Computer Systems Modeling & Verification

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Evaluation Modalities

- **attendance and participation** (50% of the final grade)
  - **class attendance** is required: any absence must be justified (before the session if possible, after otherwise)
  - **active participation in lessons** is part of the evaluation

- **on-paper exam** (50% of the final grade)

- **remedial exam** (beware: only for the "on-paper exam" part)

Course content

Computer Systems Modeling & Verification

- **Computer System**: hardware and software components
- **Modeling**
  - *Specification*: requires some mathematical formalism
- **Verification**
  - *Properties*: requires a logic to check or prove them

Course content – details

Computer Systems Modeling & Verification

- **Computer System**: hardware and software components
- **Modeling**
  - *Specification*: requires some mathematical formalism
    Axiomatic systems (non executable)
    Equational systems (pure functional programs)
    Deductive systems (pure logic programs)
- **Verification**
  - *Properties*: requires a method to check or prove them
    Static: from type checking to program proving
    Dynamic: from classical unit testing to property-based testing

Course content – outline

- **Preliminaries**
  - imperative programming and unit testing
  - functional programming and logic
- **Part I: static verification (static analysis)**
  - typing rules as a deductive system
  - mode-based extraction of a functional type-checker
- **Part II: dynamic verification (testing)**
  - test coverage
  - design-by-contract
  - self-testing and property-based testing

Course organization

- **Lectures, Tutorials and Practicals**
  (slides and assignments available on Moodle)

- **Prototypes** written in **Python**[1]

  Why Python?

  - not the best programming language, but...
  - one of the most popular language today
  - and also used in several courses in M2

1. up to last year, we used OCaml and Ada

Prototypes

- a type-checker for mini-python[2]
- a transpiler from mini-python to a C-like language
- an interpreter for mini-python
- a test coverage framework for mini-python
- a property-based testing framework for mini-python

2. only a small fragment of the full python syntax

Python

What is Python?

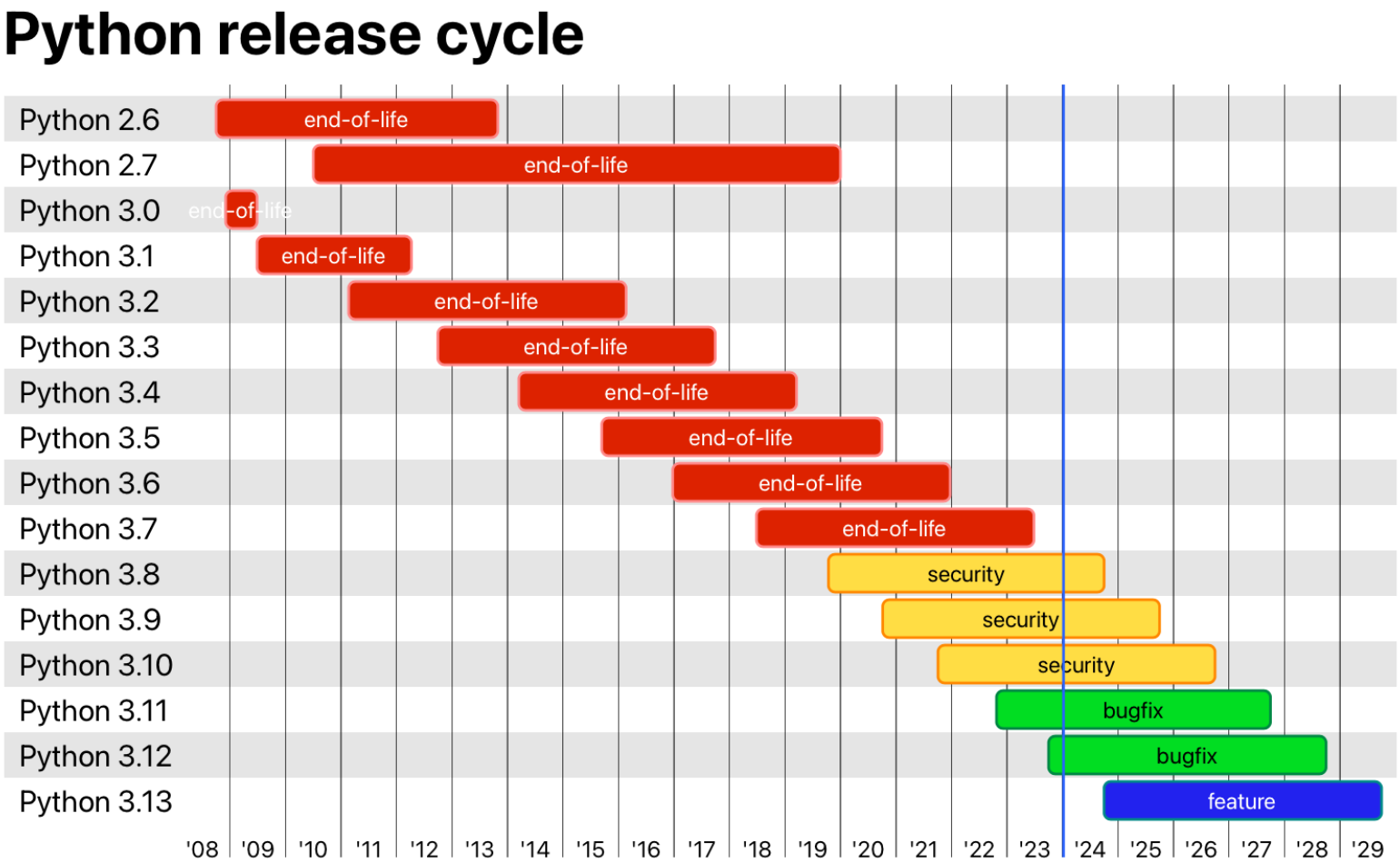
- high level programming language
- bytecode compiler, bytecode interpreted by default
  (but optimizing compilers are available)
- supports three main programming styles
  (imperative, functional, object-oriented)
- General purpose tool (yet also good for specialized work with extension libraries)

Availability

- Python is free (and open source)
- Python is platform independent (works on Windows, Linux/Unix, Mac OS, ...)

Status of Python Versions

https://devguide.python.org/versions



What's New in Python?

- https://peps.python.org/pep-0484
  (Type Hints - 2014)
- https://peps.python.org/pep-0526
  (Syntax for Variable Annotations - 2016)
- https://peps.python.org/pep-0589
  (TypedDict - 2019)
- https://docs.python.org/3/whatsnew/3.10.html
  (PEP 634: Structural Pattern Matching)
- https://docs.python.org/3.12/whatsnew/3.12.html
  (PEP 695: Type Parameter Syntax)

Python: a modern programming language?

	Java	(Java/Type)Script	Python
records	Y (java 17) [2021]	Y	Y (dataclasses)
pattern matching	Y (java 21) [2023]	Y (partial)	Y (3.10) [2021]
exceptions	Y	Y	Y
object-oriented	Y	Y	Y
functional programming	Y (java 8) [2014]	Y	Y
static type checking	Y	N/Y (gradual)	Y (gradual) [2014]
proper generics	Y (java 5) [2009]	Y	Y (3.12) [2023]

In this course:

- only **modern python** with **type hints** – including **generics** (3.12)
- mostly **functional programming** with **pattern matching**

Python environment

A standard python installation comes with CPython:

- an interpreter (a bytecode compiler & a VM that runs for the bytecode)
- the interpreter can also be used interactively
  REPL: Read Eval Print Loop

Remarks

- There is no explicit compilation step (the compilation step is hidden).
- Type hints are ignored by (the bytecode compiler and) the interpreter.

```
>>> x: int = "ok"
>>> type(x)
<class 'str'>
```

Type Hints

Static type checkers

- **Mypy** (reference implementation)
  - https://mypy.readthedocs.io/en/stable/index.html (mypy documentation)
  - https://mypy.readthedocs.io/en/stable/cheat_sheet_py3.html (Type hints cheat sheet)
  - https://mypy.readthedocs.io/en/stable/builtin_types.html (Built-in types)
- **Pyright** (included in the recommended VS Code extension)
  - https://github.com/microsoft/pyright
- **Pytype** (google), **Pyre** (facebook), ...

Support materials

- Material from the course *Python for Computational Science*[3]
  Beware: no type hints in this course
- *Introduction to Python for Computational Science and Engineering* Textbook (2022)
- *Python for Computational Science*
  Lecture slides (2024)

3. *Python for Computational Science*, Hans Fangohr et al. University of Southampton

Python documentation

Official Python documentation:

- Python documentation page
- Python Standard Library
- Python tutorial
- Python Package Index (pip repository)

Online documentation about types, for example:

- Mypy documentation
- Type hints cheat sheet
- Built-in types
- Pyright

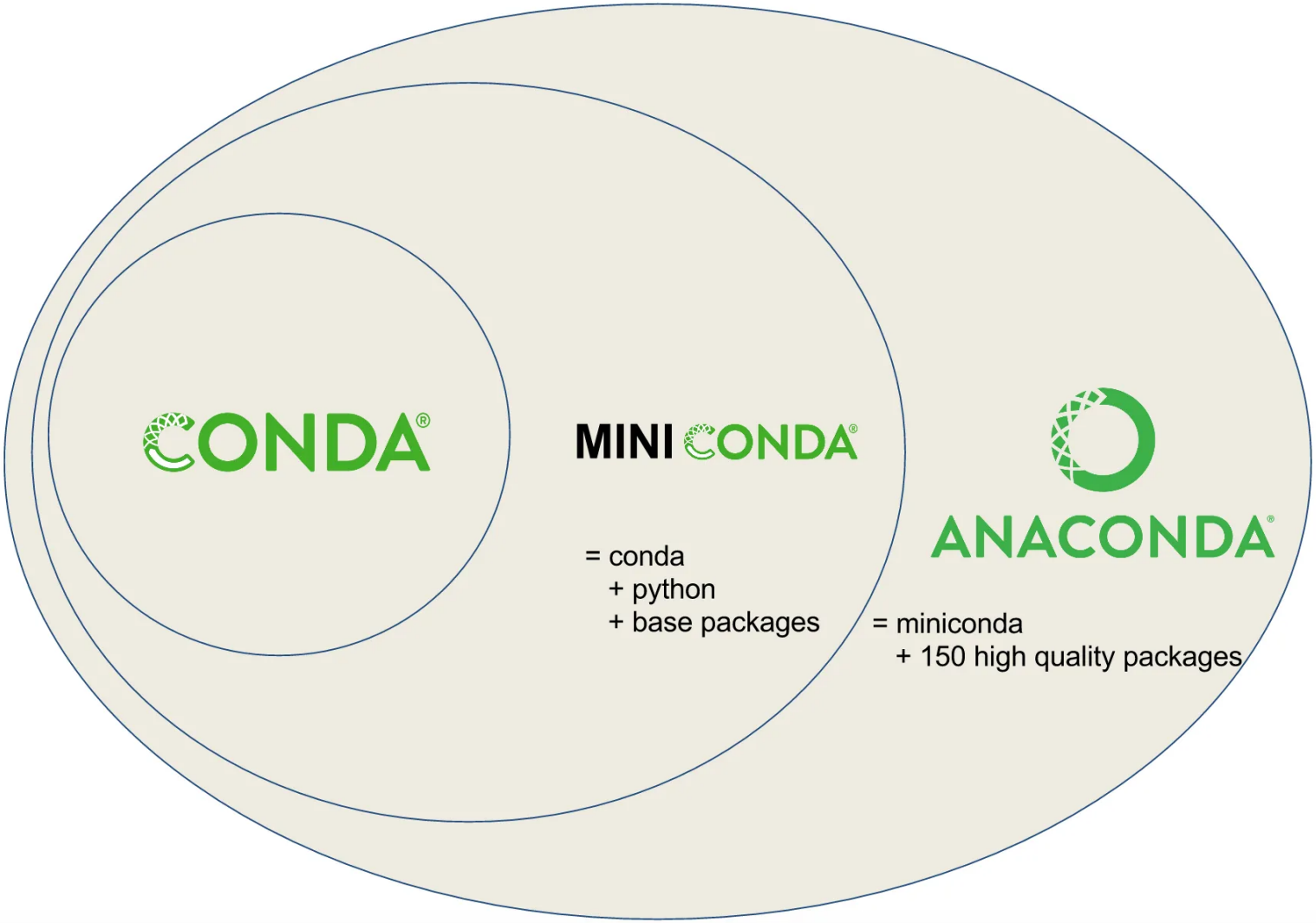
Installation of Python

Several options

- System's package manager (admin rights required)
- Official python binary installer (admin rights required)
  https://www.python.org/downloads
- Anaconda (popular distribution for data scientists)
  https://www.anaconda.com/download
- Miniconda (minimal anaconda distribution)
  https://docs.conda.io/en/main/miniconda.html

Note. Anaconda (or miniconda) allows you to install different versions of python and to switch easily between them (and admin rights are not required).

Conda package manager



Configuration of Python for CSMV (optional)

Using either anaconda or miniconda

Create a new conda environment for CSMV (with the default python version):

In the terminal, type

```
conda create -n CSMV
```

You can then then switch between versions using

```
conda activate CSMV
```

or

```
conda activate base
```

Note. In VS Code, you need to select the interpreter (and then "activation" is automatic in the integrated terminal).

Installing packages

Using conda or pip (official package manager)

In the terminal, type

```
conda install some-package
```

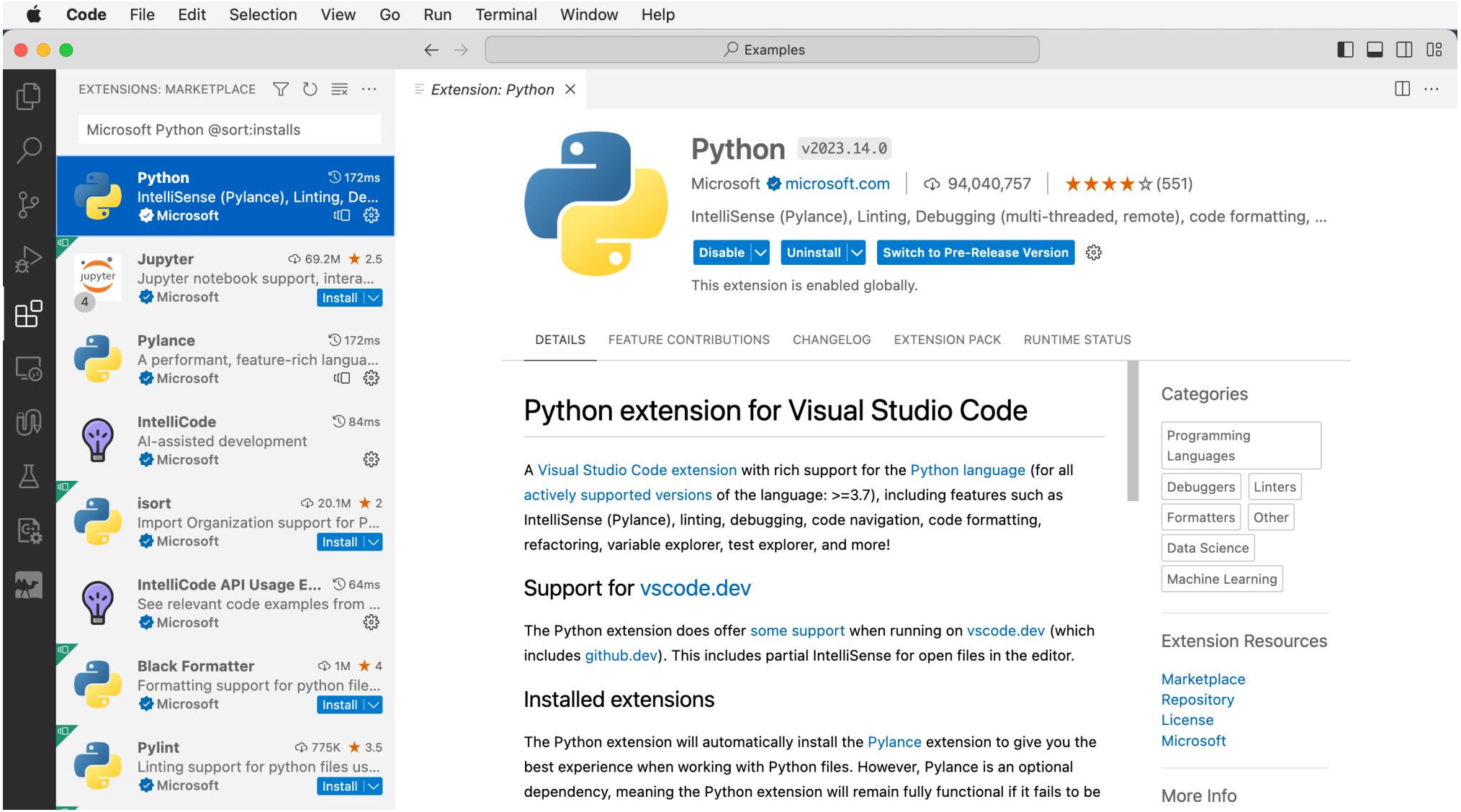
or

```
pip install some-package
```

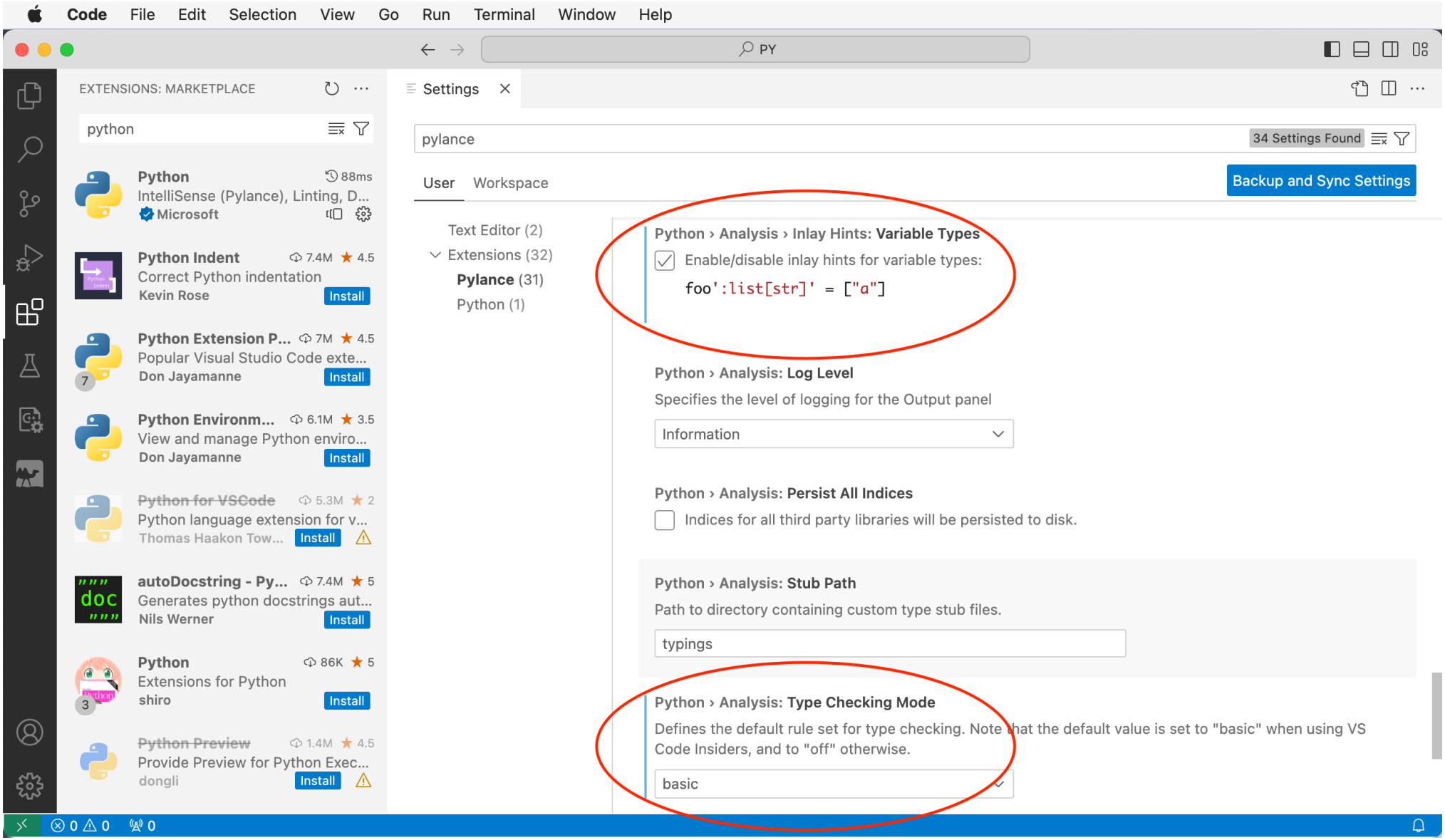
Note. You should avoid mixing both kind of packages. However, if you need to, you should install conda packages first, and then pip packages[4].

4. https://www.anaconda.com/blog/using-pip-in-a-conda-environment

Installing Python extension for VS Code



Configuration of Python extension



Installation of autopep8 extension