Basic Python

ML4HEP 2026 Pre-school Lectures

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Lecture 1, 11/05/2026

Course Outline

- Python in a Nutshell
- Python interactive
- Basic data types
- Variable scope / global vs local scope
- Type system & conversion
- Control flow, loop
- Basic I/O

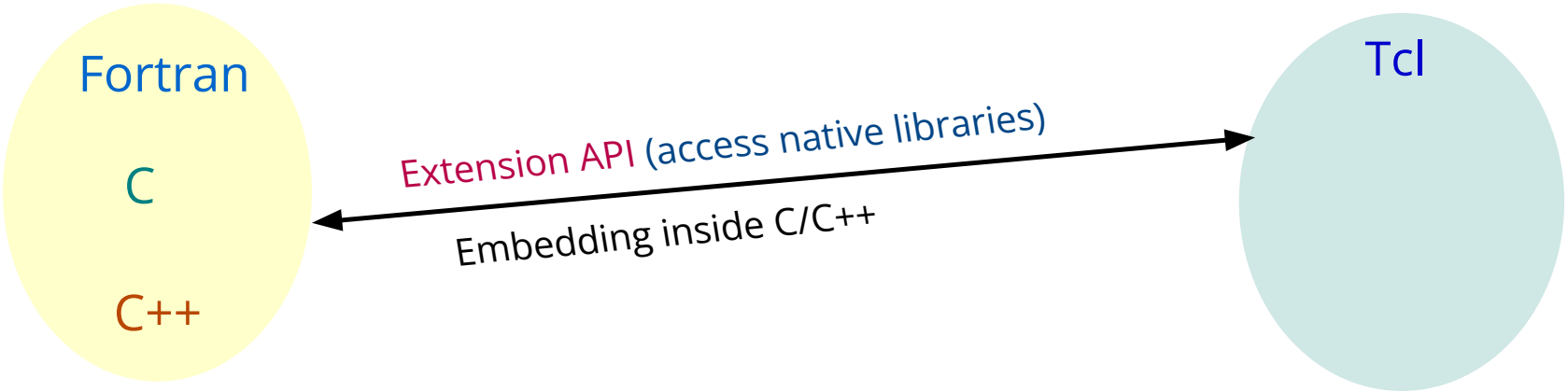
Python's place in the computing world

Programming Languages in the Scientific World

Compiled

Byte Compiled
(partly compiled + interpreted)

Interpreted



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- fast
- source level portability

- dynamic type
- portable
- relatively slow
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- interface to C/C++/Fortran

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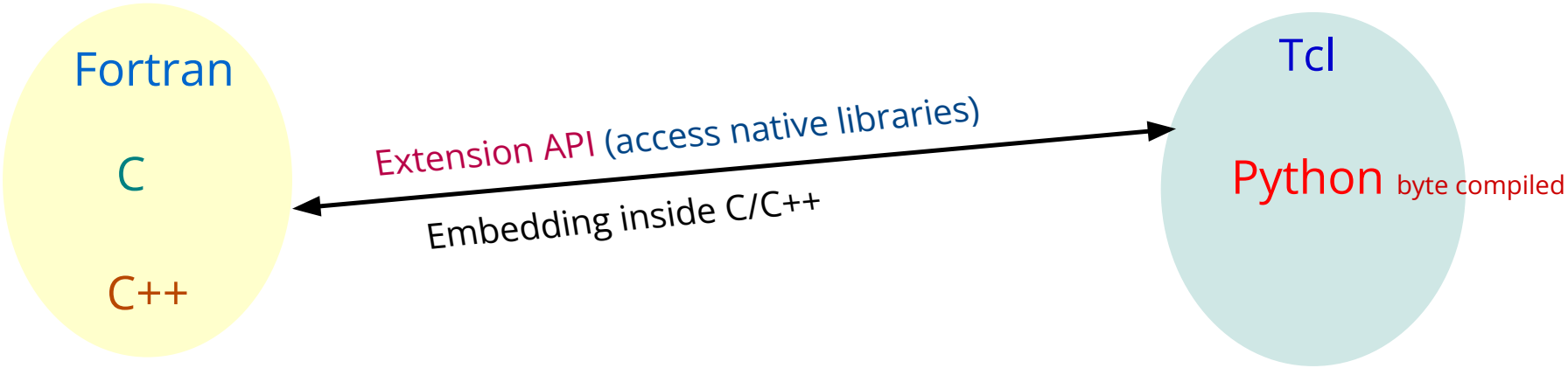

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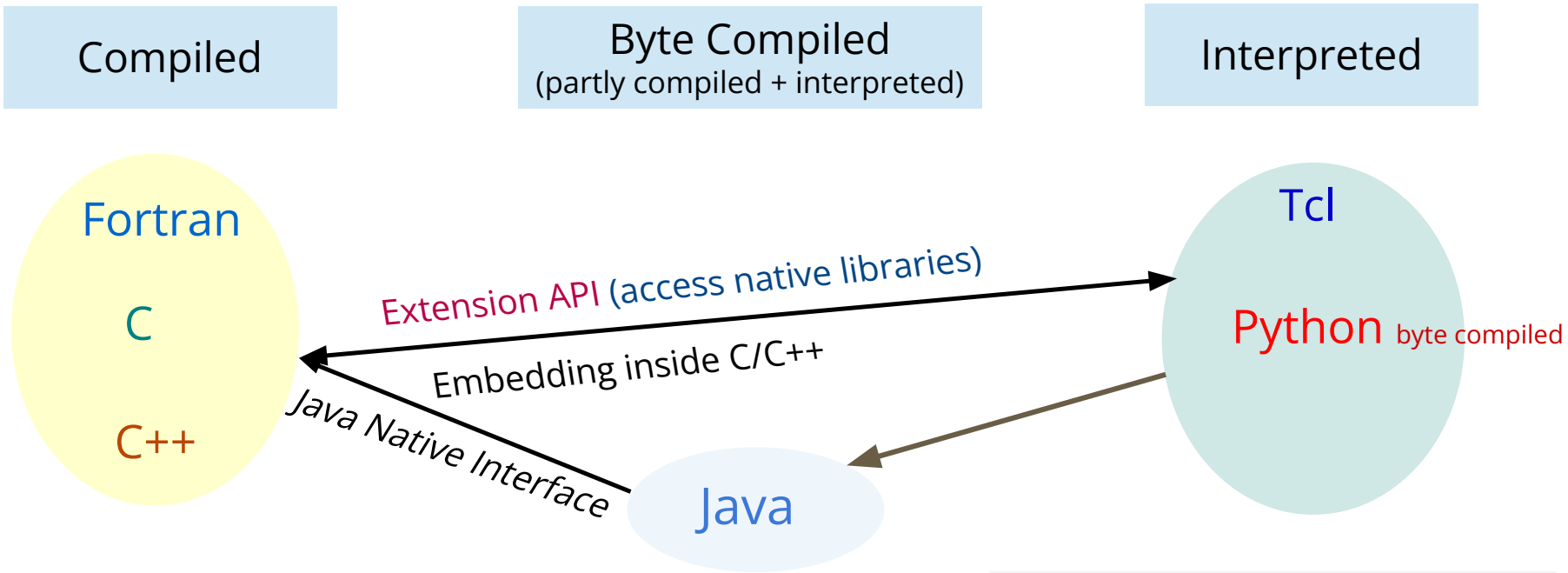

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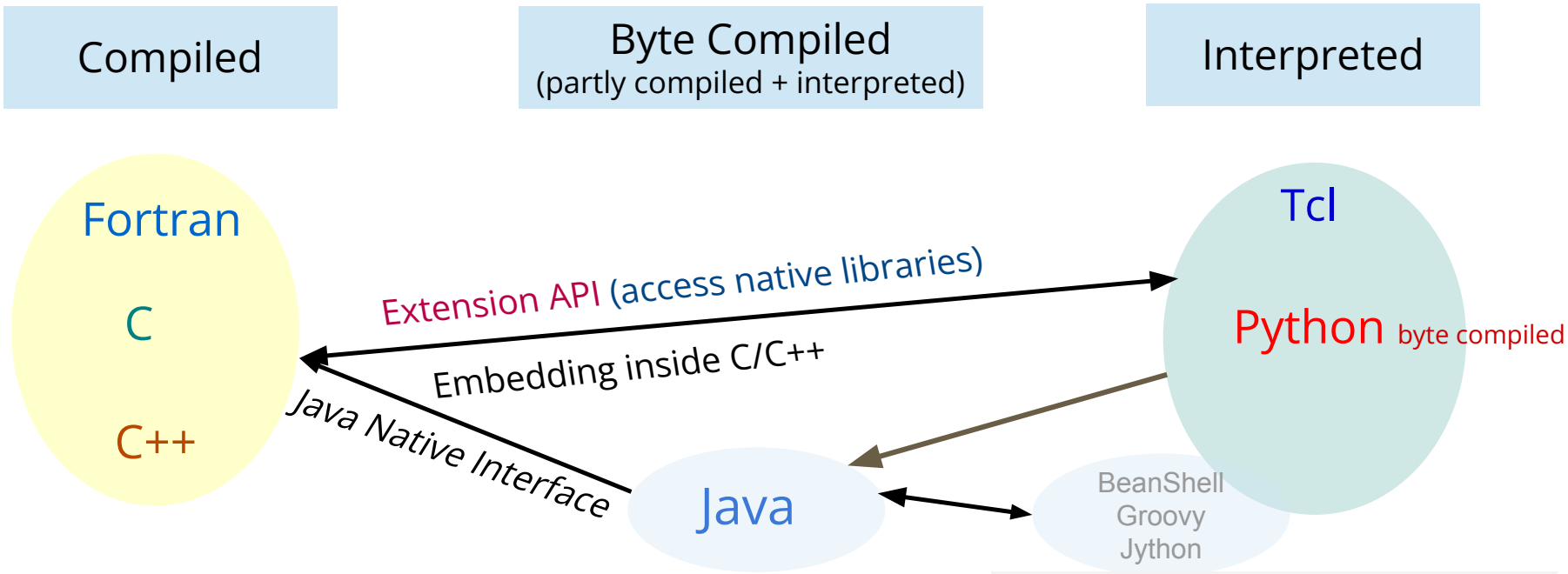

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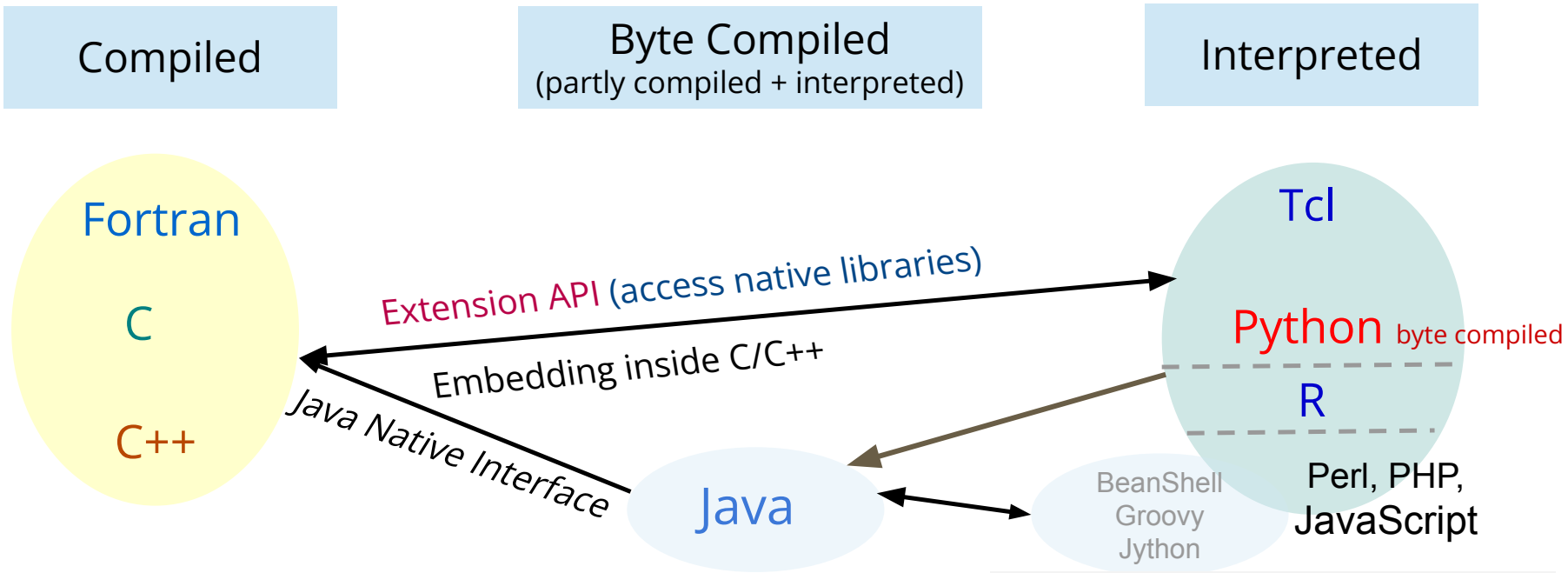

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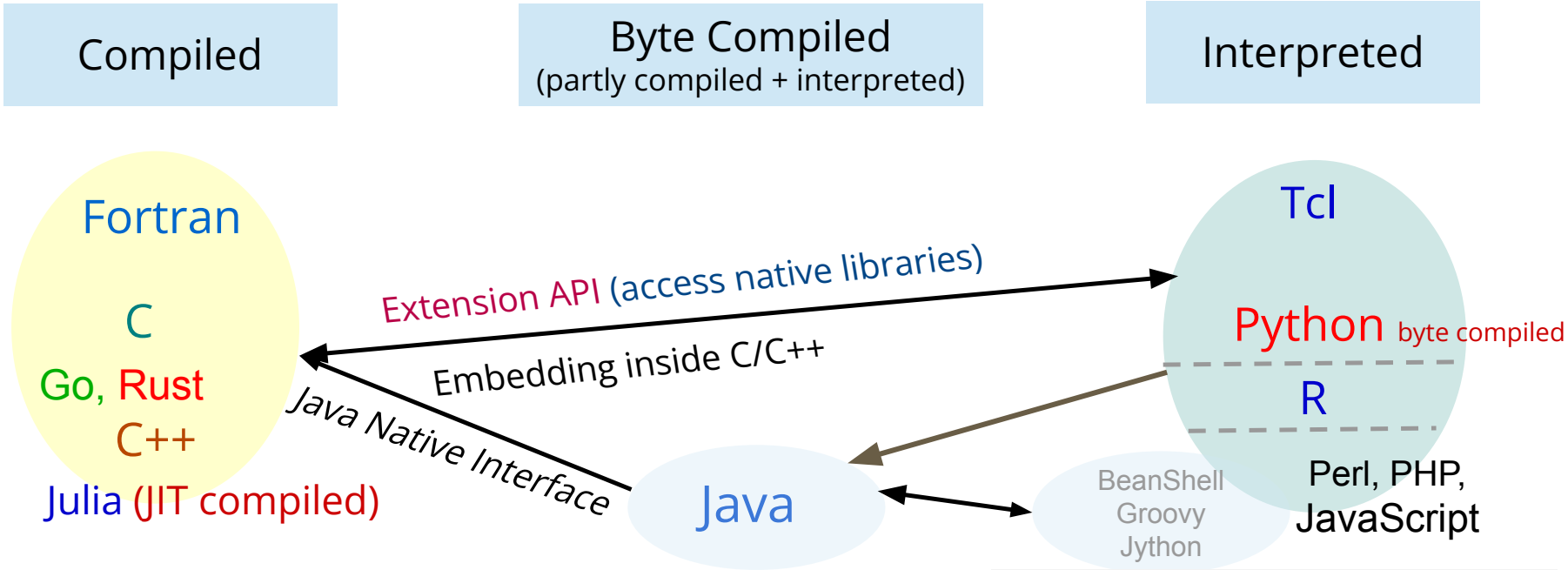

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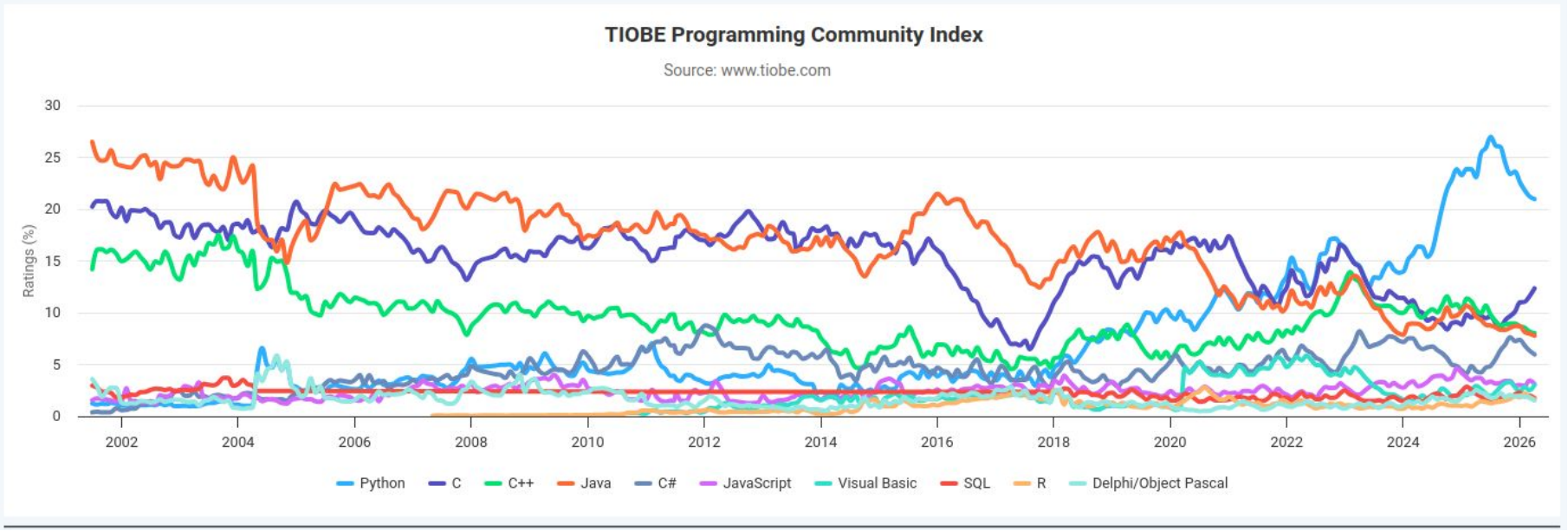
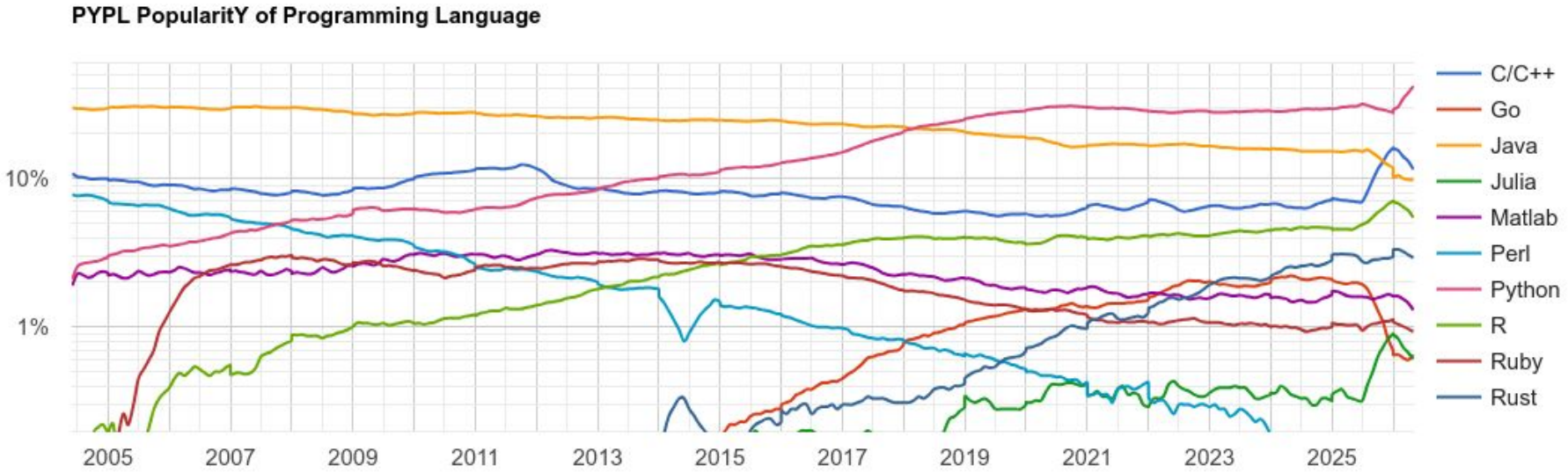
Popularity of Python



TIOBE ratings are based on the number of skilled engineers world-wide, courses and third party vendors. Popular web sites Google, Amazon, Wikipedia, Bing and more than 20 others are used to calculate the ratings.

Popularity of Python

https://pypl.github.io/PYPL.html



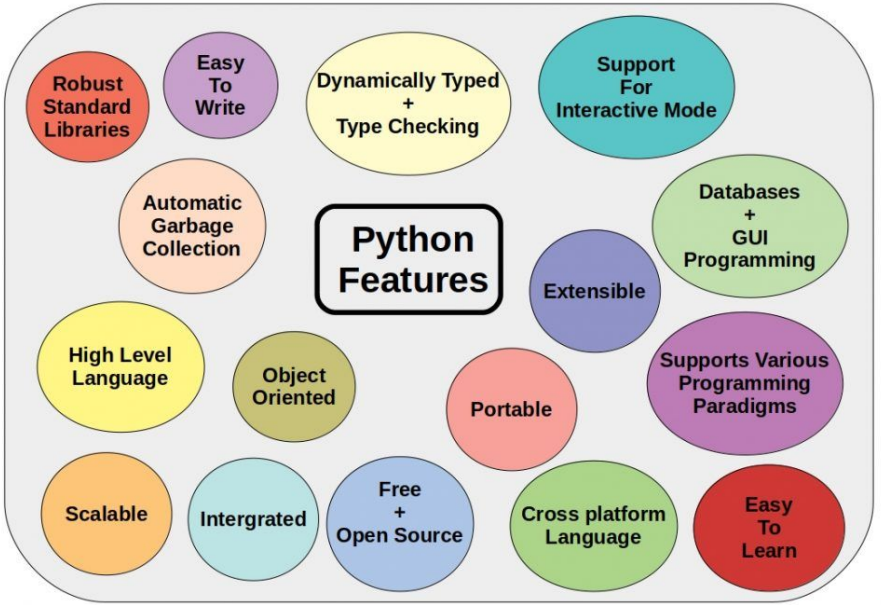
The PYPL PopularitY of Programming Language Index is created by analyzing how often language tutorials are searched on Google.

Python has slowly become the numero uno in the last 5 years, thanks to its ubiquitous role in Machine Learning!

Python at a glance

Python Design Highlights

- Supports all major programming paradigms
  - procedural, object oriented and functional
  - imperative as well as declarative
- Simple syntax, white space significant, pass by-reference
- Dynamically typed, loosely bound
- Scripting & driver language
  - binds different components together
  - seamlessly supports multi-language environment (Extension & Embedding)



https://starship-knowledge.com/awesome-python-data-science-libraries

Python Design Highlights

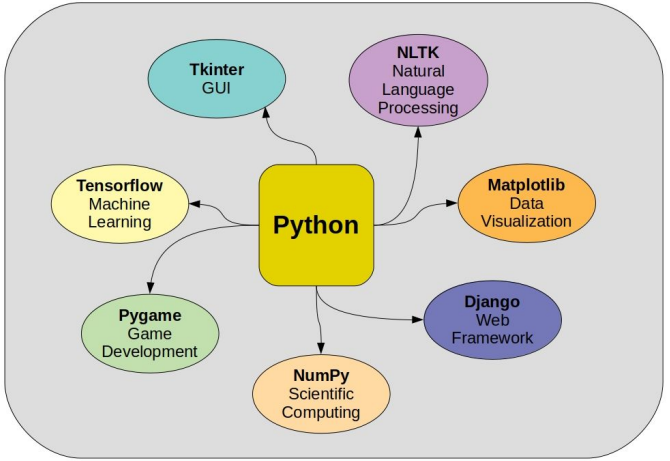
- One can programmatically build Python code as string on-the-fly, and execute inside a running Python program
- Object Orientation from ground up (no data hiding, though!)
- A very high level language (VHLL)
  - built-in support for exception
  - introspection is an integral part of the language
- High level API to seamlessly access C/C++/Java/Fortran libraries
  - opens up infinite possibilities
  - Python objects can be directly created from the native library (.so)

Integrated Development Environment

- Interactive environment
  - python shell
  - ipython (https://ipython.org)
  - jupyter notebook - https://jupyter.org/
  - IDLE, spyder, PyCharm
  - SWAN - https://swan.web.cern.ch/ - a platform to perform interactive data analysis on the cloud

Python application domain

- Scientific computing, data science
  - NumPy, pandas, PyTables, PyROOT, Machine Learning frameworks (classical, quantum)
- System administration
- Web frameworks
  - CGI, CherryPy, Flask, Django, TurboGears and a hell lot more
- Interface to databases, XML and json parsers
- GUI development
  - Tkinter, PyGtk, PyQT/PySide, wxPython



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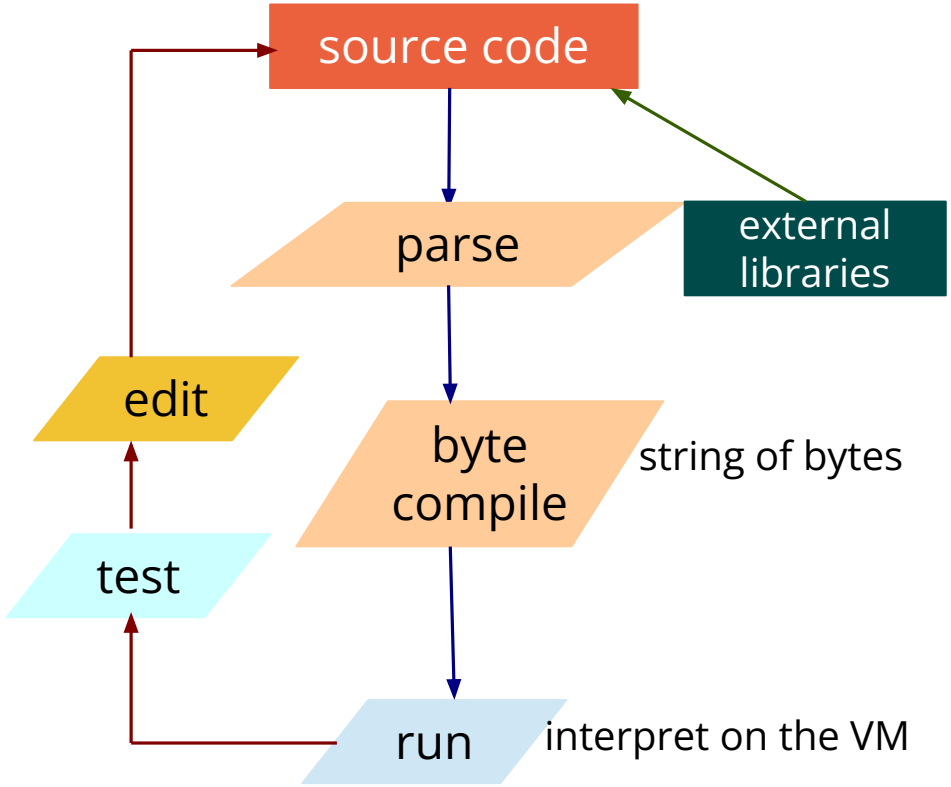
Python as an interpreted language

- A Python interpreter
  - parses a Python program/source file (.py)
    - compiles into byte-code (.pyc)
  - executes byte-code
    - interprets on a virtual machine (VM)
  - no need for compilation and linking phases
    - no binary executable

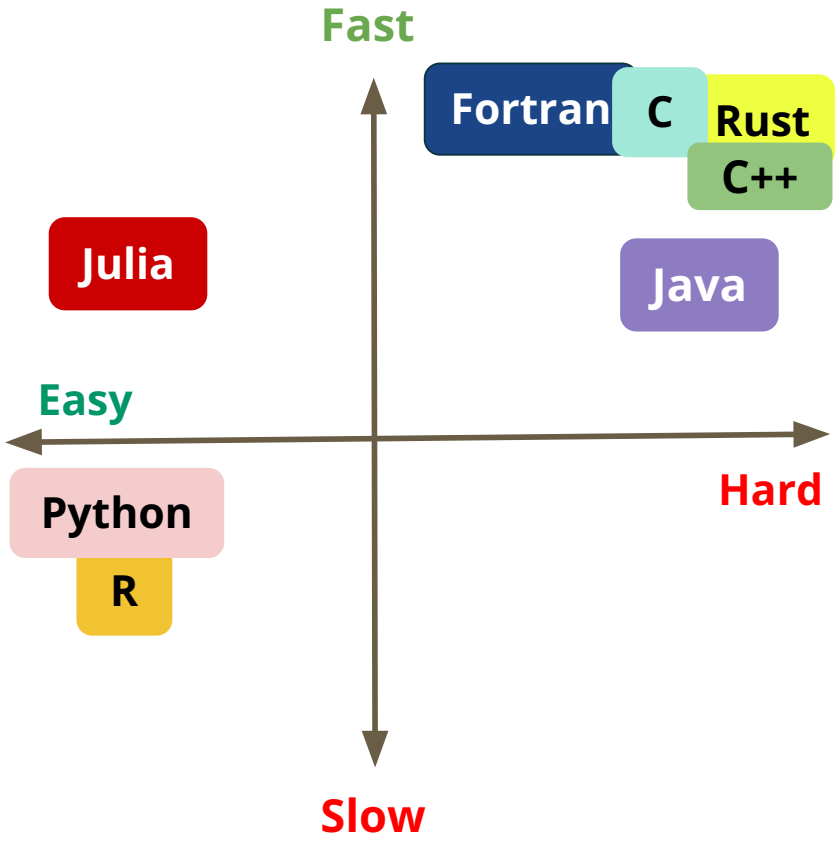


https://www.datacamp.com/community/tutorials/data-science-python-ide

Portability & Performance

- Python source code is inherently portable across platforms/architectures
  - the underlying virtual machine (VM) instance takes care of architecture dependence
  - in most cases you pay a performance penalty
    - vis-a-vis Fortran/C/C++/Go/Rust(/Julia)
    - benefits usually outweigh lack of performance
    - there are alternative implementations of Python to address performance issues with certain limitations
      - Cython - uses additional C/C++ extension libraries
      - PyPy (w/ JIT) - works with pure Python, not with C extension
      - numba (w/ JIT) - sprinkle decorators to accelerate code execution

Portability & Performance



Language	Energy	Time	Memory
C	1.00	1.00	1.17
Rust	1.03	1.04	1.54
C++	1.34	1.56	1.34
Fortran	2.52	1.89	1.24
Java	1.95	4.20	6.01
Julia	na	na	na
Python	75.88	71.90	2.80
R	na	na	na

https://dl.acm.org/doi/pdf/10.1145/3136014.3136031

Interactive Python

Interactive Python

```
$ python3
>>> credits
>>> copyright
>>> help(1) # help on integer
>>> help()
help> keywords
help> quit
>>>
```

Get information, extensive help

There are more than one ways to exit an interactive session

```
>>> CTRL-D
>>> quit()
>>> raise SystemExit
>>> import sys
>>> sys.exit()
```

Python as a calculator

```
$ python3
Python 3.8.10 (default, Mar 15 2022, 12:22:08)
[GCC 9.4.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> 2 + 2
4
>>> a = 2
>>> b = 2
>>> c = a * b
>>> print(c)
4
>>> bin(16)
'0b10000'
>>> pow(2,3)
8
>>> log(10)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'log' is not defined
```

Python does not load the full `math` library in memory

- Two major releases in use: python2 and python3
- python3 is the default on modern OSes, breaks backward compatibility
- python3 is used in this course

Python as a calculator

```
>>> import math  # load a module
>>> dir(math)    # see what it offers
[... 'log', 'log10', 'log1p', 'modf', 'pi', 'pow',
'radians', 'sin', 'sinh', 'sqrt', 'tan', 'tanh',
'trunc']

>>> math.pi
3.141592653589793

>>> from math import sqrt,pow
>>> pow(2,3)
8.0

>>> sqrt(10)
3.1622776601683795

>>> _ # result of the last expression
3.1622776601683795
```

Code Execution: script, eval, exec

Python script (on Linux)

```
#!/usr/bin/env python3
# first.py
for i in list(range(10)):
  print(i, end=" ")
```

Shell magic!

Find the default Python interpreter

```
[1]$ python first.py
0 1 2 3 4 5 6 7 8 9

[2]$ chmod a+x first.py

[3]$ ./first.py
0 1 2 3 4 5 6 7 8 9
```

Turn on execution bit

eval

```
$ python3
>>> result = eval('1.0 + 1.0')
>>> print(result, type(result))
2.0 <class 'float'>
>>> print(eval("len('hello world!')"))
12
>>> print(eval("__import__('os').getcwd()"))
/home/sarkar/python/examples
```

exec

- one can construct Python code as string and execute on-the-fly from within a running Python program

```
>>> code = 'print("hello world!")'
>>> exec(code)
hello world!
```

Data type, variable scope, namespace

Built-in Data Types

Data type	Example
Numbers	`3.1415, 1234, 9999999999, 3+4j`
String	`"Hello", "guido v"`
List	`[1, [2,'three'], 4]`
Dictionary	`{'compiled': 'Fortran,C,C++', 'interpreted': 'Perl, Python, Ruby'}`
Tuple	`1,'world!',3,4` or `(1,'world!', 2, 3)`
File	`f = open('myfile.dat', 'r').readlines()`

Python - dynamically typed, loosely bound

- Name (refer) a variable, no need to declare the type
  - variable type is context sensitive
  - from Python 3.6 static type is allowed, basically as a hint
- Python keeps track of type of an object referenced by a variable name during it's lifetime i.e Python is NOT weakly typed

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>>> a = [1,2,3,4]
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>>> a = [1,2,3,4]
>>> print(type(a))
<class 'list'>
```

```
>>> a = 1,2,3,4
>>> print(type(a))
<class 'tuple'>
```

```
>>> a = None
>>> print(type(a))
<class 'NoneType'>
```

Variable Scope & Lifetime

- Scope
  - part of a program where a variable is accessible
- Lifetime
  - duration for which a variable is accessible
- In general, variables defined
  - in the main body of a program have global scope
    - visible throughout the file, and also inside any file which imports that file
    - global scope is usually a bad idea
  - inside a function have local scope
  - in a class have local scope, but can be accessed from outside through the object (no data hiding)

Variable Scope & Lifetime

```
# global
a = 0

if a == 0:
  b = 1

# what do we expect?
print(b)
```

```
# local
def test_scope(c):
  d = 3
  print(c, d)

# call the function
d = 5
test_scope(7)

# what do we expect?
print(c, d)
```

Type System

- static vs dynamic
  - type checking at compile time vs leaving the responsibility to runtime
- strong vs weak
  - how runtime treats types
  - 1 + “1” gives error for strongly typed language (e.g Python)
- explicit vs implicit
  - how type conversion takes place

```
>>> int("Hello")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: invalid literal for int() with base 10: 'Hello'
>>> int('5')
5
>>> float('5.2')
5.2
```

Datatype conversion

int(x [,base]) - converts x to an integer. Base specifies the base if x is a string
long(x [,base]) - converts x to a long integer. Base specifies the base if x is a string
float(x) - converts x to a floating-point number
complex(real [,imag]) - creates a complex number
str(x) - converts object x to a string representation
repr(x) - converts object x to an expression string
eval(str) - evaluates a string and returns an object
tuple(s) - converts s to a tuple
list(s) - converts s to a list
set(s) - converts s to a set
dict(d) - creates a dictionary. d must be a sequence of (key,value) tuples
chr(x) - converts an integer to a character
ord(x) - converts a single character to its integer value
hex(x) - converts an integer to a hexadecimal string
oct(x) - converts an integer to an octal string

True or False

- The empty string is mapped to `False`, every other string is mapped to `True`

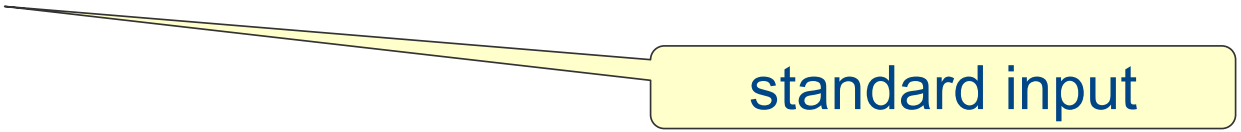
```
>>> s = ''
>>> if s:
...     print('hello')
...
>>> s = 'rob'
>>> if s:
...     print('hello')
...
hello
```

- For integers, 0 is mapped to `False` and every other value to `True`
- For floating point numbers, 0.0 is mapped to `False` and every other value to `True`

```
>>> a = 1
>>> if a:
...     print('hello')
...
hello
```

Control Flow

```
x = int(input("Enter an integer: "))
if x < 0:
   x = 0
   print('Negative changed to zero')
elif x == 0:
   print('Zero')
elif x == 1:
   print('One')
else:
   print('More than one')
```



- Note
  - if-elif-else construct slightly unconventional
  - indentation is mandatory

`pass` statements

The `pass` statement does nothing. It can be used when a statement is required syntactically but the program requires no action

```
>>> while True: # infinite loop
...   pass
...
i = int(input("Enter an integer (>=0): "))
if i > 0:
  pass   # place-holder for future code
else:
  print("i is zero")
```

Loop: for & while

```
>>> list(range(10))
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
>>> for i in range(10):
...     print(i, end = " ")
...
0 1 2 3 4 5 6 7 8 9
```

for

Loop: for & while

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>>> list(range(10))
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
>>> for i in range(10):
...     print(i, end = " ")
...
0 1 2 3 4 5 6 7 8 9
```

for

```
>>> index = 0
>>> while index < 10:
...     print(index, end = " ")
...     index += 1
```

while

Loop - continue & break

```
for i in range(10):
    if i%2 == 0: continue
    print(i, end = " ")
```

Loop - continue & break

```
for i in range(10):
    if i%2 == 0: continue
    print(i, end = " ")
```

```
for i in range(10):
    if i**2 > 25: break
    print(i, end = " ")
```

pass by reference

```
def square(items):
    for i,x in enumerate(items):
        items[i] = x * x  # modify items in-place

a = [1, 2, 3, 4, 5]
print(a)
square(a)  # changes a to [1, 4, 9, 16, 25]
print(a)
```

Iteration over collection

```
# list
for element in [1, 2, 3]:
  print(element, end = " ")
```

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for element in (1, 2, 3):
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for element in (1, 2, 3):
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# dictionary
for key in {'one':1,'two':2}:
  print(key, end = " ")
```

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```
# character string
for char in "123":
  print(char, end = " ")
```

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```
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# file
for line in open("file.txt"):
  print(line, end = " ")
```