
What's New in Python

Release 3.12.0a6

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Date April 04, 2023

This article explains the new features in Python 3.12, compared to 3.11.

For full details, see the changelog.

Note: Prerelease users should be aware that this document is currently in draft form. It will be updated substantially as Python 3.12 moves towards release, so it's worth checking back even after reading earlier versions.

1 Summary – Release highlights

Important deprecations, removals or restrictions:

- **PEP 623**, Remove `wstr` from Unicode
- **PEP 632**, Remove the `distutils` package.

2 Improved Error Messages

- Modules from the standard library are now potentially suggested as part of the error messages displayed by the interpreter when a `NameError` is raised to the top level. Contributed by Pablo Galindo in [gh-98254](https://github.com/python/cpython/pull/98254).

```
>>> sys.version_info
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'sys' is not defined. Did you forget to import 'sys'?
```

- Improve the error suggestion for `NameError` exceptions for instances. Now if a `NameError` is raised in a method and the instance has an attribute that's exactly equal to the name in the exception, the suggestion will include `self.<NAME>` instead of the closest match in the method scope. Contributed by Pablo Galindo in [gh-99139](#).

```
>>> class A:
...     def __init__(self):
...         self.blech = 1
...
...     def foo(self):
...         somethin = blech
```

```
>>> A().foo()
File "<stdin>", line 1
    somethin = blech
            ^^^^^
NameError: name 'blech' is not defined. Did you mean: 'self.blech'?
```

- Improve the `SyntaxError` error message when the user types `import x from y` instead of `from y import x`. Contributed by Pablo Galindo in [gh-98931](#).

```
>>> import a.y.z from b.y.z
File "<stdin>", line 1
    import a.y.z from b.y.z
    ^^^^^^^^^^^^^^^^^^^^^^^
SyntaxError: Did you mean to use 'from ... import ...' instead?
```

- `ImportError` exceptions raised from failed `from <module> import <name>` statements now include suggestions for the value of `<name>` based on the available names in `<module>`. Contributed by Pablo Galindo in [gh-91058](#).

```
>>> from collections import chainmap
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ImportError: cannot import name 'chainmap' from 'collections'. Did you mean:
↳ 'ChainMap'?
```

3 New Features

- Add `perf_profiling` through the new environment variable `PYTHONPERFSUPPORT`, the new command-line option `-X perf`, as well as the new `sys.activate_stack_trampoline()`, `sys.deactivate_stack_trampoline()`, and `sys.is_stack_trampoline_active()` APIs. (Design by Pablo Galindo. Contributed by Pablo Galindo and Christian Heimes with contributions from Gregory P. Smith [Google] and Mark Shannon in [gh-96123](#).)

4 Other Language Changes

- `types.MappingProxyType` instances are now hashable if the underlying mapping is hashable. (Contributed by Serhiy Storchaka in [gh-87995](#).)
- `memoryview` now supports the half-float type (the “e” format code). (Contributed by Dong-hee Na and Antoine Pitrou in [gh-90751](#).)
- The parser now raises `SyntaxError` when parsing source code containing null bytes. (Contributed by Pablo Galindo in [gh-96670](#).)
- `ast.parse()` now raises `SyntaxError` instead of `ValueError` when parsing source code containing null bytes. (Contributed by Pablo Galindo in [gh-96670](#).)
- The Garbage Collector now runs only on the eval breaker mechanism of the Python bytecode evaluation loop instead of object allocations. The GC can also run when `PyErr_CheckSignals()` is called so C extensions that need to run for a long time without executing any Python code also have a chance to execute the GC periodically. (Contributed by Pablo Galindo in [gh-97922](#).)
- A backslash-character pair that is not a valid escape sequence now generates a `SyntaxWarning`, instead of `DeprecationWarning`. For example, `re.compile("\d+\.\d+")` now emits a `SyntaxWarning("\d" is an invalid escape sequence)`, use raw strings for regular expression: `re.compile(r"\d+\.\d+")`. In a future Python version, `SyntaxError` will eventually be raised, instead of `SyntaxWarning`. (Contributed by Victor Stinner in [gh-98401](#).)
- Octal escapes with value larger than `0o377` (ex: `"\477"`), deprecated in Python 3.11, now produce a `SyntaxWarning`, instead of `DeprecationWarning`. In a future Python version they will be eventually a `SyntaxError`. (Contributed by Victor Stinner in [gh-98401](#).)
- All builtin and extension callables expecting boolean parameters now accept arguments of any type instead of just `bool` and `int`. (Contributed by Serhiy Storchaka in [gh-60203](#).)
- Variables used in the target part of comprehensions that are not stored to can now be used in assignment expressions (`:=`). For example, in `[(b := 1) for a, b.prop in some_iter]`, the assignment to `b` is now allowed. Note that assigning to variables stored to in the target part of comprehensions (like `a`) is still disallowed, as per [PEP 572](#). (Contributed by Nikita Sobolev in [gh-100581](#).)
- `slice` objects are now hashable, allowing them to be used as dict keys and set items. (Contributed by Will Bradshaw and Furkan Onder in [gh-101264](#).)

5 New Modules

- None yet.

6 Improved Modules

6.1 array

- The `array.array` class now supports subscripting, making it a generic type. (Contributed by Jelle Zijlstra in [gh-98658](#).)

6.2 asyncio

- On Linux, asyncio uses `PidfdChildWatcher` by default if `os.pidfd_open()` is available and functional instead of `ThreadedChildWatcher`. (Contributed by Kumar Aditya in [gh-98024](#).)
- The child watcher classes `MultiLoopChildWatcher`, `FastChildWatcher`, `AbstractChildWatcher` and `SafeChildWatcher` are deprecated and will be removed in Python 3.14. It is recommended to not manually configure a child watcher as the event loop now uses the best available child watcher for each platform (`PidfdChildWatcher` if supported and `ThreadedChildWatcher` otherwise). (Contributed by Kumar Aditya in [gh-94597](#).)
- `asyncio.set_child_watcher()`, `asyncio.get_child_watcher()`, `asyncio.AbstractEventLoopPolicy.set_child_watcher()` and `asyncio.AbstractEventLoopPolicy.get_child_watcher()` are deprecated and will be removed in Python 3.14. (Contributed by Kumar Aditya in [gh-94597](#).)
- Add `loop_factory` parameter to `asyncio.run()` to allow specifying a custom event loop factory. (Contributed by Kumar Aditya in [gh-99388](#).)
- Add C implementation of `asyncio.current_task()` for 4x-6x speedup. (Contributed by Itamar Ostricher and Pranav Thulasiram Bhat in [gh-100344](#).)
- `asyncio.iscoroutine()` now returns `False` for generators as asyncio does not support legacy generator-based coroutines. (Contributed by Kumar Aditya in [gh-102748](#).)
- `asyncio.wait()` now accepts generators yielding tasks. (Contributed by Kumar Aditya in [gh-78530](#).)

6.3 inspect

- Add `inspect.markcoroutinefunction()` to mark sync functions that return a coroutine for use with `inspect.iscoroutinefunction()`. (Contributed Carlton Gibson in [gh-99247](#).)
- Add `inspect.getasyncgenstate()` and `inspect.getasyncgenlocals()` for determining the current state of asynchronous generators. (Contributed by Thomas Krennwallner in [bpo-35759](#).)

6.4 pathlib

- Add `walk()` for walking the directory trees and generating all file or directory names within them, similar to `os.walk()`. (Contributed by Stanislav Zmiev in [gh-90385](#).)
- Add `walk_up` optional parameter to `pathlib.PurePath.relative_to()` to allow the insertion of `..` entries in the result; this behavior is more consistent with `os.path.relpath()`. (Contributed by Domenico Ragusa in [bpo-40358](#).)
- Add `pathlib.Path.is_junction()` as a proxy to `os.path.isjunction()`. (Contributed by Charles Machalow in [gh-99547](#).)

6.5 dis

- Pseudo instruction opcodes (which are used by the compiler but do not appear in executable bytecode) are now exposed in the `dis` module. `HAVE_ARGUMENT` is still relevant to real opcodes, but it is not useful for pseudo instructions. Use the new `hasarg` collection instead. (Contributed by Irit Katriel in [gh-94216](#).)

6.6 fractions

- Objects of type `fractions.Fraction` now support float-style formatting. (Contributed by Mark Dickinson in [gh-100161](#).)

6.7 math

- Added `math.sumprod()` for computing a sum of products. (Contributed by Raymond Hettinger in [gh-100485](#).)

6.8 os

- Add `os.PIDFD_NONBLOCK` to open a file descriptor for a process with `os.pidfd_open()` in non-blocking mode. (Contributed by Kumar Aditya in [gh-93312](#).)
- `os.DirEntry` now includes an `os.DirEntry.is_junction()` method to check if the entry is a junction. (Contributed by Charles Machalow in [gh-99547](#).)
- Add `os.listdirives()`, `os.listvolumes()` and `os.listmounts()` functions on Windows for enumerating drives, volumes and mount points. (Contributed by Steve Dower in [gh-102519](#).)
- `os.stat()` and `os.lstat()` are now more accurate on Windows. The `st_birthtime` field will now be filled with the creation time of the file, and `st_ctime` is deprecated but still contains the creation time (but in the future will return the last metadata change, for consistency with other platforms). `st_dev` may be up to 64 bits and `st_ino` up to 128 bits depending on your file system, and `st_rdev` is always set to zero rather than incorrect values. Both functions may be significantly faster on newer releases of Windows. (Contributed by Steve Dower in [gh-99726](#).)

6.9 os.path

- Add `os.path.isjunction()` to check if a given path is a junction. (Contributed by Charles Machalow in [gh-99547](#).)
- Add `os.path.splitroot()` to split a path into a triad (`drive`, `root`, `tail`). (Contributed by Barney Gale in [gh-101000](#).)

6.10 shutil

- `shutil.make_archive()` now passes the `root_dir` argument to custom archivers which support it. In this case it no longer temporarily changes the current working directory of the process to `root_dir` to perform archiving. (Contributed by Serhiy Storchaka in [gh-74696](#).)
- `shutil.rmtree()` now accepts a new argument `onexc` which is an error handler like `onerror` but which expects an exception instance rather than a (`typ`, `val`, `tb`) triplet. `onerror` is deprecated and will be removed in Python 3.14. (Contributed by Irit Katriel in [gh-102828](#).)

6.11 sqlite3

- Add a command-line interface. (Contributed by Erlend E. Aasland in [gh-77617](#).)
- Add the `autocommit` attribute to `Connection` and the `autocommit` parameter to `connect()` to control [PEP 249](#)-compliant transaction handling. (Contributed by Erlend E. Aasland in [gh-83638](#).)

6.12 threading

- Add `threading.settrace_all_threads()` and `threading.setprofile_all_threads()` that allow to set tracing and profiling functions in all running threads in addition to the calling one. (Contributed by Pablo Galindo in [gh-93503](#).)

6.13 unicodedata

- The Unicode database has been updated to version 15.0.0. (Contributed by Benjamin Peterson in [gh-96734](#).)

6.14 unittest

Added `--durations` command line option, showing the N slowest test cases:

```
python3 -m unittest --durations=3 lib.tests.test_threading
.....
Slowest test durations
-----
1.210s      test_timeout (Lib.test.test_threading.BarrierTests)
1.003s      test_default_timeout (Lib.test.test_threading.BarrierTests)
0.518s      test_timeout (Lib.test.test_threading.EventTests)

(0.000 durations hidden.  Use -v to show these durations.)
-----
Ran 158 tests in 9.869s

OK (skipped=3)
```

(Contributed by Giampaolo Rodola in [bpo-4080](#))

6.15 uuid

- Add a command-line interface. (Contributed by Adam Chhina in [gh-88597](#).)

6.16 tempfile

The `tempfile.NamedTemporaryFile` function has a new optional parameter `delete_on_close` (Contributed by Evgeny Zorin in [gh-58451](#).)

6.17 typing

- Add `typing.override()`, an override decorator telling to static type checkers to verify that a method overrides some method or attribute of the same name on a base class, as per [PEP 698](#). (Contributed by Steven Troxler in [gh-101564](#).)
- `isinstance()` checks against runtime-checkable protocols now use `inspect.getattr_static()` rather than `hasattr()` to lookup whether attributes exist. This means that descriptors and `__getattr__()` methods are no longer unexpectedly evaluated during `isinstance()` checks against runtime-checkable protocols. However, it may also mean that some objects which used to be considered instances of a runtime-checkable protocol may no longer be considered instances of that protocol on Python 3.12+, and vice versa. Most users are unlikely to be affected by this change. (Contributed by Alex Waygood in [gh-102433](#).)

6.18 sys

- Add `sys.activate_stack_trampoline()` and `sys.deactivate_stack_trampoline()` for activating and deactivating stack profiler trampolines, and `sys.is_stack_trampoline_active()` for querying if stack profiler trampolines are active. (Contributed by Pablo Galindo and Christian Heimes with contributions from Gregory P. Smith [Google] and Mark Shannon in [gh-96123](#).)
- Add `sys.last_exc` which holds the last unhandled exception that was raised (for post-mortem debugging use cases). Deprecate the three fields that have the same information in its legacy form: `sys.last_type`, `sys.last_value` and `sys.last_traceback`. (Contributed by Irit Katriel in [gh-102778](#).)

7 Optimizations

- Removed `wstr` and `wstr_length` members from Unicode objects. It reduces object size by 8 or 16 bytes on 64bit platform. ([PEP 623](#)) (Contributed by Inada Naoki in [gh-92536](#).)
- Added experimental support for using the BOLT binary optimizer in the build process, which improves performance by 1-5%. (Contributed by Kevin Modzelewski in [gh-90536](#).)
- Speed up the regular expression substitution (functions `re.sub()` and `re.subn()` and corresponding `re.Pattern` methods) for replacement strings containing group references by 2–3 times. (Contributed by Serhiy Storchaka in [gh-91524](#).)

8 CPython bytecode changes

- Removed the `LOAD_METHOD` instruction. It has been merged into `LOAD_ATTR`. `LOAD_ATTR` will now behave like the old `LOAD_METHOD` instruction if the low bit of its `oparg` is set. (Contributed by Ken Jin in [gh-93429](#).)
- Removed the `JUMP_IF_FALSE_OR_POP` and `JUMP_IF_TRUE_OR_POP` instructions. (Contributed by Irit Katriel in [gh-102859](#).)

9 Demos and Tools

- Remove the `Tools/demo/` directory which contained old demo scripts. A copy can be found in the [old-demos project](#). (Contributed by Victor Stinner in [gh-97681](#).)
- Remove outdated example scripts of the `Tools/scripts/` directory. A copy can be found in the [old-demos project](#). (Contributed by Victor Stinner in [gh-97669](#).)

10 Deprecated

- `typing.Hashable` and `typing.Sized` aliases for `collections.abc.Hashable` and `collections.abc.Sized`. ([gh-94309](#).)
- The `sqlite3` default adapters and converters are now deprecated. Instead, use the `sqlite3-adapter-converter-recipes` and tailor them to your needs. (Contributed by Erlend E. Aasland in [gh-90016](#).)
- In `execute()`, `DeprecationWarning` is now emitted when named placeholders are used together with parameters supplied as a sequence instead of as a dict. Starting from Python 3.14, using named placeholders with parameters supplied as a sequence will raise a `ProgrammingError`. (Contributed by Erlend E. Aasland in [gh-101698](#).)
- The 3-arg signatures (`type`, `value`, `traceback`) of `throw()`, `throw()` and `athrow()` are deprecated and may be removed in a future version of Python. Use the single-arg versions of these functions instead. (Contributed by Ofey Chan in [gh-89874](#).)
- `DeprecationWarning` is now raised when `__package__` on a module differs from `__spec__.parent` (previously it was `ImportWarning`). (Contributed by Brett Cannon in [gh-65961](#).)
- The `get_event_loop()` method of the default event loop policy now emits a `DeprecationWarning` if there is no current event loop set and it decides to create one. (Contributed by Serhiy Storchaka and Guido van Rossum in [gh-100160](#).)
- The `xml.etree.ElementTree` module now emits `DeprecationWarning` when testing the truth value of an `xml.etree.ElementTree.Element`. Before, the Python implementation emitted `FutureWarning`, and the C implementation emitted nothing.
- In accordance with [PEP 699](#), the `ma_version_tag` field in `PyDictObject` is deprecated for extension modules. Accessing this field will generate a compiler warning at compile time. This field will be removed in Python 3.14. (Contributed by Ramvikrams and Kumar Aditya in [gh-101193](#). PEP by Ken Jin.)
- The `st_ctime` fields return by `os.stat()` and `os.lstat()` on Windows are deprecated. In a future release, they will contain the last metadata change time, consistent with other platforms. For now, they still contain the creation time, which is also available in the new `st_birthtime` field. (Contributed by Steve Dower in [gh-99726](#).)
- The `sys.last_type`, `sys.last_value` and `sys.last_traceback` fields are deprecated. Use `sys.last_exc` instead. (Contributed by Irit Katriel in [gh-102778](#).)
- The `onerror` argument of `shutil.rmtree()` is deprecated as will be removed in Python 3.14. Use `onexc` instead. (Contributed by Irit Katriel in [gh-102828](#).)

10.1 Pending Removal in Python 3.13

The following modules and APIs have been deprecated in earlier Python releases, and will be removed in Python 3.13.

Modules (see [PEP 594](#)):

- `aifc`
- `audioop`
- `cgi`
- `cgitb`
- `chunk`
- `crypt`
- `imghdr`
- `mailcap`
- `msilib`
- `nis`
- `nntplib`
- `ossaudiodev`
- `pipes`
- `sndhdr`
- `spwd`
- `sunau`
- `telnetlib`
- `uu`
- `xdrlib`

APIs:

- `configparser.LegacyInterpolation` ([gh-90765](#))
- `locale.getdefaultlocale()` ([gh-90817](#))
- `turtle.RawTurtle.settiltangle()` ([gh-50096](#))
- `unittest.findTestCases()` ([gh-50096](#))
- `unittest.makeSuite()` ([gh-50096](#))
- `unittest.getTestCaseNames()` ([gh-50096](#))
- `webbrowser.MacOSX` ([gh-86421](#))

10.2 Pending Removal in Python 3.14

- Deprecated the following `importlib.abc` classes, scheduled for removal in Python 3.14:

- `importlib.abc.ResourceReader`
- `importlib.abc.Traversable`
- `importlib.abc.TraversableResources`

Use `importlib.resources.abc` classes instead:

- `importlib.resources.abc.Traversable`
- `importlib.resources.abc.TraversableResources`

(Contributed by Jason R. Coombs and Hugo van Kemenade in [gh-93963](#).)

- Creating immutable types (`Py_TPFLAGS_IMMUTABLETYPE`) with mutable bases using the C API.
- Deprecated the `isdst` parameter in `email.utils.localtime()`. (Contributed by Alan Williams in [gh-72346](#).)
- `__package__` and `__cached__` will cease to be set or taken into consideration by the import system ([gh-97879](#)).
- Testing the truth value of an `xml.etree.ElementTree.Element` is deprecated and will raise an exception in Python 3.14.
- The default multiprocessing start method will change to a safer one on Linux, BSDs, and other non-macOS POSIX platforms where 'fork' is currently the default ([gh-84559](#)). Adding a runtime warning about this was deemed too disruptive as the majority of code is not expected to care. Use the `get_context()` or `set_start_method()` APIs to explicitly specify when your code *requires* 'fork'. See `multiprocessing-start-methods`.
- `pty` has two undocumented `master_open()` and `slave_open()` functions that have been deprecated since Python 2 but only gained a proper `DeprecationWarning` in 3.12. Remove them in 3.14.
- Accessing `co_lnotab` was deprecated in [PEP 626](#) since 3.10 and was planned to be removed in 3.12 but it only got a proper `DeprecationWarning` in 3.12. May be removed in 3.14. (Contributed by Nikita Sobolev in [gh-101866](#).)
- The `onerror` argument of `shutil.rmtree()` is deprecated in 3.12, and will be removed in 3.14.

10.3 Pending Removal in Future Versions

The following APIs were deprecated in earlier Python versions and will be removed, although there is currently no date scheduled for their removal.

- `typing.Text` ([gh-92332](#))
- Currently Python accepts numeric literals immediately followed by keywords, for example `0in x, 1or x, 0if 1else 2`. It allows confusing and ambiguous expressions like `[0x1for x in y]` (which can be interpreted as `[0x1 for x in y]` or `[0x1f or x in y]`). A syntax warning is raised if the numeric literal is immediately followed by one of keywords and, else, for, if, in, is and or. In a future release it will be changed to a syntax error. ([gh-87999](#))

11 Removed

- Remove the `distutils` package. It was deprecated in Python 3.10 by [PEP 632](#) “Deprecate `distutils` module”. For projects still using `distutils` and cannot be updated to something else, the `setuptools` project can be installed: it still provides `distutils`. (Contributed by Victor Stinner in [gh-92584](#).)
- Removed many old deprecated `unittest` features:
 - A number of `TestCase` method aliases:

Deprecated alias	Method Name	Deprecated in
<code>failUnless</code>	<code>assertTrue()</code>	3.1
<code>failIf</code>	<code>assertFalse()</code>	3.1
<code>failUnlessEqual</code>	<code>assertEqual()</code>	3.1
<code>failIfEqual</code>	<code>assertNotEqual()</code>	3.1
<code>failUnlessAlmostEqual</code>	<code>assertAlmostEqual()</code>	3.1
<code>failIfAlmostEqual</code>	<code>assertNotAlmostEqual()</code>	3.1
<code>failUnlessRaises</code>	<code>assertRaises()</code>	3.1
<code>assert_</code>	<code>assertTrue()</code>	3.2
<code>assertEquals</code>	<code>assertEqual()</code>	3.2
<code>assertNotEquals</code>	<code>assertNotEqual()</code>	3.2
<code>assertAlmostEquals</code>	<code>assertAlmostEqual()</code>	3.2
<code>assertNotAlmostEquals</code>	<code>assertNotAlmostEqual()</code>	3.2
<code>assertRegexpMatches</code>	<code>assertRegex()</code>	3.2
<code>assertRaisesRegexp</code>	<code>assertRaisesRegex()</code>	3.2
<code>assertNotRegexpMatches</code>	<code>assertNotRegex()</code>	3.5

You can use <https://github.com/isidentical/teyit> to automatically modernise your unit tests.

- Undocumented and broken `TestCase` method `assertDictContainsSubset` (deprecated in Python 3.2).
- Undocumented `TestLoader.loadTestsFromModule` parameter `use_load_tests` (deprecated and ignored since Python 3.2).
- An alias of the `TextTestResult` class: `_TextTestResult` (deprecated in Python 3.2).

(Contributed by Serhiy Storchaka in [bpo-45162](#).)

- Several names deprecated in the `configparser` way back in 3.2 have been removed per [gh-89336](#):
 - `configparser.ParsingError` no longer has a `filename` attribute or argument. Use the `source` attribute and argument instead.
 - `configparser` no longer has a `SafeConfigParser` class. Use the shorter `ConfigParser` name instead.
 - `configparser.ConfigParser` no longer has a `readfp` method. Use `read_file()` instead.
- The following undocumented `sqlite3` features, deprecated in Python 3.10, are now removed:
 - `sqlite3.enable_shared_cache()`
 - `sqlite3.OptimizedUnicode`

If a shared cache must be used, open the database in URI mode using the `cache=shared` query parameter.

The `sqlite3.OptimizedUnicode` text factory has been an alias for `str` since Python 3.3. Code that previously set the text factory to `OptimizedUnicode` can either use `str` explicitly, or rely on the default value which is also `str`.

(Contributed by Erlend E. Aasland in [gh-92548](#).)

- `smtpd` has been removed according to the schedule in [PEP 594](#), having been deprecated in Python 3.4.7 and 3.5.4. Use `aiosmtpd` PyPI module or any other `asyncio`-based server instead. (Contributed by Oleg Iarygin in [gh-93243](#).)
- `asynchat` and `asyncore` have been removed according to the schedule in [PEP 594](#), having been deprecated in Python 3.6. Use `asyncio` instead. (Contributed by Nikita Sobolev in [gh-96580](#).)
- Remove `io.OpenWrapper` and `_pyio.OpenWrapper`, deprecated in Python 3.10: just use `open()` instead. The `open()` (`io.open()`) function is a built-in function. Since Python 3.10, `_pyio.open()` is also a static method. (Contributed by Victor Stinner in [gh-94169](#).)
- Remove the `ssl.RAND_pseudo_bytes()` function, deprecated in Python 3.6: use `os.urandom()` or `ssl.RAND_bytes()` instead. (Contributed by Victor Stinner in [gh-94199](#).)
- `gzip`: Remove the `filename` attribute of `gzip.GzipFile`, deprecated since Python 2.6, use the `name` attribute instead. In write mode, the `filename` attribute added `'.gz'` file extension if it was not present. (Contributed by Victor Stinner in [gh-94196](#).)
- Remove the `ssl.match_hostname()` function. It was deprecated in Python 3.7. OpenSSL performs host-name matching since Python 3.7, Python no longer uses the `ssl.match_hostname()` function. (Contributed by Victor Stinner in [gh-94199](#).)
- Remove the `locale.format()` function, deprecated in Python 3.7: use `locale.format_string()` instead. (Contributed by Victor Stinner in [gh-94226](#).)
- `hashlib`: Remove the pure Python implementation of `hashlib.pbkdf2_hmac()`, deprecated in Python 3.10. Python 3.10 and newer requires OpenSSL 1.1.1 ([PEP 644](#)): this OpenSSL version provides a C implementation of `pbkdf2_hmac()` which is faster. (Contributed by Victor Stinner in [gh-94199](#).)
- `xml.etree.ElementTree`: Remove the `ElementTree.Element.copy()` method of the pure Python implementation, deprecated in Python 3.10, use the `copy.copy()` function instead. The C implementation of `xml.etree.ElementTree` has no `copy()` method, only a `__copy__()` method. (Contributed by Victor Stinner in [gh-94383](#).)
- `zipimport`: Remove `find_loader()` and `find_module()` methods, deprecated in Python 3.10: use the `find_spec()` method instead. See [PEP 451](#) for the rationale. (Contributed by Victor Stinner in [gh-94379](#).)
- Remove the `ssl.wrap_socket()` function, deprecated in Python 3.7: instead, create a `ssl.SSLContext` object and call its `ssl.SSLContext.wrap_socket` method. Any package that still uses `ssl.wrap_socket()` is broken and insecure. The function neither sends a SNI TLS extension nor validates server hostname. Code is subject to [CWE-295: Improper Certificate Validation](#). (Contributed by Victor Stinner in [gh-94199](#).)
- Many previously deprecated cleanups in `importlib` have now been completed:
 - References to, and support for `module_repr()` has been eradicated.
- `importlib.util.set_package` has been removed. (Contributed by Brett Cannon in [gh-65961](#).)
- Removed the `suspicious` rule from the documentation Makefile, and removed `Doc/tools/rstlint.py`, both in favor of [sphinx-lint](#). (Contributed by Julien Palard in [gh-98179](#).)
- Remove the `keyfile` and `certfile` parameters from the `ftplib`, `imaplib`, `poplib` and `smtplib` modules, and the `key_file`, `cert_file` and `check_hostname` parameters from the `http.client` module, all deprecated since Python 3.6. Use the `context` parameter (`ssl_context` in `imaplib`) instead. (Contributed by Victor Stinner in [gh-94172](#).)
- `ftplib`: Remove the `FTP_TLS.ssl_version` class attribute: use the `context` parameter instead. (Contributed by Victor Stinner in [gh-94172](#).)

- Remove support for obsolete browsers from `webbrowser`. Removed browsers include: Grail, Mosaic, Netscape, Galeon, Skipstone, Iceape, Firebird, and Firefox versions 35 and below ([gh-102871](#)).

12 Porting to Python 3.12

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

12.1 Changes in the Python API

- More strict rules are now applied for numerical group references and group names in regular expressions. Only sequence of ASCII digits is now accepted as a numerical reference. The group name in bytes patterns and replacement strings can now only contain ASCII letters and digits and underscore. (Contributed by Serhiy Storchaka in [gh-91760](#).)
- Removed `randrange()` functionality deprecated since Python 3.10. Formerly, `randrange(10.0)` losslessly converted to `randrange(10)`. Now, it raises a `TypeError`. Also, the exception raised for non-integral values such as `randrange(10.5)` or `randrange('10')` has been changed from `ValueError` to `TypeError`. This also prevents bugs where `randrange(1e25)` would silently select from a larger range than `randrange(10**25)`. (Originally suggested by Serhiy Storchaka [gh-86388](#).)
- `argparse.ArgumentParser` changed encoding and error handler for reading arguments from file (e.g. `fromfile_prefix_chars` option) from default text encoding (e.g. `locale.getpreferredencoding(False)`) to filesystem encoding and error handler. Argument files should be encoded in UTF-8 instead of ANSI Codepage on Windows.
- Removed the `asyncore`-based `smtpd` module deprecated in Python 3.4.7 and 3.5.4. A recommended replacement is the `asyncio`-based `aiosmtpd` PyPI module.
- `shlex.split()`: Passing `None` for `s` argument now raises an exception, rather than reading `sys.stdin`. The feature was deprecated in Python 3.9. (Contributed by Victor Stinner in [gh-94352](#).)
- The `os` module no longer accepts bytes-like paths, like `bytearray` and `memoryview` types: only the exact `bytes` type is accepted for bytes strings. (Contributed by Victor Stinner in [gh-98393](#).)
- `syslog.openlog()` and `syslog.closelog()` now fail if used in subinterpreters. `syslog.syslog()` may still be used in subinterpreters, but now only if `syslog.openlog()` has already been called in the main interpreter. These new restrictions do not apply to the main interpreter, so only a very small set of users might be affected. This change helps with interpreter isolation. Furthermore, `syslog` is a wrapper around process-global resources, which are best managed from the main interpreter. (Contributed by Dong-hee Na in [gh-99127](#).)
- The undocumented locking behavior of `cached_property()` is removed, because it locked across all instances of the class, leading to high lock contention. This means that a cached property getter function could now run more than once for a single instance, if two threads race. For most simple cached properties (e.g. those that are idempotent and simply calculate a value based on other attributes of the instance) this will be fine. If synchronization is needed, implement locking within the cached property getter function or around multi-threaded access points.

13 Build Changes

- Python no longer uses `setup.py` to build shared C extension modules. Build parameters like headers and libraries are detected in `configure` script. Extensions are built by `Makefile`. Most extensions use `pkg-config` and fall back to manual detection. (Contributed by Christian Heimes in [gh-93939](#).)
- `va_start()` with two parameters, like `va_start(args, format)`, is now required to build Python. `va_start()` is no longer called with a single parameter. (Contributed by Kumar Aditya in [gh-93207](#).)
- CPython now uses the ThinLTO option as the default link time optimization policy if the Clang compiler accepts the flag. (Contributed by Dong-hee Na in [gh-89536](#).)
- Add `COMPILEALL_OPTS` variable in `Makefile` to override `compileall` options (default: `-j0`) in `make install`. Also merged the 3 `compileall` commands into a single command to build `.pyc` files for all optimization levels (0, 1, 2) at once. (Contributed by Victor Stinner in [gh-99289](#).)

14 C API Changes

14.1 New Features

- **PEP 697**: Introduced the Unstable C API tier, intended for low-level tools like debuggers and JIT compilers. This API may change in each minor release of CPython without deprecation warnings. Its contents are marked by the `PyUnstable_` prefix in names.

Code object constructors:

- `PyUnstable_Code_New()` (renamed from `PyCode_New`)
- `PyUnstable_Code_NewWithPosOnlyArgs()` (renamed from `PyCode_NewWithPosOnlyArgs`)

Extra storage for code objects (**PEP 523**):

- `PyUnstable_Eval_RequestCodeExtraIndex()` (renamed from `_PyEval_RequestCodeExtraIndex`)
- `PyUnstable_Code_GetExtra()` (renamed from `_PyCode_GetExtra`)
- `PyUnstable_Code_SetExtra()` (renamed from `_PyCode_SetExtra`)

The original names will continue to be available until the respective API changes.

(Contributed by Petr Viktorin in [gh-101101](#).)

- Added the new limited C API function `PyType_FromMetaclass()`, which generalizes the existing `PyType_FromModuleAndSpec()` using an additional metaclass argument. (Contributed by Wenzel Jakob in [gh-93012](#).)
- API for creating objects that can be called using the vectorcall protocol was added to the Limited API:
 - `Py_TPFLAGS_HAVE_VECTORCALL`
 - `PyVectorcall_NARGS()`
 - `PyVectorcall_Call()`
 - `vectorcallfunc`

The `Py_TPFLAGS_HAVE_VECTORCALL` flag is now removed from a class when the class's `__call__()` method is reassigned. This makes vectorcall safe to use with mutable types (i.e. heap types without the immutable flag, `Py_TPFLAGS_IMMUTABLETYPE`). Mutable types that do not override `tp_call` now inherit the `Py_TPFLAGS_HAVE_VECTORCALL` flag. (Contributed by Petr Viktorin in [gh-93274](#).)

The `Py_TPFLAGS_MANAGED_DICT` and `Py_TPFLAGS_MANAGED_WEAKREF` flags have been added. This allows extension classes to support object `__dict__` and weakrefs with less bookkeeping, using less memory and with faster access.

- API for performing calls using the vectorcall protocol was added to the Limited API:

- `PyObject_Vectorcall()`
 - `PyObject_VectorcallMethod()`
 - `Py_VECTORCALL_ARGUMENTS_OFFSET`

This means that both the incoming and outgoing ends of the vector call protocol are now available in the Limited API. (Contributed by Wenzel Jakob in [gh-98586](#).)

- Added two new public functions, `PyEval_SetProfileAllThreads()` and `PyEval_SetTraceAllThreads()`, that allow to set tracing and profiling functions in all running threads in addition to the calling one. (Contributed by Pablo Galindo in [gh-93503](#).)
- Added new function `PyFunction_SetVectorcall()` to the C API which sets the vectorcall field of a given `PyFunctionObject`. (Contributed by Andrew Frost in [gh-92257](#).)
- The C API now permits registering callbacks via `PyDict_AddWatcher()`, `PyDict_Watch()` and related APIs to be called whenever a dictionary is modified. This is intended for use by optimizing interpreters, JIT compilers, or debuggers. (Contributed by Carl Meyer in [gh-91052](#).)
- Added `PyType_AddWatcher()` and `PyType_Watch()` API to register callbacks to receive notification on changes to a type. (Contributed by Carl Meyer in [gh-91051](#).)
- Added `PyCode_AddWatcher()` and `PyCode_ClearWatcher()` APIs to register callbacks to receive notification on creation and destruction of code objects. (Contributed by Itamar Ostricher in [gh-91054](#).)
- Add `PyFrame_GetVar()` and `PyFrame_GetVarString()` functions to get a frame variable by its name. (Contributed by Victor Stinner in [gh-91248](#).)
- Add `PyErr_GetRaisedException()` and `PyErr_SetRaisedException()` for saving and restoring the current exception. These functions return and accept a single exception object, rather than the triple arguments of the now-deprecated `PyErr_Fetch()` and `PyErr_Restore()`. This is less error prone and a bit more efficient. (Contributed by Mark Shannon in [gh-101578](#).)
- Add `_PyErr_ChainExceptions1`, which takes an exception instance, to replace the legacy-API `_PyErr_ChainExceptions`, which is now deprecated. (Contributed by Mark Shannon in [gh-101578](#).)
- Add `PyException_GetArgs()` and `PyException_SetArgs()` as convenience functions for retrieving and modifying the `args` passed to the exception's constructor. (Contributed by Mark Shannon in [gh-101578](#).)
- Add `PyErr_DisplayException()`, which takes an exception instance, to replace the legacy-api `PyErr_Display()`. (Contributed by Irit Katriel in [gh-102755](#).)

14.2 Porting to Python 3.12

- Legacy Unicode APIs based on `Py_UNICODE*` representation has been removed. Please migrate to APIs based on UTF-8 or `wchar_t*`.
- Argument parsing functions like `PyArg_ParseTuple()` doesn't support `Py_UNICODE*` based format (e.g. `u`, `Z`) anymore. Please migrate to other formats for Unicode like `s`, `z`, `es`, and `U`.
- `tp_weaklist` for all static builtin types is always `NULL`. This is an internal-only field on `PyTypeObject` but we're pointing out the change in case someone happens to be accessing the field directly anyway. To avoid breakage, consider using the existing public C-API instead, or, if necessary, the (internal-only) `_PyObject_GET_WEAKREFS_LISTPTR()` macro.

- This internal-only `PyObject.tp_subclasses` may now not be a valid object pointer. Its type was changed to `void*` to reflect this. We mention this in case someone happens to be accessing the internal-only field directly.

To get a list of subclasses, call the Python method `__subclasses__()` (using `PyObject_CallMethod()`, for example).

- An unrecognized format character in `PyUnicode_FromFormat()` and `PyUnicode_FromFormatV()` now sets a `SystemError`. In previous versions it caused all the rest of the format string to be copied as-is to the result string, and any extra arguments discarded. (Contributed by Serhiy Storchaka in [gh-95781](#).)
- Fixed wrong sign placement in `PyUnicode_FromFormat()` and `PyUnicode_FromFormatV()`. (Contributed by Philip Georgi in [gh-95504](#).)
- Extension classes wanting to add a `__dict__` or weak reference slot should use `Py_TPFLAGS_MANAGED_DICT` and `Py_TPFLAGS_MANAGED_WEAKREF` instead of `tp_dictoffset` and `tp_weaklistoffset`, respectively. The use of `tp_dictoffset` and `tp_weaklistoffset` is still supported, but does not fully support multiple inheritance ([gh-95589](#)), and performance may be worse. Classes declaring `Py_TPFLAGS_MANAGED_DICT` should call `_PyObject_VisitManagedDict()` and `_PyObject_ClearManagedDict()` to traverse and clear their instance's dictionaries. To clear weakrefs, call `PyObject_ClearWeakRefs()`, as before.
- The `PyUnicode_FSDecoder()` function no longer accepts bytes-like paths, like `bytearray` and `memoryview` types: only the exact `bytes` type is accepted for bytes strings. (Contributed by Victor Stinner in [gh-98393](#).)
- The `Py_CLEAR`, `Py_SETREF` and `Py_XSETREF` macros now only evaluate their arguments once. If an argument has side effects, these side effects are no longer duplicated. (Contributed by Victor Stinner in [gh-98724](#).)
- The interpreter's error indicator is now always normalized. This means that `PyErr_SetObject()`, `PyErr_SetString()` and the other functions that set the error indicator now normalize the exception before storing it. (Contributed by Mark Shannon in [gh-101578](#).)
- `_Py_RefTotal` is no longer authoritative and only kept around for ABI compability. Note that it is an internal global and only available on debug builds. If you happen to be using it then you'll need to start using `_Py_GetGlobalRefTotal()`.

14.3 Deprecated

- Deprecate global configuration variable:
 - `Py_DebugFlag`: use `PyConfig.parser_debug`
 - `Py_VerboseFlag`: use `PyConfig.verbose`
 - `Py_QuietFlag`: use `PyConfig.quiet`
 - `Py_InteractiveFlag`: use `PyConfig.interactive`
 - `Py_InspectFlag`: use `PyConfig.inspect`
 - `Py_OptimizeFlag`: use `PyConfig.optimization_level`
 - `Py_NoSiteFlag`: use `PyConfig.site_import`
 - `Py_BytesWarningFlag`: use `PyConfig.bytes_warning`
 - `Py_FrozenFlag`: use `PyConfig.pathconfig_warnings`
 - `Py_IgnoreEnvironmentFlag`: use `PyConfig.use_environment`
 - `Py_DontWriteBytecodeFlag`: use `PyConfig.write_bytecode`

- `Py_NoUserSiteDirectory`: use `PyConfig.user_site_directory`
- `Py_UnbufferedStdioFlag`: use `PyConfig.buffered_stdio`
- `Py_HashRandomizationFlag`: use `PyConfig.use_hash_seed` and `PyConfig.hash_seed`
- `Py_IsolatedFlag`: use `PyConfig.isolated`
- `Py_LegacyWindowsFSEncodingFlag`: use `PyPreConfig.legacy_windows_fs_encoding`
- `Py_LegacyWindowsStdioFlag`: use `PyConfig.legacy_windows_stdio`
- `Py_FileSystemDefaultEncoding`: use `PyConfig.filesystem_encoding`
- `Py_FileSystemDefaultEncodeErrors`: use `PyConfig.filesystem_errors`
- `Py_UTF8Mode`: use `PyPreConfig.utf8_mode` (see `Py_PreInitialize()`)

The `Py_InitializeFromConfig()` API should be used with `PyConfig` instead. (Contributed by Victor Stinner in [gh-77782](#).)

- Creating immutable types (`Py_TPFLAGS_IMMUTABLETYPE`) with mutable bases is deprecated and will be disabled in Python 3.14.
- The `structmember.h` header is deprecated, though it continues to be available and there are no plans to remove it.

Its contents are now available just by including `Python.h`, with a `Py` prefix added if it was missing:

- `PyMemberDef`, `PyMember_GetOne()` and `PyMember_SetOne()`
- Type macros like `Py_T_INT`, `Py_T_DOUBLE`, etc. (previously `T_INT`, `T_DOUBLE`, etc.)
- The flags `Py_READONLY` (previously `READONLY`) and `Py_AUDIT_READ` (previously all uppercase)

Several items are not exposed from `Python.h`:

- `T_OBJECT` (use `Py_T_OBJECT_EX`)
- `T_NONE` (previously undocumented, and pretty quirky)
- The macro `WRITE_RESTRICTED` which does nothing.
- The macros `RESTRICTED` and `READ_RESTRICTED`, equivalents of `Py_AUDIT_READ`.
- In some configurations, `<stddef.h>` is not included from `Python.h`. It should be included manually when using `offsetof()`.

The deprecated header continues to provide its original contents under the original names. Your old code can stay unchanged, unless the extra include and non-namespaced macros bother you greatly.

(Contributed in [gh-47146](#) by Petr Viktorin, based on earlier work by Alexander Belopolsky and Matthias Braun.)

- `PyErr_Fetch()` and `PyErr_Restore()` are deprecated. Use `PyErr_GetRaisedException()` and `PyErr_SetRaisedException()` instead. (Contributed by Mark Shannon in [gh-101578](#).)
- `PyErr_Display()` is deprecated. Use `PyErr_DisplayException()` instead. (Contributed by Irit Katriel in [gh-102755](#)).
- `_PyErr_ChainExceptions` is deprecated. Use `_PyErr_ChainExceptions1` instead. (Contributed by Irit Katriel in [gh-102192](#).)

14.4 Removed

- Remove the `token.h` header file. There was never any public tokenizer C API. The `token.h` header file was only designed to be used by Python internals. (Contributed by Victor Stinner in [gh-92651](#).)
- Legacy Unicode APIs have been removed. See [PEP 623](#) for detail.
 - `PyUnicode_WCHAR_KIND`
 - `PyUnicode_AS_UNICODE()`
 - `PyUnicode_AsUnicode()`
 - `PyUnicode_AsUnicodeAndSize()`
 - `PyUnicode_AS_DATA()`
 - `PyUnicode_FromUnicode()`
 - `PyUnicode_GET_SIZE()`
 - `PyUnicode_GetSize()`
 - `PyUnicode_GET_DATA_SIZE()`
- Remove the `PyUnicode_InternImmortal()` function and the `SSTATE_INTERNEDED_IMMORTAL` macro. (Contributed by Victor Stinner in [gh-85858](#).)
- Remove Jython compatibility hacks from several stdlib modules and tests. (Contributed by Nikita Sobolev in [gh-99482](#).)
- Remove `_use_broken_old_ctypes_structure_semantics_` flag from `ctypes` module. (Contributed by Nikita Sobolev in [gh-99285](#).)

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