a block of memory of adequate length for the instance, suitably aligned, and initialized to zeros, but with `ob_refcnt` set to `1` and `ob_type` set to the type argument. If the type's *tp_itemsize* is non-zero, the object's `ob_size` field should be initialized to *nitems* and the length of the allocated memory block should be `tp_basicsize + nitems*tp_itemsize`, rounded up to a multiple of `sizeof(void*)`; otherwise, *nitems* is not used and the length of the block should be *tp_basicsize*.

Do not use this function to do any other instance initialization, not even to allocate additional memory; that should be done by *tp_new*.

This field is inherited by static subtypes, but not by dynamic subtypes (subtypes created by a class statement); in the latter, this field is always set to *PyType_GenericAlloc()*, to force a standard heap allocation strategy. That is also the recommended value for statically defined types.

newfunc **PyTypeObject.tp_new**

An optional pointer to an instance creation function.

If this function is *NULL* for a particular type, that type cannot be called to create new instances; presumably there is some other way to create instances, like a factory function.

The function signature is

```
PyObject *tp_new(PyTypeObject *subtype, PyObject *args, PyObject *kwds)
```

The subtype argument is the type of the object being created; the *args* and *kwds* arguments represent positional and keyword arguments of the call to the type. Note that subtype doesn't have to equal the type whose *tp_new* function is called; it may be a subtype of that type (but not an unrelated type).

The *tp_new* function should call `subtype->tp_alloc(subtype, nitems)` to allocate space for the object, and then do only as much further initialization as is absolutely necessary. Initialization that can safely be ignored or repeated should be placed in the *tp_init* handler. A good rule of thumb is that for immutable types, all initialization should take place in *tp_new*, while for mutable types, most initialization should be deferred to *tp_init*.

This field is inherited by subtypes, except it is not inherited by static types whose *tp_base* is *NULL* or `&PyBaseObject_Type`.

destructor **PyTypeObject.tp_free**

An optional pointer to an instance deallocation function. Its signature is `freefunc`:

```
void tp_free(void *)
```

An initializer that is compatible with this signature is *PyObject_Free()*.

This field is inherited by static subtypes, but not by dynamic subtypes (subtypes created by a class statement); in the latter, this field is set to a deallocator suitable to match *PyType_GenericAlloc()* and the value of the *Py_TPFLAGS_HAVE_GC* flag bit.

inquiry **PyTypeObject.tp_is_gc**

An optional pointer to a function called by the garbage collector.

The garbage collector needs to know whether a particular object is collectible or not. Normally, it is sufficient to look at the object's type's *tp_flags* field, and check the *Py_TPFLAGS_HAVE_GC* flag bit. But some types have a mixture of statically and dynamically allocated instances, and the statically allocated instances are not collectible. Such types should define this function; it should return `1` for a collectible instance, and `0` for a non-collectible instance. The signature is

```
int tp_is_gc(PyObject *self)
```

(The only example of this are types themselves. The metatype, *PyType_Type*, defines this function to distinguish between statically and dynamically allocated types.)

This field is inherited by subtypes.

*PyObject** **PyTypeObject.tp_bases**

Tuple of base types.

This is set for types created by a class statement. It should be *NULL* for statically defined types.

This field is not inherited.

*PyObject** **PyTypeObject.tp_mro**
Tuple containing the expanded set of base types, starting with the type itself and ending with `object`, in Method Resolution Order.

This field is not inherited; it is calculated fresh by *PyType_Ready()*.

destructor **PyTypeObject.tp_finalize**
An optional pointer to an instance finalization function. Its signature is `destructor`:

```
void tp_finalize(PyObject *)
```

If *tp_finalize* is set, the interpreter calls it once when finalizing an instance. It is called either from the garbage collector (if the instance is part of an isolated reference cycle) or just before the object is deallocated. Either way, it is guaranteed to be called before attempting to break reference cycles, ensuring that it finds the object in a sane state.

tp_finalize should not mutate the current exception status; therefore, a recommended way to write a non-trivial finalizer is:

```
static void
local_finalize(PyObject *self)
{
    PyObject *error_type, *error_value, *error_traceback;

    /* Save the current exception, if any. */
    PyErr_Fetch(&error_type, &error_value, &error_traceback);

    /* ... */

    /* Restore the saved exception. */
    PyErr_Restore(error_type, error_value, error_traceback);
}
```

For this field to be taken into account (even through inheritance), you must also set the *Py_TPFLAGS_HAVE_FINALIZE* flags bit.

This field is inherited by subtypes.

New in version 3.4.

See also:

"Safe object finalization" (**PEP 442**)

*PyObject** **PyTypeObject.tp_cache**
Unused. Not inherited. Internal use only.

*PyObject** **PyTypeObject.tp_subclasses**
List of weak references to subclasses. Not inherited. Internal use only.

*PyObject** **PyTypeObject.tp_weaklist**
Weak reference list head, for weak references to this type object. Not inherited. Internal use only.

The remaining fields are only defined if the feature test macro `COUNT_ALLOCS` is defined, and are for internal use only. They are documented here for completeness. None of these fields are inherited by subtypes.

Py_ssize_t **PyTypeObject.tp_allocs**
Number of allocations.

Py_ssize_t **PyTypeObject.tp_frees**
Number of frees.

Py_ssize_t **PyTypeObject.tp_maxalloc**
Maximum simultaneously allocated objects.

*PyTypeObject** **PyTypeObject.tp_next**
Pointer to the next type object with a non-zero *tp_allocs* field.

Also, note that, in a garbage collected Python, tp_dealloc may be called from any Python thread, not just the thread which created the object (if the object becomes part of a refcount cycle, that cycle might be collected by a garbage collection on any thread). This is not a problem for Python API calls, since the thread on which tp_dealloc is called will own the Global Interpreter Lock (GIL). However, if the object being destroyed in turn destroys objects from some other C or C++ library, care should be taken to ensure that destroying those objects on the thread which called tp_dealloc will not violate any assumptions of the library.

11.4 Number Object Structures

PyNumberMethods
This structure holds pointers to the functions which an object uses to implement the number protocol. Each function is used by the function of similar name documented in the *Number Protocol* section.

Here is the structure definition:

```
typedef struct {
     binaryfunc nb_add;
     binaryfunc nb_subtract;
     binaryfunc nb_multiply;
     binaryfunc nb_remainder;
     binaryfunc nb_divmod;
     ternaryfunc nb_power;
     unaryfunc nb_negative;
     unaryfunc nb_positive;
     unaryfunc nb_absolute;
     inquiry nb_bool;
     unaryfunc nb_invert;
     binaryfunc nb_lshift;
     binaryfunc nb_rshift;
     binaryfunc nb_and;
     binaryfunc nb_xor;
     binaryfunc nb_or;
     unaryfunc nb_int;
     void *nb_reserved;
     unaryfunc nb_float;

     binaryfunc nb_inplace_add;
     binaryfunc nb_inplace_subtract;
     binaryfunc nb_inplace_multiply;
     binaryfunc nb_inplace_remainder;
     ternaryfunc nb_inplace_power;
     binaryfunc nb_inplace_lshift;
     binaryfunc nb_inplace_rshift;
     binaryfunc nb_inplace_and;
     binaryfunc nb_inplace_xor;
     binaryfunc nb_inplace_or;

     binaryfunc nb_floor_divide;
     binaryfunc nb_true_divide;
     binaryfunc nb_inplace_floor_divide;
     binaryfunc nb_inplace_true_divide;
```

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```
    unaryfunc nb_index;

    binaryfunc nb_matrix_multiply;
    binaryfunc nb_inplace_matrix_multiply;
} PyNumberMethods;
```

Note: Binary and ternary functions must check the type of all their operands, and implement the necessary conversions (at least one of the operands is an instance of the defined type). If the operation is not defined for the given operands, binary and ternary functions must return `Py_NotImplemented`, if another error occurred they must return `NULL` and set an exception.

Note: The `nb_reserved` field should always be `NULL`. It was previously called `nb_long`, and was renamed in Python 3.0.1.

11.5 Mapping Object Structures

PyMappingMethods
This structure holds pointers to the functions which an object uses to implement the mapping protocol. It has three members:

lenfunc **PyMappingMethods.mp_length**
This function is used by *PyMapping_Size()* and *PyObject_Size()*, and has the same signature. This slot may be set to *NULL* if the object has no defined length.

binaryfunc **PyMappingMethods.mp_subscript**
This function is used by *PyObject_GetItem()* and *PySequence_GetSlice()*, and has the same signature as `PyObject_GetItem()`. This slot must be filled for the *PyMapping_Check()* function to return `1`, it can be *NULL* otherwise.

objobjargproc **PyMappingMethods.mp_ass_subscript**
This function is used by *PyObject_SetItem()*, *PyObject_DelItem()*, `PyObject_SetSlice()` and `PyObject_DelSlice()`. It has the same signature as `PyObject_SetItem()`, but *v* can also be set to *NULL* to delete an item. If this slot is *NULL*, the object does not support item assignment and deletion.

11.6 Sequence Object Structures

PySequenceMethods
This structure holds pointers to the functions which an object uses to implement the sequence protocol.

lenfunc **PySequenceMethods.sq_length**
This function is used by *PySequence_Size()* and *PyObject_Size()*, and has the same signature. It is also used for handling negative indices via the *sq_item* and the *sq_ass_item* slots.

binaryfunc **PySequenceMethods.sq_concat**
This function is used by *PySequence_Concat()* and has the same signature. It is also used by the `+` operator, after trying the numeric addition via the `nb_add` slot.

ssizeargfunc **PySequenceMethods.sq_repeat**
: This function is used by *PySequence_Repeat()* and has the same signature. It is also used by the `*` operator, after trying numeric multiplication via the `nb_multiply` slot.

ssizeargfunc **PySequenceMethods.sq_item**
: This function is used by *PySequence_GetItem()* and has the same signature. It is also used by *PyObject_GetItem()*, after trying the subscription via the *mp_subscript* slot. This slot must be filled for the *PySequence_Check()* function to return `1`, it can be *NULL* otherwise.

  Negative indexes are handled as follows: if the `sq_length` slot is filled, it is called and the sequence length is used to compute a positive index which is passed to `sq_item`. If `sq_length` is *NULL*, the index is passed as is to the function.

ssizeobjargproc **PySequenceMethods.sq_ass_item**
: This function is used by *PySequence_SetItem()* and has the same signature. It is also used by *PyObject_SetItem()* and *PyObject_DelItem()*, after trying the item assignment and deletion via the *mp_ass_subscript* slot. This slot may be left to *NULL* if the object does not support item assignment and deletion.

objobjproc **PySequenceMethods.sq_contains**
: This function may be used by *PySequence_Contains()* and has the same signature. This slot may be left to *NULL*, in this case `PySequence_Contains()` simply traverses the sequence until it finds a match.

binaryfunc **PySequenceMethods.sq_inplace_concat**
: This function is used by *PySequence_InPlaceConcat()* and has the same signature. It should modify its first operand, and return it. This slot may be left to *NULL*, in this case `PySequence_InPlaceConcat()` will fall back to *PySequence_Concat()*. It is also used by the augmented assignment `+=`, after trying numeric inplace addition via the `nb_inplace_add` slot.

ssizeargfunc **PySequenceMethods.sq_inplace_repeat**
: This function is used by *PySequence_InPlaceRepeat()* and has the same signature. It should modify its first operand, and return it. This slot may be left to *NULL*, in this case `PySequence_InPlaceRepeat()` will fall back to *PySequence_Repeat()*. It is also used by the augmented assignment `*=`, after trying numeric inplace multiplication via the `nb_inplace_multiply` slot.

11.7 Buffer Object Structures

PyBufferProcs
: This structure holds pointers to the functions required by the *Buffer protocol*. The protocol defines how an exporter object can expose its internal data to consumer objects.

getbufferproc **PyBufferProcs.bf_getbuffer**
: The signature of this function is:

```
int (PyObject *exporter, Py_buffer *view, int flags);
```

  Handle a request to *exporter* to fill in *view* as specified by *flags*. Except for point (3), an implementation of this function MUST take these steps:

  1. Check if the request can be met. If not, raise `PyExc_BufferError`, set `view->obj` to *NULL* and return `-1`.
  2. Fill in the requested fields.
  3. Increment an internal counter for the number of exports.
  4. Set `view->obj` to *exporter* and increment `view->obj`.
  5. Return `0`.

If *exporter* is part of a chain or tree of buffer providers, two main schemes can be used:

- Re-export: Each member of the tree acts as the exporting object and sets `view->obj` to a new reference to itself.
- Redirect: The buffer request is redirected to the root object of the tree. Here, `view->obj` will be a new reference to the root object.

The individual fields of *view* are described in section *Buffer structure*, the rules how an exporter must react to specific requests are in section *Buffer request types*.

All memory pointed to in the *Py_buffer* structure belongs to the exporter and must remain valid until there are no consumers left. *format*, *shape*, *strides*, *suboffsets* and *internal* are read-only for the consumer.

PyBuffer_FillInfo() provides an easy way of exposing a simple bytes buffer while dealing correctly with all request types.

PyObject_GetBuffer() is the interface for the consumer that wraps this function.

releasebufferproc **PyBufferProcs.bf_releasebuffer**

The signature of this function is:

```
void (PyObject *exporter, Py_buffer *view);
```

Handle a request to release the resources of the buffer. If no resources need to be released, *PyBufferProcs.bf_releasebuffer* may be *NULL*. Otherwise, a standard implementation of this function will take these optional steps:

1. Decrement an internal counter for the number of exports.
2. If the counter is `0`, free all memory associated with *view*.

The exporter MUST use the *internal* field to keep track of buffer-specific resources. This field is guaranteed to remain constant, while a consumer MAY pass a copy of the original buffer as the *view* argument.

This function MUST NOT decrement `view->obj`, since that is done automatically in *PyBuffer_Release()* (this scheme is useful for breaking reference cycles).

PyBuffer_Release() is the interface for the consumer that wraps this function.

11.8 Async Object Structures

New in version 3.5.

PyAsyncMethods

This structure holds pointers to the functions required to implement *awaitable* and *asynchronous iterator* objects.

Here is the structure definition:

```
typedef struct {
    unaryfunc am_await;
    unaryfunc am_aiter;
    unaryfunc am_anext;
} PyAsyncMethods;
```

unaryfunc **PyAsyncMethods.am_await**

The signature of this function is:

```
PyObject *am_await(PyObject *self)
```

The returned object must be an iterator, i.e. *PyIter_Check()* must return `1` for it.

This slot may be set to *NULL* if an object is not an *awaitable*.

unaryfunc **PyAsyncMethods.am_aiter**
The signature of this function is:

```
PyObject *am_aiter(PyObject *self)
```

Must return an *awaitable* object. See `__anext__()` for details.

This slot may be set to *NULL* if an object does not implement asynchronous iteration protocol.

unaryfunc **PyAsyncMethods.am_anext**
The signature of this function is:

```
PyObject *am_anext(PyObject *self)
```

Must return an *awaitable* object. See `__anext__()` for details. This slot may be set to *NULL*.

11.9 Supporting Cyclic Garbage Collection

Python's support for detecting and collecting garbage which involves circular references requires support from object types which are "containers" for other objects which may also be containers. Types which do not store references to other objects, or which only store references to atomic types (such as numbers or strings), do not need to provide any explicit support for garbage collection.

To create a container type, the *tp_flags* field of the type object must include the *Py_TPFLAGS_HAVE_GC* and provide an implementation of the *tp_traverse* handler. If instances of the type are mutable, a *tp_clear* implementation must also be provided.

Py_TPFLAGS_HAVE_GC
Objects with a type with this flag set must conform with the rules documented here. For convenience these objects will be referred to as container objects.

Constructors for container types must conform to two rules:

1. The memory for the object must be allocated using *PyObject_GC_New()* or *PyObject_GC_NewVar()*.
2. Once all the fields which may contain references to other containers are initialized, it must call *PyObject_GC_Track()*.

TYPE* **PyObject_GC_New**(TYPE, *PyTypeObject* *type*)
Analogous to *PyObject_New()* but for container objects with the *Py_TPFLAGS_HAVE_GC* flag set.

TYPE* **PyObject_GC_NewVar**(TYPE, *PyTypeObject* *type*, Py_ssize_t *size*)
Analogous to *PyObject_NewVar()* but for container objects with the *Py_TPFLAGS_HAVE_GC* flag set.

TYPE* **PyObject_GC_Resize**(TYPE, *PyVarObject* *op*, Py_ssize_t *newsize*)
Resize an object allocated by *PyObject_NewVar()*. Returns the resized object or *NULL* on failure. *op* must not be tracked by the collector yet.

void **PyObject_GC_Track**(*PyObject* *op*)
Adds the object *op* to the set of container objects tracked by the collector. The collector can run at unexpected times so objects must be valid while being tracked. This should be called once all the fields followed by the *tp_traverse* handler become valid, usually near the end of the constructor.

void **_PyObject_GC_TRACK**(*PyObject* *op*)
A macro version of *PyObject_GC_Track()*. It should not be used for extension modules.

Similarly, the deallocator for the object must conform to a similar pair of rules:

1. Before fields which refer to other containers are invalidated, *PyObject_GC_UnTrack()* must be called.
2. The object's memory must be deallocated using *PyObject_GC_Del()*.

void **PyObject_GC_Del**(void **op*)
Releases memory allocated to an object using *PyObject_GC_New()* or *PyObject_GC_NewVar()*.

void **PyObject_GC_UnTrack**(void **op*)
Remove the object *op* from the set of container objects tracked by the collector. Note that *PyObject_GC_Track()* can be called again on this object to add it back to the set of tracked objects. The deallocator (*tp_dealloc* handler) should call this for the object before any of the fields used by the *tp_traverse* handler become invalid.

void **_PyObject_GC_UNTRACK**(*PyObject* **op*)
A macro version of *PyObject_GC_UnTrack()*. It should not be used for extension modules.

The *tp_traverse* handler accepts a function parameter of this type:

int **(*visitproc)**(*PyObject* **object*, void **arg*)
Type of the visitor function passed to the *tp_traverse* handler. The function should be called with an object to traverse as *object* and the third parameter to the *tp_traverse* handler as *arg*. The Python core uses several visitor functions to implement cyclic garbage detection; it's not expected that users will need to write their own visitor functions.

The *tp_traverse* handler must have the following type:

int **(*traverseproc)**(*PyObject* **self*, *visitproc* *visit*, void **arg*)
Traversal function for a container object. Implementations must call the *visit* function for each object directly contained by *self*, with the parameters to *visit* being the contained object and the *arg* value passed to the handler. The *visit* function must not be called with a *NULL* object argument. If *visit* returns a non-zero value that value should be returned immediately.

To simplify writing *tp_traverse* handlers, a *Py_VISIT()* macro is provided. In order to use this macro, the *tp_traverse* implementation must name its arguments exactly *visit* and *arg*:

void **Py_VISIT**(*PyObject* **o*)
If *o* is not *NULL*, call the *visit* callback, with arguments *o* and *arg*. If *visit* returns a non-zero value, then return it. Using this macro, *tp_traverse* handlers look like:

```
static int
my_traverse(Noddy *self, visitproc visit, void *arg)
{
    Py_VISIT(self->foo);
    Py_VISIT(self->bar);
    return 0;
}
```

The *tp_clear* handler must be of the *inquiry* type, or *NULL* if the object is immutable.

int **(*inquiry)**(*PyObject* **self*)
Drop references that may have created reference cycles. Immutable objects do not have to define this method since they can never directly create reference cycles. Note that the object must still be valid after calling this method (don't just call *Py_DECREF()* on a reference). The collector will call this method if it detects that this object is involved in a reference cycle.

CHAPTER

TWELVE

API AND ABI VERSIONING

`PY_VERSION_HEX` is the Python version number encoded in a single integer.

For example if the `PY_VERSION_HEX` is set to `0x030401a2`, the underlying version information can be found by treating it as a 32 bit number in the following manner:

Bytes	Bits (big endian order)	Meaning
1	1-8	`PY_MAJOR_VERSION` (the 3 in `3.4.1a2`)
2	9-16	`PY_MINOR_VERSION` (the 4 in `3.4.1a2`)
3	17-24	`PY_MICRO_VERSION` (the 1 in `3.4.1a2`)
4	25-28	`PY_RELEASE_LEVEL` (`0xA` for alpha, `0xB` for beta, `0xC` for release candidate and `0xF` for final), in this case it is alpha.
	29-32	`PY_RELEASE_SERIAL` (the 2 in `3.4.1a2`, zero for final releases)

Thus `3.4.1a2` is hexversion `0x030401a2`.

All the given macros are defined in Include/patchlevel.h.

APPENDIX

A

GLOSSARY

>>> The default Python prompt of the interactive shell. Often seen for code examples which can be executed interactively in the interpreter.

... The default Python prompt of the interactive shell when entering code for an indented code block, when within a pair of matching left and right delimiters (parentheses, square brackets, curly braces or triple quotes), or after specifying a decorator.

2to3 A tool that tries to convert Python 2.x code to Python 3.x code by handling most of the incompatibilities which can be detected by parsing the source and traversing the parse tree.

2to3 is available in the standard library as `lib2to3`; a standalone entry point is provided as `Tools/scripts/2to3`. See 2to3-reference.

abstract base class Abstract base classes complement *duck-typing* by providing a way to define interfaces when other techniques like `hasattr()` would be clumsy or subtly wrong (for example with magic methods). ABCs introduce virtual subclasses, which are classes that don't inherit from a class but are still recognized by `isinstance()` and `issubclass()`; see the `abc` module documentation. Python comes with many built-in ABCs for data structures (in the `collections.abc` module), numbers (in the `numbers` module), streams (in the `io` module), import finders and loaders (in the `importlib.abc` module). You can create your own ABCs with the `abc` module.

annotation A label associated with a variable, a class attribute or a function parameter or return value, used by convention as a *type hint*.

Annotations of local variables cannot be accessed at runtime, but annotations of global variables, class attributes, and functions are stored in the `__annotations__` special attribute of modules, classes, and functions, respectively.

See *variable annotation*, *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

argument A value passed to a *function* (or *method*) when calling the function. There are two kinds of argument:

- *keyword argument*: an argument preceded by an identifier (e.g. `name=`) in a function call or passed as a value in a dictionary preceded by `**`. For example, `3` and `5` are both keyword arguments in the following calls to `complex()`:

```
complex(real=3, imag=5)
complex(**{'real': 3, 'imag': 5})
```

- *positional argument*: an argument that is not a keyword argument. Positional arguments can appear at the beginning of an argument list and/or be passed as elements of an *iterable* preceded by `*`. For example, `3` and `5` are both positional arguments in the following calls:

```
complex(3, 5)
complex(*(3, 5))
```

Arguments are assigned to the named local variables in a function body. See the calls section for the rules governing this assignment. Syntactically, any expression can be used to represent an argument; the evaluated value is assigned to the local variable.

See also the *parameter* glossary entry, the FAQ question on the difference between arguments and parameters, and **PEP 362**.

asynchronous context manager An object which controls the environment seen in an `async with` statement by defining `__aenter__()` and `__aexit__()` methods. Introduced by **PEP 492**.

asynchronous generator A function which returns an *asynchronous generator iterator*. It looks like a coroutine function defined with `async def` except that it contains `yield` expressions for producing a series of values usable in an `async for` loop.

Usually refers to a asynchronous generator function, but may refer to an *asynchronous generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

An asynchronous generator function may contain `await` expressions as well as `async for`, and `async with` statements.

asynchronous generator iterator An object created by a *asynchronous generator* function.

This is an *asynchronous iterator* which when called using the `__anext__()` method returns an awaitable object which will execute that the body of the asynchronous generator function until the next `yield` expression.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *asynchronous generator iterator* effectively resumes with another awaitable returned by `__anext__()`, it picks up where it left off. See **PEP 492** and **PEP 525**.

asynchronous iterable An object, that can be used in an `async for` statement. Must return an *asynchronous iterator* from its `__aiter__()` method. Introduced by **PEP 492**.

asynchronous iterator An object that implements `__aiter__()` and `__anext__()` methods. `__anext__` must return an *awaitable* object. `async for` resolves awaitable returned from asynchronous iterator's `__anext__()` method until it raises `StopAsyncIteration` exception. Introduced by **PEP 492**.

attribute A value associated with an object which is referenced by name using dotted expressions. For example, if an object *o* has an attribute *a* it would be referenced as *o.a*.

awaitable An object that can be used in an `await` expression. Can be a *coroutine* or an object with an `__await__()` method. See also **PEP 492**.

BDFL Benevolent Dictator For Life, a.k.a. Guido van Rossum, Python's creator.

binary file A *file object* able to read and write *bytes-like objects*. Examples of binary files are files opened in binary mode (`'rb'`, `'wb'` or `'rb+'`), `sys.stdin.buffer`, `sys.stdout.buffer`, and instances of `io.BytesIO` and `gzip.GzipFile`.

See also *text file* for a file object able to read and write `str` objects.

bytes-like object An object that supports the *Buffer Protocol* and can export a C-*contiguous* buffer. This includes all `bytes`, `bytearray`, and `array.array` objects, as well as many common `memoryview` objects. Bytes-like objects can be used for various operations that work with binary data; these include compression, saving to a binary file, and sending over a socket.

Some operations need the binary data to be mutable. The documentation often refers to these as "read-write bytes-like objects". Example mutable buffer objects include `bytearray` and a `memoryview` of a `bytearray`. Other operations require the binary data to be stored in immutable objects ("read-only bytes-like objects"); examples of these include `bytes` and a `memoryview` of a `bytes` object.

bytecode Python source code is compiled into bytecode, the internal representation of a Python program in the CPython interpreter. The bytecode is also cached in `.pyc` files so that executing the same file is faster the second time (recompilation from source to bytecode can be avoided). This "intermediate language" is said to run on a *virtual machine* that executes the machine code corresponding to each bytecode. Do note that bytecodes are not expected to work between different Python virtual machines, nor to be stable between Python releases.

A list of bytecode instructions can be found in the documentation for the dis module.

class A template for creating user-defined objects. Class definitions normally contain method definitions which operate on instances of the class.

class variable A variable defined in a class and intended to be modified only at class level (i.e., not in an instance of the class).

coercion The implicit conversion of an instance of one type to another during an operation which involves two arguments of the same type. For example, `int(3.15)` converts the floating point number to the integer `3`, but in `3+4.5`, each argument is of a different type (one int, one float), and both must be converted to the same type before they can be added or it will raise a `TypeError`. Without coercion, all arguments of even compatible types would have to be normalized to the same value by the programmer, e.g., `float(3)+4.5` rather than just `3+4.5`.

complex number An extension of the familiar real number system in which all numbers are expressed as a sum of a real part and an imaginary part. Imaginary numbers are real multiples of the imaginary unit (the square root of `-1`), often written `i` in mathematics or `j` in engineering. Python has built-in support for complex numbers, which are written with this latter notation; the imaginary part is written with a `j` suffix, e.g., `3+1j`. To get access to complex equivalents of the `math` module, use `cmath`. Use of complex numbers is a fairly advanced mathematical feature. If you're not aware of a need for them, it's almost certain you can safely ignore them.

context manager An object which controls the environment seen in a `with` statement by defining `__enter__()` and `__exit__()` methods. See **PEP 343**.

contiguous A buffer is considered contiguous exactly if it is either *C-contiguous* or *Fortran contiguous*. Zero-dimensional buffers are C and Fortran contiguous. In one-dimensional arrays, the items must be laid out in memory next to each other, in order of increasing indexes starting from zero. In multidimensional C-contiguous arrays, the last index varies the fastest when visiting items in order of memory address. However, in Fortran contiguous arrays, the first index varies the fastest.

coroutine Coroutines is a more generalized form of subroutines. Subroutines are entered at one point and exited at another point. Coroutines can be entered, exited, and resumed at many different points. They can be implemented with the `async def` statement. See also **PEP 492**.

coroutine function A function which returns a *coroutine* object. A coroutine function may be defined with the `async def` statement, and may contain `await`, `async for`, and `async with` keywords. These were introduced by **PEP 492**.

CPython The canonical implementation of the Python programming language, as distributed on python.org. The term "CPython" is used when necessary to distinguish this implementation from others such as Jython or IronPython.

decorator A function returning another function, usually applied as a function transformation using the `@wrapper` syntax. Common examples for decorators are `classmethod()` and `staticmethod()`.

The decorator syntax is merely syntactic sugar, the following two function definitions are semantically equivalent:

```
def f(...):
    ...
f = staticmethod(f)
```

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```
@staticmethod
def f(...):
    ...
```

The same concept exists for classes, but is less commonly used there. See the documentation for function definitions and class definitions for more about decorators.

descriptor Any object which defines the methods `__get__()`, `__set__()`, or `__delete__()`. When a class attribute is a descriptor, its special binding behavior is triggered upon attribute lookup. Normally, using *a.b* to get, set or delete an attribute looks up the object named *b* in the class dictionary for *a*, but if *b* is a descriptor, the respective descriptor method gets called. Understanding descriptors is a key to a deep understanding of Python because they are the basis for many features including functions, methods, properties, class methods, static methods, and reference to super classes.

For more information about descriptors' methods, see descriptors.

dictionary An associative array, where arbitrary keys are mapped to values. The keys can be any object with `__hash__()` and `__eq__()` methods. Called a hash in Perl.

dictionary view The objects returned from `dict.keys()`, `dict.values()`, and `dict.items()` are called dictionary views. They provide a dynamic view on the dictionary's entries, which means that when the dictionary changes, the view reflects these changes. To force the dictionary view to become a full list use `list(dictview)`. See dict-views.

docstring A string literal which appears as the first expression in a class, function or module. While ignored when the suite is executed, it is recognized by the compiler and put into the `__doc__` attribute of the enclosing class, function or module. Since it is available via introspection, it is the canonical place for documentation of the object.

duck-typing A programming style which does not look at an object's type to determine if it has the right interface; instead, the method or attribute is simply called or used ("If it looks like a duck and quacks like a duck, it must be a duck.") By emphasizing interfaces rather than specific types, well-designed code improves its flexibility by allowing polymorphic substitution. Duck-typing avoids tests using `type()` or `isinstance()`. (Note, however, that duck-typing can be complemented with *abstract base classes*.) Instead, it typically employs `hasattr()` tests or *EAFP* programming.

EAFP Easier to ask for forgiveness than permission. This common Python coding style assumes the existence of valid keys or attributes and catches exceptions if the assumption proves false. This clean and fast style is characterized by the presence of many `try` and `except` statements. The technique contrasts with the *LBYL* style common to many other languages such as C.

expression A piece of syntax which can be evaluated to some value. In other words, an expression is an accumulation of expression elements like literals, names, attribute access, operators or function calls which all return a value. In contrast to many other languages, not all language constructs are expressions. There are also *statement*s which cannot be used as expressions, such as `if`. Assignments are also statements, not expressions.

extension module A module written in C or C++, using Python's C API to interact with the core and with user code.

f-string String literals prefixed with `'f'` or `'F'` are commonly called "f-strings" which is short for formatted string literals. See also **PEP 498**.

file object An object exposing a file-oriented API (with methods such as `read()` or `write()`) to an underlying resource. Depending on the way it was created, a file object can mediate access to a real on-disk file or to another type of storage or communication device (for example standard input/output, in-memory buffers, sockets, pipes, etc.). File objects are also called *file-like objects* or *streams*.

There are actually three categories of file objects: raw *binary files*, buffered *binary files* and *text files*. Their interfaces are defined in the `io` module. The canonical way to create a file object is by using the

`open()` function.

file-like object A synonym for *file object*.

finder An object that tries to find the *loader* for a module that is being imported.

Since Python 3.3, there are two types of finder: *meta path finders* for use with `sys.meta_path`, and *path entry finders* for use with `sys.path_hooks`.

See **PEP 302**, **PEP 420** and **PEP 451** for much more detail.

floor division Mathematical division that rounds down to nearest integer. The floor division operator is `//`. For example, the expression `11 // 4` evaluates to `2` in contrast to the `2.75` returned by float true division. Note that `(-11) // 4` is `-3` because that is `-2.75` rounded *downward*. See **PEP 238**.

function A series of statements which returns some value to a caller. It can also be passed zero or more *arguments* which may be used in the execution of the body. See also *parameter*, *method*, and the function section.

function annotation An *annotation* of a function parameter or return value.

Function annotations are usually used for *type hints*: for example this function is expected to take two `int` arguments and is also expected to have an `int` return value:

```
def sum_two_numbers(a: int, b: int) -> int:
   return a + b
```

Function annotation syntax is explained in section function.

See *variable annotation* and **PEP 484**, which describe this functionality.

___future___ A pseudo-module which programmers can use to enable new language features which are not compatible with the current interpreter.

By importing the `__future__` module and evaluating its variables, you can see when a new feature was first added to the language and when it becomes the default:

```
>>> import __future__
>>> __future__.division
_Feature((2, 2, 0, 'alpha', 2), (3, 0, 0, 'alpha', 0), 8192)
```

garbage collection The process of freeing memory when it is not used anymore. Python performs garbage collection via reference counting and a cyclic garbage collector that is able to detect and break reference cycles. The garbage collector can be controlled using the `gc` module.

generator A function which returns a *generator iterator*. It looks like a normal function except that it contains `yield` expressions for producing a series of values usable in a for-loop or that can be retrieved one at a time with the `next()` function.

Usually refers to a generator function, but may refer to a *generator iterator* in some contexts. In cases where the intended meaning isn't clear, using the full terms avoids ambiguity.

generator iterator An object created by a *generator* function.

Each `yield` temporarily suspends processing, remembering the location execution state (including local variables and pending try-statements). When the *generator iterator* resumes, it picks up where it left off (in contrast to functions which start fresh on every invocation).

generator expression An expression that returns an iterator. It looks like a normal expression followed by a `for` expression defining a loop variable, range, and an optional `if` expression. The combined expression generates values for an enclosing function:

```
>>> sum(i*i for i in range(10))         # sum of squares 0, 1, 4, ... 81
285
```

generic function A function composed of multiple functions implementing the same operation for different types. Which implementation should be used during a call is determined by the dispatch algorithm.

See also the *single dispatch* glossary entry, the `functools.singledispatch()` decorator, and **PEP 443**.

GIL See *global interpreter lock*.

global interpreter lock The mechanism used by the *CPython* interpreter to assure that only one thread executes Python *bytecode* at a time. This simplifies the CPython implementation by making the object model (including critical built-in types such as `dict`) implicitly safe against concurrent access. Locking the entire interpreter makes it easier for the interpreter to be multi-threaded, at the expense of much of the parallelism afforded by multi-processor machines.

However, some extension modules, either standard or third-party, are designed so as to release the GIL when doing computationally-intensive tasks such as compression or hashing. Also, the GIL is always released when doing I/O.

Past efforts to create a "free-threaded" interpreter (one which locks shared data at a much finer granularity) have not been successful because performance suffered in the common single-processor case. It is believed that overcoming this performance issue would make the implementation much more complicated and therefore costlier to maintain.

hash-based pyc A bytecode cache file that uses the hash rather than the last-modified time of the corresponding source file to determine its validity. See pyc-invalidation.

hashable An object is *hashable* if it has a hash value which never changes during its lifetime (it needs a `__hash__()` method), and can be compared to other objects (it needs an `__eq__()` method). Hashable objects which compare equal must have the same hash value.

Hashability makes an object usable as a dictionary key and a set member, because these data structures use the hash value internally.

All of Python's immutable built-in objects are hashable; mutable containers (such as lists or dictionaries) are not. Objects which are instances of user-defined classes are hashable by default. They all compare unequal (except with themselves), and their hash value is derived from their `id()`.

IDLE An Integrated Development Environment for Python. IDLE is a basic editor and interpreter environment which ships with the standard distribution of Python.

immutable An object with a fixed value. Immutable objects include numbers, strings and tuples. Such an object cannot be altered. A new object has to be created if a different value has to be stored. They play an important role in places where a constant hash value is needed, for example as a key in a dictionary.

import path A list of locations (or *path entries*) that are searched by the *path based finder* for modules to import. During import, this list of locations usually comes from `sys.path`, but for subpackages it may also come from the parent package's `__path__` attribute.

importing The process by which Python code in one module is made available to Python code in another module.

importer An object that both finds and loads a module; both a *finder* and *loader* object.

interactive Python has an interactive interpreter which means you can enter statements and expressions at the interpreter prompt, immediately execute them and see their results. Just launch `python` with no arguments (possibly by selecting it from your computer's main menu). It is a very powerful way to test out new ideas or inspect modules and packages (remember `help(x)`).

interpreted Python is an interpreted language, as opposed to a compiled one, though the distinction can be blurry because of the presence of the bytecode compiler. This means that source files can be run directly without explicitly creating an executable which is then run. Interpreted languages typically

have a shorter development/debug cycle than compiled ones, though their programs generally also run more slowly. See also *interactive*.

interpreter shutdown When asked to shut down, the Python interpreter enters a special phase where it gradually releases all allocated resources, such as modules and various critical internal structures. It also makes several calls to the *garbage collector*. This can trigger the execution of code in user-defined destructors or weakref callbacks. Code executed during the shutdown phase can encounter various exceptions as the resources it relies on may not function anymore (common examples are library modules or the warnings machinery).

The main reason for interpreter shutdown is that the `__main__` module or the script being run has finished executing.

iterable An object capable of returning its members one at a time. Examples of iterables include all sequence types (such as `list`, `str`, and `tuple`) and some non-sequence types like `dict`, *file objects*, and objects of any classes you define with an `__iter__()` method or with a `__getitem__()` method that implements *Sequence* semantics.

Iterables can be used in a `for` loop and in many other places where a sequence is needed (`zip()`, `map()`, ...). When an iterable object is passed as an argument to the built-in function `iter()`, it returns an iterator for the object. This iterator is good for one pass over the set of values. When using iterables, it is usually not necessary to call `iter()` or deal with iterator objects yourself. The `for` statement does that automatically for you, creating a temporary unnamed variable to hold the iterator for the duration of the loop. See also *iterator*, *sequence*, and *generator*.

iterator An object representing a stream of data. Repeated calls to the iterator's `__next__()` method (or passing it to the built-in function `next()`) return successive items in the stream. When no more data are available a `StopIteration` exception is raised instead. At this point, the iterator object is exhausted and any further calls to its `__next__()` method just raise `StopIteration` again. Iterators are required to have an `__iter__()` method that returns the iterator object itself so every iterator is also iterable and may be used in most places where other iterables are accepted. One notable exception is code which attempts multiple iteration passes. A container object (such as a `list`) produces a fresh new iterator each time you pass it to the `iter()` function or use it in a `for` loop. Attempting this with an iterator will just return the same exhausted iterator object used in the previous iteration pass, making it appear like an empty container.

More information can be found in typeiter.

key function A key function or collation function is a callable that returns a value used for sorting or ordering. For example, `locale.strxfrm()` is used to produce a sort key that is aware of locale specific sort conventions.

A number of tools in Python accept key functions to control how elements are ordered or grouped. They include `min()`, `max()`, `sorted()`, `list.sort()`, `heapq.merge()`, `heapq.nsmallest()`, `heapq.nlargest()`, and `itertools.groupby()`.

There are several ways to create a key function. For example. the `str.lower()` method can serve as a key function for case insensitive sorts. Alternatively, a key function can be built from a `lambda` expression such as `lambda r: (r[0], r[2])`. Also, the `operator` module provides three key function constructors: `attrgetter()`, `itemgetter()`, and `methodcaller()`. See the Sorting HOW TO for examples of how to create and use key functions.

keyword argument See *argument*.

lambda An anonymous inline function consisting of a single *expression* which is evaluated when the function is called. The syntax to create a lambda function is `lambda [parameters]: expression`

LBYL Look before you leap. This coding style explicitly tests for pre-conditions before making calls or lookups. This style contrasts with the *EAFP* approach and is characterized by the presence of many `if` statements.

In a multi-threaded environment, the LBYL approach can risk introducing a race condition between "the looking" and "the leaping". For example, the code, `if key in mapping: return mapping[key]` can fail if another thread removes *key* from *mapping* after the test, but before the lookup. This issue can be solved with locks or by using the EAFP approach.

list A built-in Python *sequence*. Despite its name it is more akin to an array in other languages than to a linked list since access to elements is O(1).

list comprehension A compact way to process all or part of the elements in a sequence and return a list with the results. `result = ['{:#04x}'.format(x) for x in range(256) if x % 2 == 0]` generates a list of strings containing even hex numbers (0x..) in the range from 0 to 255. The `if` clause is optional. If omitted, all elements in `range(256)` are processed.

loader An object that loads a module. It must define a method named `load_module()`. A loader is typically returned by a *finder*. See **PEP 302** for details and `importlib.abc.Loader` for an *abstract base class*.

mapping A container object that supports arbitrary key lookups and implements the methods specified in the `Mapping` or `MutableMapping` abstract base classes. Examples include `dict`, `collections.defaultdict`, `collections.OrderedDict` and `collections.Counter`.

meta path finder A *finder* returned by a search of `sys.meta_path`. Meta path finders are related to, but different from *path entry finders*.

See `importlib.abc.MetaPathFinder` for the methods that meta path finders implement.

metaclass The class of a class. Class definitions create a class name, a class dictionary, and a list of base classes. The metaclass is responsible for taking those three arguments and creating the class. Most object oriented programming languages provide a default implementation. What makes Python special is that it is possible to create custom metaclasses. Most users never need this tool, but when the need arises, metaclasses can provide powerful, elegant solutions. They have been used for logging attribute access, adding thread-safety, tracking object creation, implementing singletons, and many other tasks.

More information can be found in metaclasses.

method A function which is defined inside a class body. If called as an attribute of an instance of that class, the method will get the instance object as its first *argument* (which is usually called `self`). See *function* and *nested scope*.

method resolution order Method Resolution Order is the order in which base classes are searched for a member during lookup. See The Python 2.3 Method Resolution Order for details of the algorithm used by the Python interpreter since the 2.3 release.

module An object that serves as an organizational unit of Python code. Modules have a namespace containing arbitrary Python objects. Modules are loaded into Python by the process of *importing*.

See also *package*.

module spec A namespace containing the import-related information used to load a module. An instance of `importlib.machinery.ModuleSpec`.

MRO See *method resolution order*.

mutable Mutable objects can change their value but keep their `id()`. See also *immutable*.

named tuple Any tuple-like class whose indexable elements are also accessible using named attributes (for example, `time.localtime()` returns a tuple-like object where the *year* is accessible either with an index such as `t[0]` or with a named attribute like `t.tm_year`).

A named tuple can be a built-in type such as `time.struct_time`, or it can be created with a regular class definition. A full featured named tuple can also be created with the factory function `collections.namedtuple()`. The latter approach automatically provides extra features such as a self-documenting representation like `Employee(name='jones', title='programmer')`.

namespace The place where a variable is stored. Namespaces are implemented as dictionaries. There are the local, global and built-in namespaces as well as nested namespaces in objects (in methods). Namespaces support modularity by preventing naming conflicts. For instance, the functions `builtins.open` and `os.open()` are distinguished by their namespaces. Namespaces also aid readability and maintainability by making it clear which module implements a function. For instance, writing `random.seed()` or `itertools.islice()` makes it clear that those functions are implemented by the `random` and `itertools` modules, respectively.

namespace package A **PEP 420** *package* which serves only as a container for subpackages. Namespace packages may have no physical representation, and specifically are not like a *regular package* because they have no `__init__.py` file.

See also *module*.

nested scope The ability to refer to a variable in an enclosing definition. For instance, a function defined inside another function can refer to variables in the outer function. Note that nested scopes by default work only for reference and not for assignment. Local variables both read and write in the innermost scope. Likewise, global variables read and write to the global namespace. The `nonlocal` allows writing to outer scopes.

new-style class Old name for the flavor of classes now used for all class objects. In earlier Python versions, only new-style classes could use Python's newer, versatile features like `__slots__`, descriptors, properties, `__getattribute__()`, class methods, and static methods.

object Any data with state (attributes or value) and defined behavior (methods). Also the ultimate base class of any *new-style class*.

package A Python *module* which can contain submodules or recursively, subpackages. Technically, a package is a Python module with an `__path__` attribute.

See also *regular package* and *namespace package*.

parameter A named entity in a *function* (or method) definition that specifies an *argument* (or in some cases, arguments) that the function can accept. There are five kinds of parameter:

- *positional-or-keyword*: specifies an argument that can be passed either *positionally* or as a *keyword argument*. This is the default kind of parameter, for example *foo* and *bar* in the following:

```
def func(foo, bar=None): ...
```

- *positional-only*: specifies an argument that can be supplied only by position. Python has no syntax for defining positional-only parameters. However, some built-in functions have positional-only parameters (e.g. `abs()`).
- *keyword-only*: specifies an argument that can be supplied only by keyword. Keyword-only parameters can be defined by including a single var-positional parameter or bare `*` in the parameter list of the function definition before them, for example *kw_only1* and *kw_only2* in the following:

```
def func(arg, *, kw_only1, kw_only2): ...
```

- *var-positional*: specifies that an arbitrary sequence of positional arguments can be provided (in addition to any positional arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `*`, for example *args* in the following:

```
def func(*args, **kwargs): ...
```

- *var-keyword*: specifies that arbitrarily many keyword arguments can be provided (in addition to any keyword arguments already accepted by other parameters). Such a parameter can be defined by prepending the parameter name with `**`, for example *kwargs* in the example above.

Parameters can specify both optional and required arguments, as well as default values for some optional arguments.

See also the *argument* glossary entry, the FAQ question on the difference between arguments and parameters, the `inspect.Parameter` class, the function section, and **PEP 362**.

path entry A single location on the *import path* which the *path based finder* consults to find modules for importing.

path entry finder A *finder* returned by a callable on `sys.path_hooks` (i.e. a *path entry hook*) which knows how to locate modules given a *path entry*.

See `importlib.abc.PathEntryFinder` for the methods that path entry finders implement.

path entry hook A callable on the `sys.path_hook` list which returns a *path entry finder* if it knows how to find modules on a specific *path entry*.

path based finder One of the default *meta path finders* which searches an *import path* for modules.

path-like object An object representing a file system path. A path-like object is either a `str` or `bytes` object representing a path, or an object implementing the `os.PathLike` protocol. An object that supports the `os.PathLike` protocol can be converted to a `str` or `bytes` file system path by calling the `os.fspath()` function; `os.fsdecode()` and `os.fsencode()` can be used to guarantee a `str` or `bytes` result instead, respectively. Introduced by **PEP 519**.

PEP Python Enhancement Proposal. A PEP is a design document providing information to the Python community, or describing a new feature for Python or its processes or environment. PEPs should provide a concise technical specification and a rationale for proposed features.

PEPs are intended to be the primary mechanisms for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python. The PEP author is responsible for building consensus within the community and documenting dissenting opinions.

See **PEP 1**.

portion A set of files in a single directory (possibly stored in a zip file) that contribute to a namespace package, as defined in **PEP 420**.

positional argument See *argument*.

provisional API A provisional API is one which has been deliberately excluded from the standard library's backwards compatibility guarantees. While major changes to such interfaces are not expected, as long as they are marked provisional, backwards incompatible changes (up to and including removal of the interface) may occur if deemed necessary by core developers. Such changes will not be made gratuitously – they will occur only if serious fundamental flaws are uncovered that were missed prior to the inclusion of the API.

Even for provisional APIs, backwards incompatible changes are seen as a "solution of last resort" - every attempt will still be made to find a backwards compatible resolution to any identified problems.

This process allows the standard library to continue to evolve over time, without locking in problematic design errors for extended periods of time. See **PEP 411** for more details.

provisional package See *provisional API*.

Python 3000 Nickname for the Python 3.x release line (coined long ago when the release of version 3 was something in the distant future.) This is also abbreviated "Py3k".

Pythonic An idea or piece of code which closely follows the most common idioms of the Python language, rather than implementing code using concepts common to other languages. For example, a common idiom in Python is to loop over all elements of an iterable using a `for` statement. Many other languages don't have this type of construct, so people unfamiliar with Python sometimes use a numerical counter instead:

```
for i in range(len(food)):
    print(food[i])
```

As opposed to the cleaner, Pythonic method:

```
for piece in food:
    print(piece)
```

qualified name A dotted name showing the "path" from a module's global scope to a class, function or method defined in that module, as defined in **PEP 3155**. For top-level functions and classes, the qualified name is the same as the object's name:

```
>>> class C:
...     class D:
...         def meth(self):
...             pass
...
>>> C.__qualname__
'C'
>>> C.D.__qualname__
'C.D'
>>> C.D.meth.__qualname__
'C.D.meth'
```

When used to refer to modules, the *fully qualified name* means the entire dotted path to the module, including any parent packages, e.g. `email.mime.text`:

```
>>> import email.mime.text
>>> email.mime.text.__name__
'email.mime.text'
```

reference count The number of references to an object. When the reference count of an object drops to zero, it is deallocated. Reference counting is generally not visible to Python code, but it is a key element of the *CPython* implementation. The `sys` module defines a `getrefcount()` function that programmers can call to return the reference count for a particular object.

regular package A traditional *package*, such as a directory containing an `__init__.py` file.

See also *namespace package*.

___slots___ A declaration inside a class that saves memory by pre-declaring space for instance attributes and eliminating instance dictionaries. Though popular, the technique is somewhat tricky to get right and is best reserved for rare cases where there are large numbers of instances in a memory-critical application.

sequence An *iterable* which supports efficient element access using integer indices via the `__getitem__()` special method and defines a `__len__()` method that returns the length of the sequence. Some built-in sequence types are `list`, `str`, `tuple`, and `bytes`. Note that `dict` also supports `__getitem__()` and `__len__()`, but is considered a mapping rather than a sequence because the lookups use arbitrary *immutable* keys rather than integers.

The `collections.abc.Sequence` abstract base class defines a much richer interface that goes beyond just `__getitem__()` and `__len__()`, adding `count()`, `index()`, `__contains__()`, and `__reversed__()`. Types that implement this expanded interface can be registered explicitly using `register()`.

single dispatch A form of *generic function* dispatch where the implementation is chosen based on the type of a single argument.

slice An object usually containing a portion of a *sequence*. A slice is created using the subscript notation, `[]` with colons between numbers when several are given, such as in `variable_name[1:3:5]`. The bracket (subscript) notation uses `slice` objects internally.

special method A method that is called implicitly by Python to execute a certain operation on a type, such as addition. Such methods have names starting and ending with double underscores. Special methods are documented in specialnames.

statement A statement is part of a suite (a "block" of code). A statement is either an *expression* or one of several constructs with a keyword, such as `if`, `while` or `for`.

struct sequence A tuple with named elements. Struct sequences expose an interface similar to *named tuple* in that elements can either be accessed either by index or as an attribute. However, they do not have any of the named tuple methods like `_make()` or `_asdict()`. Examples of struct sequences include `sys.float_info` and the return value of `os.stat()`.

text encoding A codec which encodes Unicode strings to bytes.

text file A *file object* able to read and write `str` objects. Often, a text file actually accesses a byte-oriented datastream and handles the *text encoding* automatically. Examples of text files are files opened in text mode (`'r'` or `'w'`), `sys.stdin`, `sys.stdout`, and instances of `io.StringIO`.

See also *binary file* for a file object able to read and write *bytes-like objects*.

triple-quoted string A string which is bound by three instances of either a quotation mark (") or an apostrophe ('). While they don't provide any functionality not available with single-quoted strings, they are useful for a number of reasons. They allow you to include unescaped single and double quotes within a string and they can span multiple lines without the use of the continuation character, making them especially useful when writing docstrings.

type The type of a Python object determines what kind of object it is; every object has a type. An object's type is accessible as its `__class__` attribute or can be retrieved with `type(obj)`.

type alias A synonym for a type, created by assigning the type to an identifier.

Type aliases are useful for simplifying *type hints*. For example:

```
from typing import List, Tuple

def remove_gray_shades(
        colors: List[Tuple[int, int, int]]) -> List[Tuple[int, int, int]]:
    pass
```

could be made more readable like this:

```
from typing import List, Tuple

Color = Tuple[int, int, int]

def remove_gray_shades(colors: List[Color]) -> List[Color]:
    pass
```

See `typing` and **PEP 484**, which describe this functionality.

type hint An *annotation* that specifies the expected type for a variable, a class attribute, or a function parameter or return value.

Type hints are optional and are not enforced by Python but they are useful to static type analysis tools, and aid IDEs with code completion and refactoring.

Type hints of global variables, class attributes, and functions, but not local variables, can be accessed using `typing.get_type_hints()`.

See `typing` and **PEP 484**, which describe this functionality.

universal newlines A manner of interpreting text streams in which all of the following are recognized as ending a line: the Unix end-of-line convention `'\n'`, the Windows convention `'\r\n'`, and the old

Macintosh convention `'\r'`. See **PEP 278** and **PEP 3116**, as well as `bytes.splitlines()` for an additional use.

variable annotation An *annotation* of a variable or a class attribute.

When annotating a variable or a class attribute, assignment is optional:

```
class C:
    field: 'annotation'
```

Variable annotations are usually used for *type hints*: for example this variable is expected to take `int` values:

```
count: int = 0
```

Variable annotation syntax is explained in section annassign.

See *function annotation*, **PEP 484** and **PEP 526**, which describe this functionality.

virtual environment A cooperatively isolated runtime environment that allows Python users and applications to install and upgrade Python distribution packages without interfering with the behaviour of other Python applications running on the same system.

See also `venv`.

virtual machine A computer defined entirely in software. Python's virtual machine executes the *bytecode* emitted by the bytecode compiler.

Zen of Python Listing of Python design principles and philosophies that are helpful in understanding and using the language. The listing can be found by typing "`import this`" at the interactive prompt.

APPENDIX

B

ABOUT THESE DOCUMENTS

These documents are generated from reStructuredText sources by Sphinx, a document processor specifically written for the Python documentation.

Development of the documentation and its toolchain is an entirely volunteer effort, just like Python itself. If you want to contribute, please take a look at the reporting-bugs page for information on how to do so. New volunteers are always welcome!

Many thanks go to:

- Fred L. Drake, Jr., the creator of the original Python documentation toolset and writer of much of the content;
- the Docutils project for creating reStructuredText and the Docutils suite;
- Fredrik Lundh for his Alternative Python Reference project from which Sphinx got many good ideas.

B.1 Contributors to the Python Documentation

Many people have contributed to the Python language, the Python standard library, and the Python documentation. See Misc/ACKS in the Python source distribution for a partial list of contributors.

It is only with the input and contributions of the Python community that Python has such wonderful documentation – Thank You!

APPENDIX

C

HISTORY AND LICENSE

C.1 History of the software

Python was created in the early 1990s by Guido van Rossum at Stichting Mathematisch Centrum (CWI, see https://www.cwi.nl/) in the Netherlands as a successor of a language called ABC. Guido remains Python's principal author, although it includes many contributions from others.

In 1995, Guido continued his work on Python at the Corporation for National Research Initiatives (CNRI, see https://www.cnri.reston.va.us/) in Reston, Virginia where he released several versions of the software.

In May 2000, Guido and the Python core development team moved to BeOpen.com to form the BeOpen PythonLabs team. In October of the same year, the PythonLabs team moved to Digital Creations (now Zope Corporation; see http://www.zope.com/). In 2001, the Python Software Foundation (PSF, see https://www.python.org/psf/) was formed, a non-profit organization created specifically to own Python-related Intellectual Property. Zope Corporation is a sponsoring member of the PSF.

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1.6.1	1.6	2001	CNRI	no
2.1	2.0+1.6.1	2001	PSF	no
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2.1.1	2.1+2.0.1	2001	PSF	yes
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The `_random` module includes code based on a download from http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/MT2002/emt19937ar.html. The following are the verbatim comments from the original code:

```
A C-program for MT19937, with initialization improved 2002/1/26.
Coded by Takuji Nishimura and Makoto Matsumoto.

Before using, initialize the state by using init_genrand(seed)
or init_by_array(init_key, key_length).

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Any feedback is very welcome.
http://www.math.sci.hiroshima-u.ac.jp/~m-mat/MT/emt.html
email: m-mat @ math.sci.hiroshima-u.ac.jp (remove space)
```

C.3.2 Sockets

The `socket` module uses the functions, `getaddrinfo()`, and `getnameinfo()`, which are coded in separate source files from the WIDE Project, http://www.wide.ad.jp/.

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Modified by Jack Jansen, CWI, July 1995:
- Use binascii module to do the actual line-by-line conversion
  between ascii and binary. This results in a 1000-fold speedup. The C
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- Arguments more compliant with Python standard
```

C.3.7 XML Remote Procedure Calls

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C.3.9 Select kqueue

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C.3.10 SipHash24

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Original location:
   https://github.com/majek/csiphash/

Solution inspired by code from:
   Samuel Neves (supercop/crypto_auth/siphash24/little)
   djb (supercop/crypto_auth/siphash24/little2)
   Jean-Philippe Aumasson (https://131002.net/siphash/siphash24.c)
```

C.3.11 strtod and dtoa

The file `Python/dtoa.c`, which supplies C functions dtoa and strtod for conversion of C doubles to and from strings, is derived from the file of the same name by David M. Gay, currently available from http://www.netlib.org/fp/. The original file, as retrieved on March 16, 2009, contains the following copyright and licensing notice:

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C.3.13 expat

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C.3.14 libffi

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C.3.15 zlib

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C.3.16 cfuhash

The implementation of the hash table used by the `tracemalloc` is based on the cfuhash project:

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C.3.17 libmpdec

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