
Python
C API
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In Python, there is something called the “C API”...


Past

Break API at each release

- 3.8: Remove `PyTypeObject.tp_print`
- 3.10: Remove `PyObject_AsWriteBuffer()`
- 3.11: Remove `PyFrameObject` members
- etc.

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ABI issues

- #73323: fpectl module
  Module removed in Python 3.7
- #83780: PyGC_Head in Python 3.7.5
  Structure made internal in Python 3.9
- 3.8: Debug & release builds compatible
  Py_TRACE_REFS off by default
- 3.12: Immortal objects (PEP 683): refcount
  Py_INCREF() opaque in limited API 3.12

Delay after Python releases

Python 3.12 alpha1 (Oct 24, 2022)

- Cython: **7 months** (May, 24)
- numpy: **10 months** & 3 weeks (Sep, 16)
- cffi: **11 months** (Sep, 28)

Python 3.12 rc1: August, 1
Python 3.12.0 final: October, 2

Ship many Python versions

- RHEL 8 (2019-2029+) uses Python 3.6
- Python 3.6 (2016-2021)
- 2022: Black, psycopg3, TensorFlow, Plone, ... dropped Python 3.6 support
- Python 2.7, 3.6, 3.8, 3.9, 3.11 (5 versions)
- Fedora 38: Python 2.7, 3.6-3.12 (8 versions)
- RHEL: one numpy package per Python version (4 packages)
- Security vulnerabilities...

❤️ Stable ABI ❤️

- Added to Python 3.2 (2011)
- Used by 550+ PyPI packages
- cryptography, PySide, PyO3 (Rust), vim, …
- WIP: nanobind (C++), pybind11 fork
- One package per {OS+libc, arch}:
  `manylinux2_aarch64`
  `musllinux_x86_64` (Alpine Linux)
  `win32`
  `macosx-universal2`

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C API Statistics

- 37 000 lines
- 227 header files
- 941 public exported functions

`https://pythoncapi.readthedocs.io/stats.html`

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Present

Complete Limited C API

Python 3.11 adds:

- `Py_buffer`

Python 3.12 adds:

- `PyType_FromMetaclass()`
- `PyVectorcall_Call()`
- PEP 697: Extending Opaque Types

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Test Limited C API

- Python 3.10: add `Misc/stable_abi.txt` and build `xxlimited` with `Py_LIMITED_API`
- Python 3.11: add `test_stable_abi_ctypes`
- Python 3.12: add heap types relative and vectorcall tests
- Python 3.13: add Argument Clinic tests

Remove private funcs

- Move 300 private functions to the internal C API:

  `Include/cpython/` → `Include/internal/`

- No longer exported
- Exported: 385 (3.12) → 85 (main)
- Public API requires doc and tests
- Add `PyLong_AsInt()` and `Py_IsFinalizing()`

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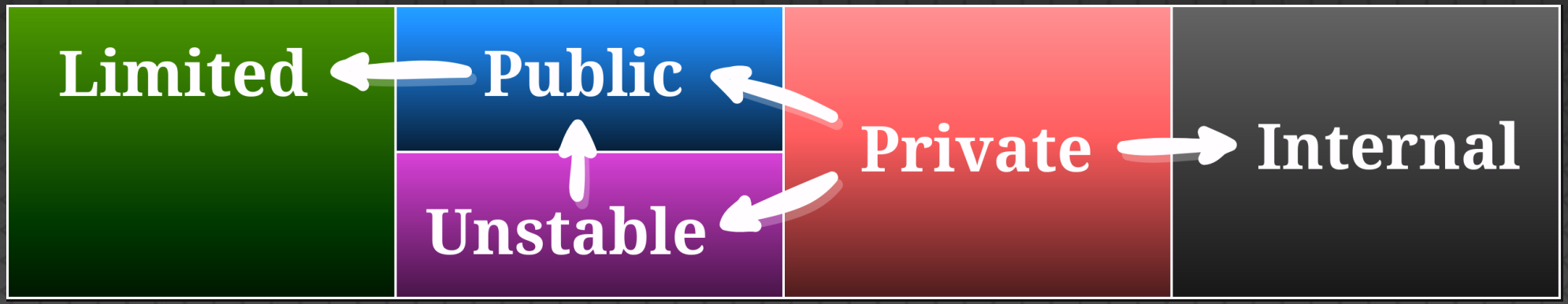
Remove private funcs



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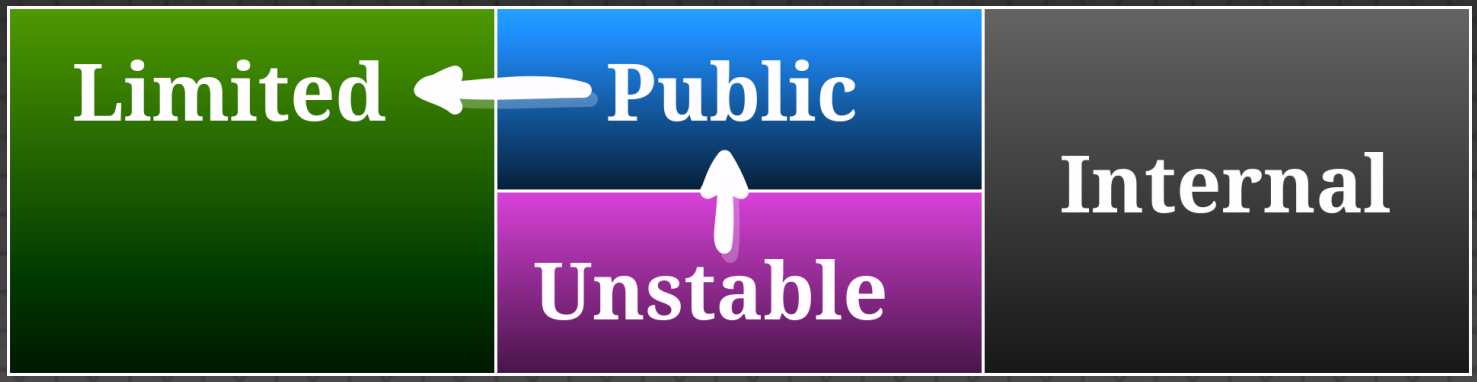
Remove private funcs



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Stdlib issues

- FIXED (3.10): Limited API incompatible with debug build
- FIXED (3.12): Missing PyMemberDef
- Mostly FIXED (3.12): static types
- WIP: Performance: vectorcall, Argument Clinic

Modernize Stdlib ext

- Work done in Python 3.9 – 3.12 (4 releases)
- Static types: 22% (59/226)
  Heap types: 78% (207/266)
- Legacy init API: 15% (21/141)
  Multi-phase init: 85% (120/141) PEP 489
- 5/363 C files (tests) use `Py_LIMITED_API`

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Fix the C API

- Add new APIs fixing known issues:
  `PyWeakref_GetRef()`: borrowed ref
  `PyDict_GetItemRef()`: error checking
- Add to pythoncapi-compat
- Deprecate old API
- Help affected projects (report issue, fix)
- If needed, keep old API longer
- Remove old API

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No Python 4 needed

- New API usable on old Python with pythoncapi-compat
- Updated code works on old and new Python
- Limitation: new features not available on old Python
  3.8: Vectorcall
  3.12: `PyType_FromMetaclass()`

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No Python 4 needed

- Spread API changes over multiple Python versions
- Limit changes per release: give time to 3rd party code to update
- Tooling and good doc help
- Code search to list affected projects: `search_pypi_top.py`
- Tool for text replace: `upgrade_pythoncapi.py`

No Python 4 needed

- **Incremental** approach: **adapt speed** depending on feedback
- **Revert** if maintainers **need more time**
- `Py_TYPE()` change took **3 years**: May 2020-October 2022
- It takes **months** to get a Cython/numpy release, longer for other projects
- C extensions maintainers **burnout**

Guidelines

- Don't return borrowed references (NoGIL)
- Design with stable ABI in mind
- `PyDict_GetItemRef(dict, key, &value)`
  - `-1`: error
  - `0`: not found
  - `1`: found

  No need to check for **`PyErr_Occurred()`**

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Opaque Structures

- Add `getter` and `setter` functions
- DONE: **`PyInterpreterState`** (3.8) and **`PyGC_Head`** (3.9) conversions were fine
- DONE: **`PyFrameObject`** (3.11) conversion was more tricky
- TODO: Remove **`PyThreadState`** and **`PyCodeObject`** members from public API


Future

Stdlib uses limited API

- If no performance impact
- If not using the internal C API
- **Better tests** than xxlimited: more realistic code with existing tests
- **Candidates**: _bisect, _scproxy, _stat, _testmultiphase, _uuid, fcntl, grp, pwd, resource, syslog
- Perf impact: **_statistics** (1.8x slower).
  It can be fixed!

Stable ABI by default

- When? **Now!**
- How? Change **setuptools**?
- Who? Me?
- Need an easy way to **opt-out**

Cython uses limited API

- Experimental build mode
- Enable it by default?

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HPy

- Common goal: move away from implementation details
- Different implementation
- HPy also takes PyPy in account
- TODO: make `PyObject*` opaque to converge to a similar API, but HPy has an additional `ctx` parameter

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C extensions on day 1

C extensions built with stable ABI become available on day 1 of Python 3.13 alpha 1

Instead of having to wait for 1 year for Python 3.13 final, if not longer

Less friction

- More freedom to change C structures
- More freedom to change internals
- Less friction between core devs "breaking things" and users
- “It just works™”
- Past examples:
  `PyGC_Head` and **`PyInterpreterState`**
  `Py_INCREF``()/DECREF()` as functions

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Working Group

- Steering Council wants to delegate
- So far, responsibilities were unclear
- Governance to make sure that decisions can be taken in a timely manner
- PEP: C API Known Issues
- PEP: Guidelines for C API additions
- PEP: C API Roadmap: next 5 years


Take
away

Continue good trend

- Fix API issues one by one, “slowly”
- Revert before final release if needed
- Work even closer with C API consumers: Cython, pybind11, HPy, PyO3, etc.
- Better documentation and tests
- Better migration tools
- Help projects to embrace the stable ABI

Actions

- Create a **concrete** C API **working group**
- Define **guidelines** for new APIs
- Convert some private functions to **public**
- **Complete** limited C API
- Use limited API in some **stdlib extensions**
- Consider using limited C API by **default**
- `PyCodeObject` and `PyThreadState`
- Consider making `PyObject*` opaque

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Let's talk!

Sources

- Drawing by **Djamila Knopf**
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