Python

ACTL3143 & ACTL5111 Deep Learning for Actuaries

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Lecture Outline

- **Data Science & Python**
- Python Data Types
- Collections
- Control Flow
- Python Functions
- Import syntax
- Lambda functions

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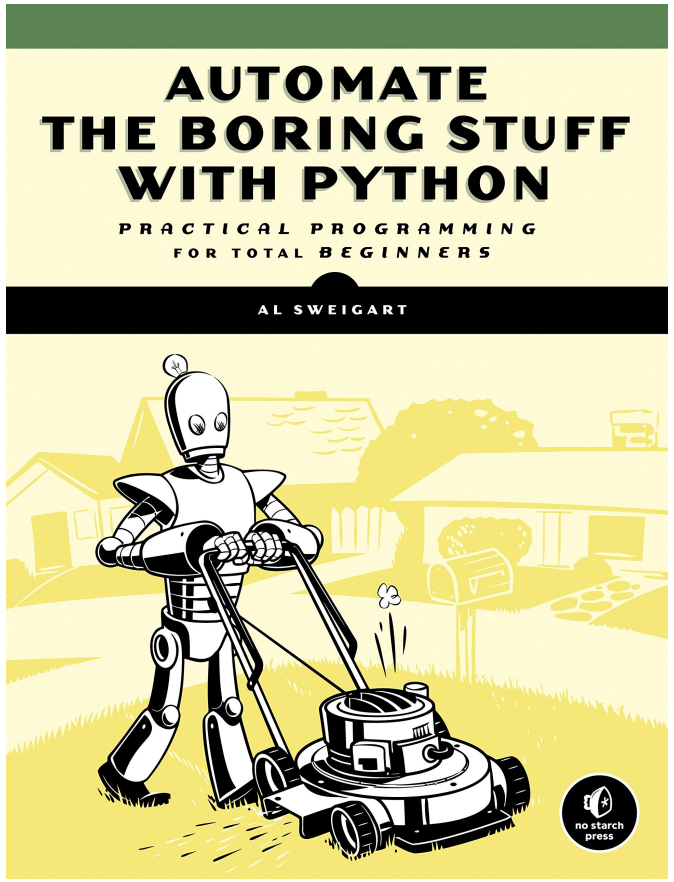
About Python



Free book Automate the Boring Stuff with Python

It is *general purpose* language

Python powers:

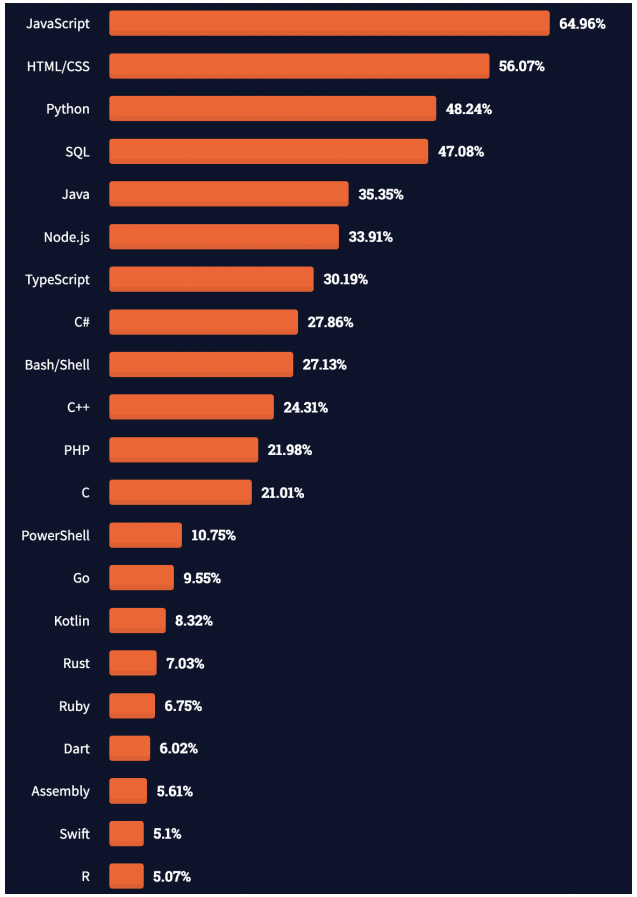
- Instagram
- Spotify
- Netflix
- Uber
- Reddit...

Python is on Mars.

Sources: Blog post and Github.

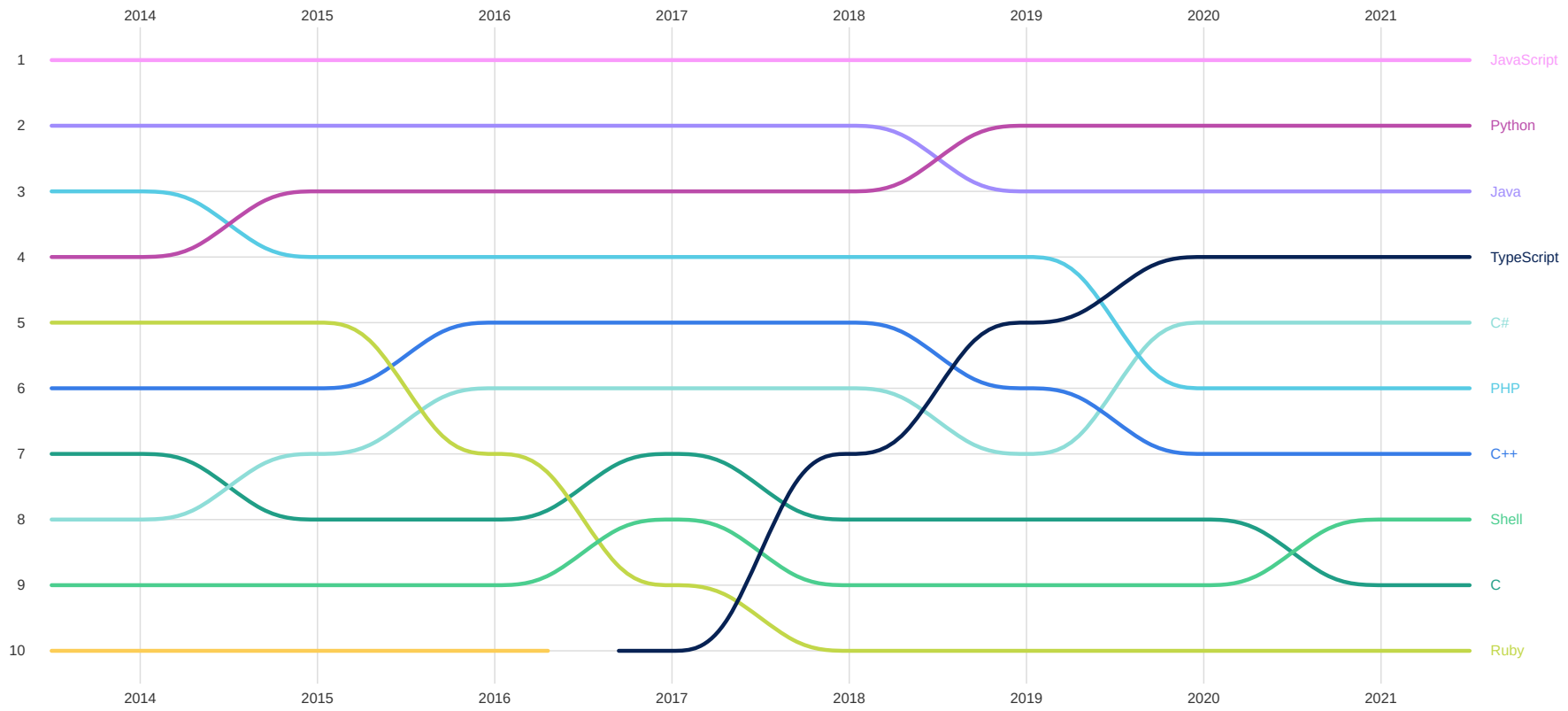
Stack Overflow 2021 Dev. Survey

- Python is 3rd most popular language
- Python is the most wanted language
- In 'Other frameworks and libraries', they note that "several data science libraries for Python make strong showings".



Popular languages.

Github's 2021 State of the Octoverse



Top languages over the years

Source: Kaggle (2021), State of Machine Learning and Data Science.

Python and machine learning

> …[T]he entire machine learning and data science industry has been dominated by these two approaches: **deep learning** and **gradient boosted trees**… Users of gradient boosted trees tend to use Scikit-learn, XGBoost, or LightGBM. Meanwhile, most practitioners of deep learning use Keras, often in combination with its parent framework TensorFlow. The common point of these tools is **they're all Python libraries**: Python is by far the most widely used language for machine learning and data science.

Source: François Chollet (2021), *Deep Learning with Python, Second Edition*, Section 1.2.7.

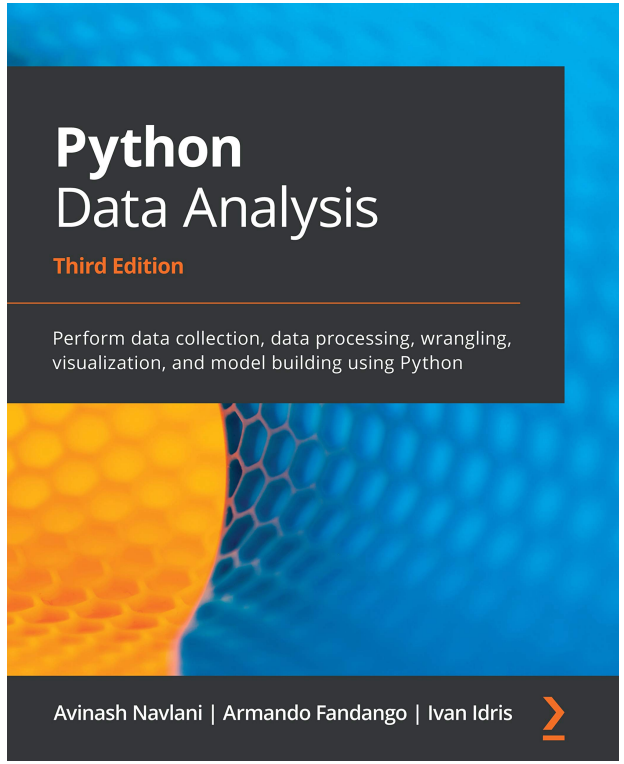
Python for data science

In R you can run:

```r
pchisq(3, 10)
```

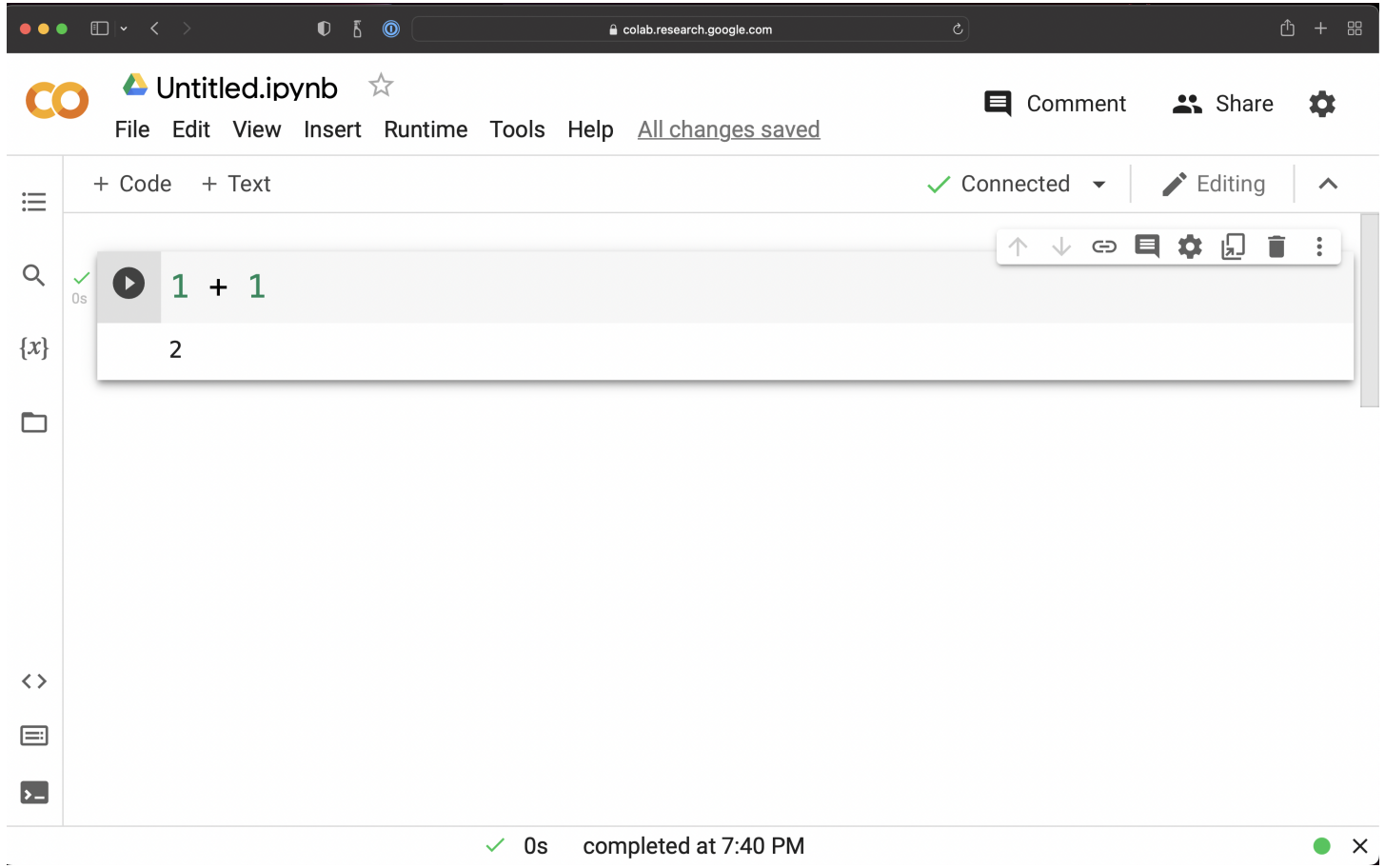
In Python it is

```python
from scipy import stats
stats.chi2(10).cdf(3)
```



In Leganto

Google Colaboratory



An example notebook in Google Colaboratory.

http://colab.research.google.com

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Variables and basic types

```
1 + 2
```

```
3
```

```
x = 1
x + 2.0
```

```
3.0
```

```
type(2.0)
```

```
float
```

```
type(1), type(x)
```

```
(int, int)
```

```
does_math_work = 1 + 1 == 2
print(does_math_work)
type(does_math_work)
```

```
True
```

```
bool
```

```
contradiction = 1 ≠ 1
contradiction
```

```
False
```

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Shorthand assignments

If we want to add 2 to a variable `x`:

```
1 x = 1
2 x = x + 2
3 x
```

3

```
1 x = 1
2 x += 2
3 x
```

3

Same for:

- `x -= 2` : take 2 from the current value of `x` ,
- `x *= 2` : double the current value of `x`,
- `x /= 2` : halve the current value of `x`.

Strings

```
1 name = "Patrick"
2 surname = 'Laub'
```

```
1 coffee = "This is Patrick's coffee"
2 quote = 'And then he said "I need a coffee!"'
```

```
1 name + surname
```

```
'PatrickLaub'
```

```
1 greeting = f"Hello {name} {surname}"
2 greeting
```

```
'Hello Patrick Laub'
```

```
1 "Patrick" in greeting
```

```
True
```

and & or

```
1 name = "Patrick"
2 surname = "Laub"
3 name.istitle() and surname.istitle()
```

```
True
```

```
1 full_name = "Dr Patrick Laub"
2 full_name.startswith("Dr ") or full_name.endswith(" PhD")
```

```
True
```

Important

The dot is used denote methods, it can't be used inside a variable name.

```
1 i.am.an.unfortunate.R.users = True
```

```
NameError: name 'i' is not defined
```

`help` to get more details

```
1 help(name.istitle)
```

```
Help on built-in function istitle:

istitle() method of builtins.str instance
    Return True if the string is a title-cased string, False otherwise.

    In a title-cased string, upper- and title-case characters may only
    follow uncased characters and lowercase characters only cased ones.
```

f-strings

```
1 print(f"Five squared is {5*5} and five cubed is {5**3}")
2 print("Five squared is {5*5} and five cubed is {5**3}")
```

```
Five squared is 25 and five cubed is 125
Five squared is {5*5} and five cubed is {5**3}
```

Use f-strings and avoid the older alternatives:

```
1 print(f"Hello {name} {surname}")
2 print("Hello " + name + " " + surname)
3 print("Hello {} {}".format(name, surname))
4 print("Hello %s %s" % (name, surname))
```

```
Hello Patrick Laub
Hello Patrick Laub
Hello Patrick Laub
Hello Patrick Laub
```

Converting types

```
1 digit = 3
2 digit
```

```
3
```

```
1 type(digit)
```

```
int
```

```
1 num = float(digit)
2 num
```

```
3.0
```

```
1 type(num)
```

```
float
```

```
1 num_str = str(num)
2 num_str
```

```
'3.0'
```

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Quiz

What is the output of:

```
1 x = 1
2 y = 1.0
3 print(f"{x == y} and {type(x) == type(y)}")
```

```
True and False
```

What would you add before line 3 to get “True and True”?

```
1 x = 1
2 y = 1.0
3 x = float(x)  # or y = int(y)
4 print(f"{x == y} and {type(x) == type(y)}")
```

```
True and True
```

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Lists

```
1 desires = ["Coffee", "Cake", "Sleep"]
2 desires
```

```
['Coffee', 'Cake', 'Sleep']
```

```
1 len(desires)
```

```
3
```

```
1 desires[0]
```

```
'Coffee'
```

```
1 desires[-1]
```

```
'Sleep'
```

```
1 desires[2] = "Nap"
2 desires
```

```
['Coffee', 'Cake', 'Nap']
```

Slicing lists

```
1 print([0, 1, 2])
2 desires
```

```
[0, 1, 2]
['Coffee', 'Cake', 'Nap']
```

```
1 desires[0:2]
```

```
['Coffee', 'Cake']
```

```
1 desires[0:1]
```

```
['Coffee']
```

```
1 desires[:2]
```

```
['Coffee', 'Cake']
```

A common indexing error

```
1 desires[1.0]
```

```
TypeError: list indices must be integers or slices, not float
```

```
1 desires[: len(desires) / 2]
```

```
TypeError: slice indices must be integers or None or have an __index__ method
```

```
1 len(desires) / 2, len(desires) // 2
```

```
(1.5, 1)
```

```
1 desires[: len(desires) // 2]
```

```
['Coffee']
```

Editing lists

```
1 desires = ["Coffee", "Cake", "Sleep"]
2 desires.append("Gadget")
3 desires
```

```
['Coffee', 'Cake', 'Sleep', 'Gadget']
```

```
1 desires.pop()
```

```
'Gadget'
```

```
1 desires
```

```
['Coffee', 'Cake', 'Sleep']
```

```
1 desires.sort()
2 desires
```

```
['Cake', 'Coffee', 'Sleep']
```

```
1 desires[3] = "Croissant"
```

```
IndexError: list assignment index out of range
```

None

```
1 desires = ["Coffee", "Cake", "Sleep", "Gadget"]
2 sorted_list = desires.sort()
3 sorted_list
```

```
1 type(sorted_list)
```

```
NoneType
```

```
1 sorted_list is None
```

```
True
```

```
1 bool(sorted_list)
```

```
False
```

```
1 desires = ["Coffee", "Cake", "Sleep", "Gadget"]
2 sorted_list = sorted(desires)
3 print(desires)
4 sorted_list
```

```
['Coffee', 'Cake', 'Sleep', 'Gadget']
['Cake', 'Coffee', 'Gadget', 'Sleep']
```

Tuples ('immutable' lists)

```
1 weather = ("Sunny", "Cloudy", "Rainy")
2 print(type(weather))
3 print(len(weather))
4 print(weather[-1])
```

```
<class 'tuple'>
3
Rainy
```

```
1 weather.append("Snowy")
```

```
AttributeError: 'tuple' object has no attribute 'append'
```

```
1 weather[2] = "Snowy"
```

```
TypeError: 'tuple' object does not support item assignment
```

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One-length tuples

```
1 using_brackets_in_math = (2 + 4) * 3
2 using_brackets_to_simplify = (1 + 1 == 2)
```

```
1 failure_of_atuple = ("Snowy")
2 type(failure_of_atuple)
```

```
str
```

```
1 happy_solo_tuple = ("Snowy",)
2 type(happy_solo_tuple)
```

```
tuple
```

```
1 cheeky_solo_list = ["Snowy"]
2 type(cheeky_solo_list)
```

```
list
```

Dictionaries

```
1 phone_book = {"Patrick": "+61 1234", "Café": "(02) 5678"}
2 phone_book["Patrick"]
```

```
'+61 1234'
```

```
1 phone_book["Café"] = "+61400 000 000"
2 phone_book
```

```
{'Patrick': '+61 1234', 'Café': '+61400 000 000'}
```

```
1 phone_book.keys()
```

```
dict_keys(['Patrick', 'Café'])
```

```
1 phone_book.values()
```

```
dict_values(['+61 1234', '+61400 000 000'])
```

```
1 factorial = {0: 1, 1: 1, 2: 2, 3: 6, 4: 24, 5: 120, 6: 720, 7: 5040}
2 factorial[4]
```

```
24
```

Quiz

```
1 animals = ["dog", "cat", "bird"]
2 animals.append("teddy bear")
3 animals.pop()
4 animals.pop()
5 animals.append("koala")
6 animals.append("kangaroo")
7 print(f"{len(animals)} and {len(animals[-2])}")
```

```
4 and 5
```

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`if` and `else`

```
1 age = 50
```

```
1 if age ⩾ 30:
2     print("Gosh you're old")
```

```
Gosh you're old
```

```
1 if age ⩾ 30:
2     print("Gosh you're old")
3 else:
4     print("You're still young")
```

```
Gosh you're old
```

The weird part about Python...

```
1 if age ⩾ 30:
2     print("Gosh you're old")
3 else:
4 print("You're still young")
```

```
IndentationError: expected an indented block after 'else' statement on line 3 (2212277638.py,
line 4)
```

> ⚠ **Warning**
>
> Watch out for mixing tabs and spaces!

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An example of aging

```
1 age = 16
2
3 if age < 18:
4     friday_evening_schedule = "School things"
5 if age < 30:
6     friday_evening_schedule = "Party 🥳🍾"
7 if age ⩾ 30:
8     friday_evening_schedule = "Work"
```

```
1 print(friday_evening_schedule)
```

```
Party 🥳🍾
```

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Using `elif`

```
1  age = 16
2
3  if age < 18:
4      friday_evening_schedule = "School things"
5  elif age < 30:
6      friday_evening_schedule = "Party 🥳🍾"
7  else:
8      friday_evening_schedule = "Work"
9
10 print(friday_evening_schedule)
```

```
School things
```

`for` Loops

```
1 desires = ["coffee", "cake", "sleep"]
2 for desire in desires:
3     print(f"Patrick really wants a {desire}.")
```

```
Patrick really wants a coffee.
Patrick really wants a cake.
Patrick really wants a sleep.
```

```
1 for i in range(3):
2     print(i)
```

```
0
1
2
```

```
1 for i in range(3, 6):
2     print(i)
```

```
3
4
5
```

```
1 range(5)
```

```
range(0, 5)
```

```
1 type(range(5))
```

```
range
```

```
1 list(range(5))
```

```
[0, 1, 2, 3, 4]
```

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Advanced `for` loops

```
1 for i, desire in enumerate(desires):
2     print(f"Patrick wants a {desire}, it is priority #{i+1}.")
```

```
Patrick wants a coffee, it is priority #1.
Patrick wants a cake, it is priority #2.
Patrick wants a sleep, it is priority #3.
```

```
1 desires = ["coffee", "cake", "nap"]
2 times = ["in the morning", "at lunch", "during a boring lecture"]
3
4 for desire, time in zip(desires, times):
5     print(f"Patrick enjoys a {desire} {time}.")
```

```
Patrick enjoys a coffee in the morning.
Patrick enjoys a cake at lunch.
Patrick enjoys a nap during a boring lecture.
```

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List comprehensions

```
1 [x**2 for x in range(10)]
```

```
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

```
1 [x**2 for x in range(10) if x % 2 == 0]
```

```
[0, 4, 16, 36, 64]
```

They can get more complicated:

```
1 [x*y for x in range(4) for y in range(4)]
```

```
[0, 0, 0, 0, 0, 1, 2, 3, 0, 2, 4, 6, 0, 3, 6, 9]
```

```
1 [[x*y for x in range(4)] for y in range(4)]
```

```
[[0, 0, 0, 0], [0, 1, 2, 3], [0, 2, 4, 6], [0, 3, 6, 9]]
```

but I'd recommend just using `for` loops at that point.

While Loops

Say that we want to simulate $(X \mid X \geq 100)$ where $X \sim \text{Pareto}(1)$. Assuming we have `simulate_pareto`, a function to generate Pareto(1) variables:

```
samples = []
while len(samples) < 5:
    x = simulate_pareto()
    if x ⩾ 100:
        samples.append(x)

samples
```

```
[125.28600493316272,
 186.04974709289712,
 154.45723763510398,
 101.08310878885993,
 2852.8305399214996]
```

Breaking out of a loop

```python
while True:
    user_input = input(">> What would you like to do? ")

    if user_input == "order cake":
        print("Here's your cake! 🎂")

    elif user_input == "order coffee":
        print("Here's your coffee! ☕")

    elif user_input == "quit":
        break
```

```
>> What would you like to do? order cake
Here's your cake! 🎂
>> What would you like to do? order coffee
Here's your coffee! ☕
>> What would you like to do? order cake
Here's your cake! 🎂
>> What would you like to do? quit
```

Quiz

What does this print out?

```
if 1 / 3 + 1 / 3 + 1 / 3 == 1:
    if 2**3 == 6:
        print("Math really works!")
    else:
        print("Math sometimes works..")
else:
    print("Math doesn't work")
```

```
Math sometimes works..
```

What does this print out?

```
count = 0
for i in range(1, 10):
    count += i
    if i > 3:
        break
print(count)
```

```
10
```

Debugging the quiz code

```python
count = 0
for i in range(1, 10):
    count += i
    print(f"After i={i} count={count}")
    if i > 3:
        break
```

```
After i=1 count=1
After i=2 count=3
After i=3 count=6
After i=4 count=10
```

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Making a function

```
1 def add_one(x):
2     return x + 1
3
4 def greet_a_student(name):
5     print(f"Hi {name}, welcome to the AI class!")
```

```
1 add_one(10)
```

```
11
```

```
1 greet_a_student("Josephine")
```

```
Hi Josephine, welcome to the AI class!
```

```
1 greet_a_student("Joseph")
```

```
Hi Joseph, welcome to the AI class!
```

Here, `name` is a *parameter* and the value supplied is an *argument*.

Default arguments

Assuming we have `simulate_standard_normal`, a function to generate Normal(0, 1) variables:

```
def simulate_normal(mean=0, std=1):
    return mean + std * simulate_standard_normal()
```

```
simulate_normal()  # same as 'simulate_normal(0, 1)'
```

```
0.47143516373249306
```

```
simulate_normal(1_000)  # same as 'simulate_normal(1_000, 1)'
```

```
998.8090243052935
```

> **Note**
>
> We'll cover random numbers next week (using `numpy`).

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Use explicit parameter name

```
1 simulate_normal(mean=1_000)  # same as 'simulate_normal(1_000, 1)'
```

```
1001.4327069684261
```

```
1 simulate_normal(std=1_000)  # same as 'simulate_normal(0, 1_000)'
```

```
-312.6518960917129
```

```
1 simulate_normal(10, std=0.001)  # same as 'simulate_normal(10, 0.001)'
```

```
9.999279411266635
```

```
1 simulate_normal(std=10, 1_000)
```

```
SyntaxError: positional argument follows keyword argument (1723181129.py, line 1)
```

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Why would we need that?

E.g. to fit a Keras model, we use the `.fit` method:

```
model.fit(x=None, y=None, batch_size=None, epochs=1, verbose='auto',
        callbacks=None, validation_split=0.0, validation_data=None,
        shuffle=True, class_weight=None, sample_weight=None,
        initial_epoch=0, steps_per_epoch=None, validation_steps=None,
        validation_batch_size=None, validation_freq=1,
        max_queue_size=10, workers=1, use_multiprocessing=False)
```

Say we want all the defaults except changing `use_multiprocessing=True`:

```
model.fit(None, None, None, 1, 'auto', None, 0.0, None, True, None,
        None, 0, None, None, None, 1, 10, 1, True)
```

but it is *much nicer* to just have:

```
model.fit(use_multiprocessing=True)
```

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Quiz

What does the following print out?

```python
def get_half_of_list(numbers, first=True):
    if first:
        return numbers[: len(numbers) // 2]
    else:
        return numbers[len(numbers) // 2 :]

nums = [1, 2, 3, 4, 5, 6]
chunk = get_half_of_list(nums, False)
second_chunk = get_half_of_list(chunk)
print(second_chunk)
```

```
[4]
```

```python
f"nums ⇝ {nums[:len(nums)//2]} and {nums[len(nums)//2:]}"
```

```
'nums ⇝ [1, 2, 3] and [4, 5, 6]'
```

```python
f"chunk ⇝ {chunk[:len(chunk)//2]} and {chunk[len(chunk)//2:]}"
```

```
'chunk ⇝ [4] and [5, 6]'
```

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Multiple return values

```
1 def limits(numbers):
2     return min(numbers), max(numbers)
3
4 limits([1, 2, 3, 4, 5])
```

```
(1, 5)
```

```
1 type(limits([1, 2, 3, 4, 5]))
```

```
tuple
```

```
1 min_num, max_num = limits([1, 2, 3, 4, 5])
2 print(f"The numbers are between {min_num} and {max_num}.")
```

```
The numbers are between 1 and 5.
```

```
1 _, max_num = limits([1, 2, 3, 4, 5])
2 print(f"The maximum is {max_num}.")
```

```
The maximum is 5.
```

```
1 print(f"The maximum is {limits([1, 2, 3, 4, 5])[1]}.")
```

```
The maximum is 5.
```

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Tuple unpacking

```
1 lims = limits([1, 2, 3, 4, 5])
2 smallest_num = lims[0]
3 largest_num = lims[1]
4 print(f"The numbers are between {smallest_num} and {largest_num}.")
```

```
The numbers are between 1 and 5.
```

```
1 smallest_num, largest_num = limits([1, 2, 3, 4, 5])
2 print(f"The numbers are between {smallest_num} and {largest_num}.")
```

```
The numbers are between 1 and 5.
```

This doesn't just work for functions with multiple return values:

```
1 RESOLUTION = (1920, 1080)
2 WIDTH, HEIGHT = RESOLUTION
3 print(f"The resolution is {WIDTH} wide and {HEIGHT} tall.")
```

```
The resolution is 1920 wide and 1080 tall.
```

Short-circuiting

```
1  def is_positive(x):
2      print("Called is_positive")
3      return x > 0
4
5  def is_negative(x):
6      print("Called is_negative")
7      return x < 0
8
9  x = 10
```

```
1  x_is_positive = is_positive(x)
2  x_is_positive
```

```
Called is_positive
True
```

```
1  x_is_negative = is_negative(x)
2  x_is_negative
```

```
Called is_negative
False
```

```
1  x_not_zero = is_positive(x) or is_negative(x)
2  x_not_zero
```

```
Called is_positive
True
```

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Python standard library

```
1 import os
2 import time
```

```
1 time.sleep(0.1)
```

```
1 os.getlogin()
```

```
'plaub'
```

```
1 os.getcwd()
```

```
'/home/plaub/Dropbox/Lecturing/ACTL3143/DeepLearningForActuaries/Lecture-1-Artificial-Intelligence'
```

Import a few functions

```
1 from os import getcwd, getlogin
2 from time import sleep
```

```
1 sleep(0.1)
```

```
1 getlogin()
```

```
'plaub'
```

```
1 getcwd()
```

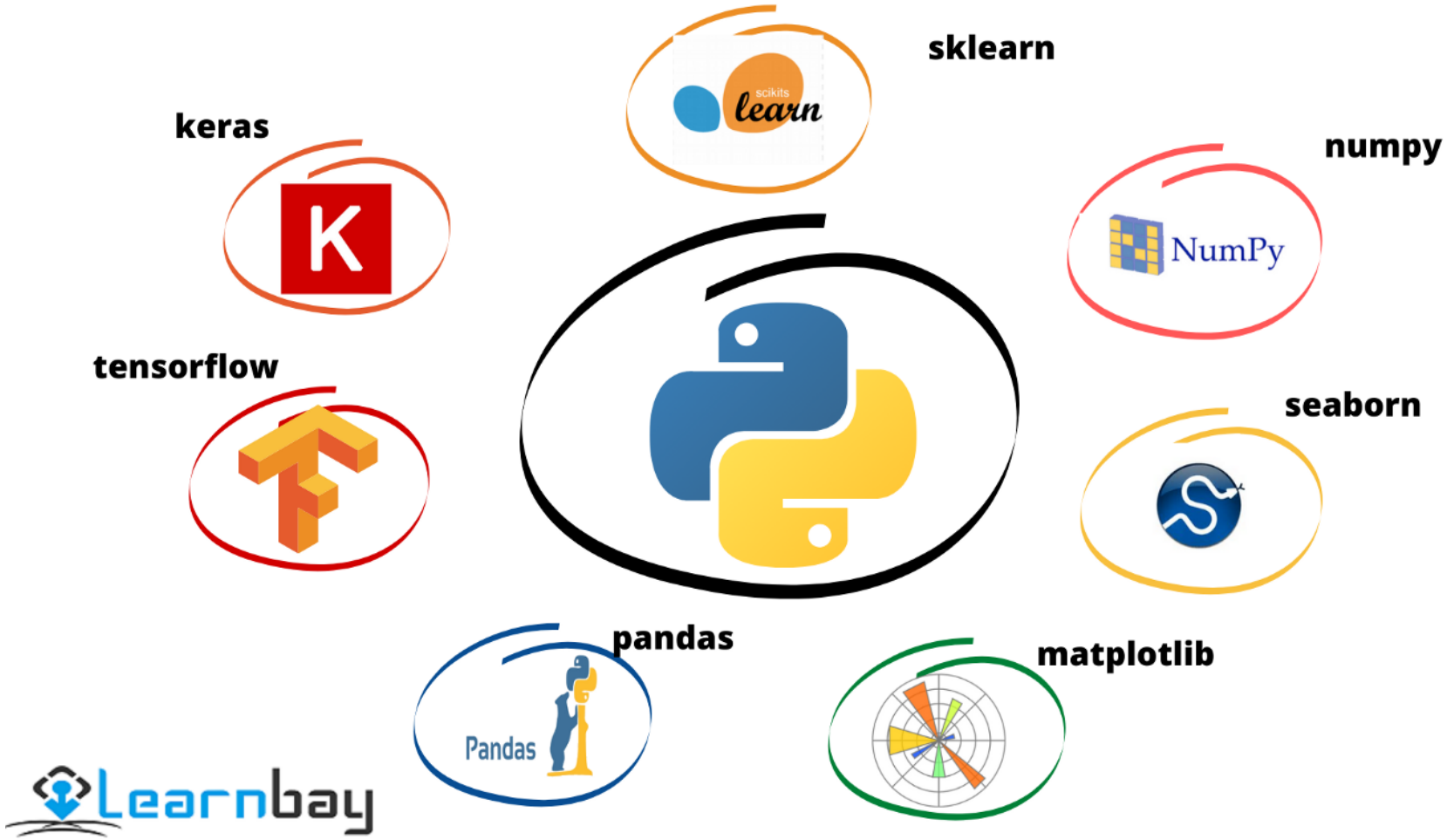
```
'/home/plaub/Dropbox/Lecturing/ACTL3143/DeepLearningForActuaries/Lecture-1-Artificial-Intelligence'
```

Timing using pure Python

```python
from time import time

start_time = time()

counting = 0
for i in range(1_000_000):
    counting += 1

end_time = time()

elapsed = end_time - start_time
print(f"Elapsed time: {elapsed} secs")
```

```
Elapsed time: 0.03851675987243652 secs
```

Data science packages



Common data science packages

Source: Learnbay.co, Python libraries for data analysis and modeling in Data science, Medium.

Importing using `as`

```python
import pandas

pandas.DataFrame(
    {
        "x": [1, 2, 3],
        "y": [4, 5, 6],
    }
)
```

	x	y
0	1	4
1	2	5
2	3	6

```python
import pandas as pd

pd.DataFrame(
    {
        "x": [1, 2, 3],
        "y": [4, 5, 6],
    }
)
```

	x	y
0	1	4
1	2	5
2	3	6

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Importing from a subdirectory

Want `keras.models.Sequential()`.

```
1 import keras
2
3 model = keras.models.Sequential()
```

Alternatives using `from`:

```
1 from keras import models
2
3 model = models.Sequential()
```

```
1 from keras.models import Sequential
2
3 model = Sequential()
```

Lecture Outline

- Data Science & Python
- Python Data Types
- Collections
- Control Flow
- Python Functions
- Import syntax
- **Lambda functions**

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Anonymous ‘lambda’ functions

Example: how to sort strings by their second letter?

```
1 names = ["Josephine", "Patrick", "Bert"]
```

If you try `help(sorted)` you’ll find the `key` parameter.

```
1 for name in names:
2     print(f"The length of '{name}' is {len(name)}.")
```

```
The length of 'Josephine' is 9.
The length of 'Patrick' is 7.
The length of 'Bert' is 4.
```

```
1 sorted(names, key=len)
```

```
['Bert', 'Patrick', 'Josephine']
```

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Anonymous ‘lambda’ functions

Example: how to sort strings by their second letter?

```
1 names = ["Josephine", "Patrick", "Bert"]
```

If you try `help(sorted)` you’ll find the `key` parameter.

```
1 def second_letter(name):
2     return name[1]
```

```
1 for name in names:
2     print(f"The second letter of '{name}' is '{second_letter(name)}'.")
```

```
The second letter of 'Josephine' is 'o'.
The second letter of 'Patrick' is 'a'.
The second letter of 'Bert' is 'e'.
```

```
1 sorted(names, key=second_letter)
```

```
['Patrick', 'Bert', 'Josephine']
```

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Anonymous ‘lambda’ functions

Example: how to sort strings by their second letter?

```
1 names = ["Josephine", "Patrick", "Bert"]
```

If you try `help(sorted)` you’ll find the `key` parameter.

```
1 sorted(names, key=lambda name: name[1])
```

```
['Patrick', 'Bert', 'Josephine']
```

Caution

Don’t use `lambda` as a variable name! You commonly see `lambd` or `lambda_` or `λ`.

with keyword

Example, opening a file:

Most basic way is:

```
1 f = open("haiku1.txt", "r")
2 print(f.read())
3 f.close()
```

```
Chaos reigns within.
Reflect, repent, and reboot.
Order shall return.
```

Instead, use:

```
1 with open("haiku2.txt", "r") as f:
2     print(f.read())
```

```
The Web site you seek
Cannot be located, but
Countless more exist.
```

Haikus from http://www.libertybasicuniversity.com/lbnews/nl107/haiku.htm

Package Versions

```
1 from watermark import watermark
2 print(watermark(python=True, packages="keras,matplotlib,numpy,pandas,seaborn,scipy,torch
```

```
Python implementation: CPython
Python version       : 3.11.9
IPython version      : 8.24.0

keras     : 3.3.3
matplotlib: 3.8.4
numpy     : 1.26.4
pandas    : 2.2.2
seaborn   : 0.13.2
scipy     : 1.11.0
torch     : 2.0.1
tensorflow: 2.16.1
tf_keras  : 2.16.0
```

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Links

If you came from C (i.e. are a joint computer science student), and were super interested in Python's internals, maybe you'd be interested in this How variables work in Python video.

Glossary

- default arguments
- dictionaries
- f-strings
- function definitions
- Google Colaboratory
- `help`
- list
- `pip install ...`
- `range`
- slicing
- tuple
- `type`
- whitespace indentation
- zero-indexing