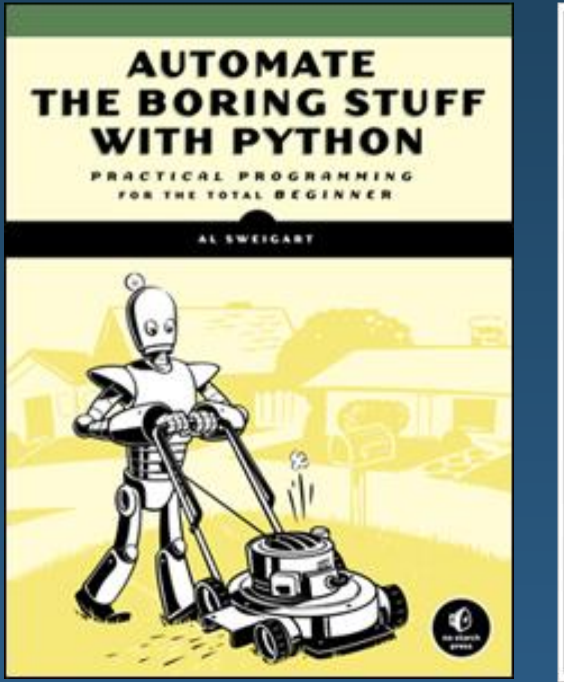
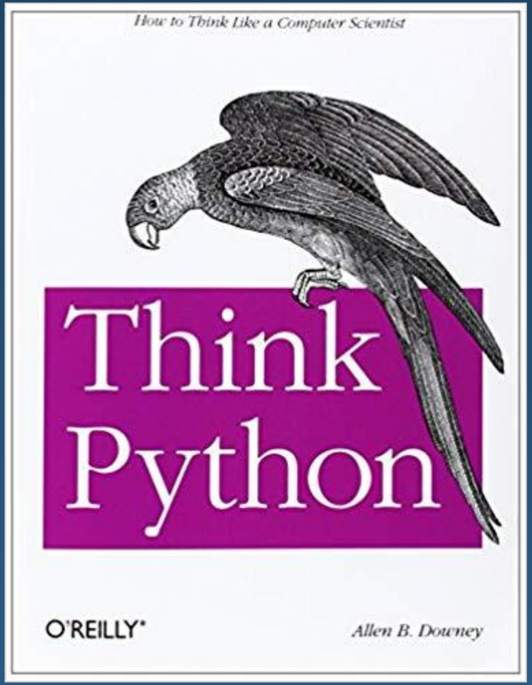
Python Basics

November 2018

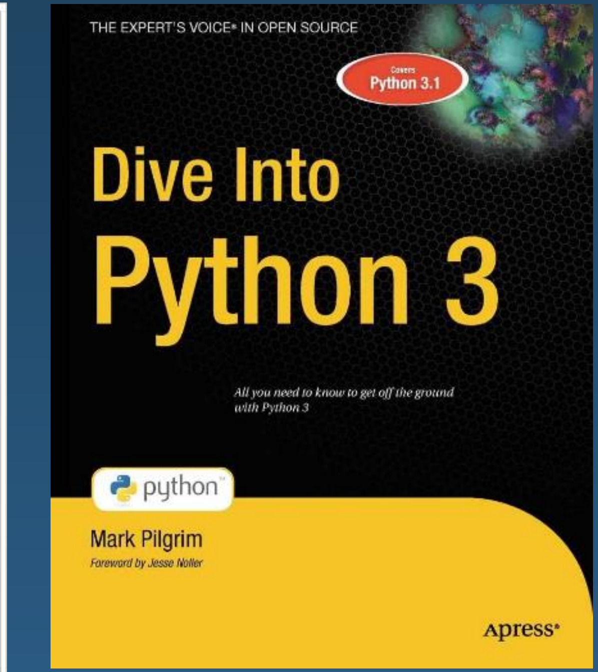
References and Recommended Materials


AUTOMATE THE BORING STUFF WITH PYTHON
PRACTICAL PROGRAMMING FOR THE TOTAL BEGINNER
AL SWEIGART

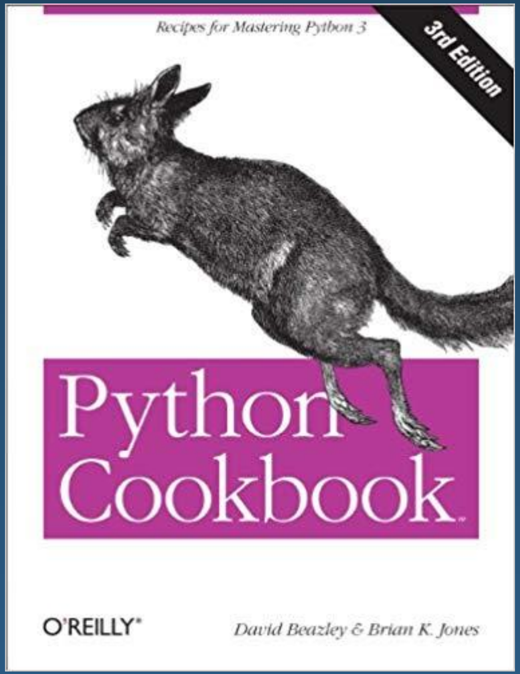
(online book)



(online book)


THE EXPERT'S VOICE® IN OPEN SOURCE
Covers Python 3.1
Dive Into Python 3
All you need to know to get off the ground with Python 3
python
Mark Pilgrim
Foreword by Jesse Noller
Apress

(中文版)


Recipes for Mastering Python 3
3rd Edition
Python Cookbook
O'REILLY
David Beazley & Brian K. Jones

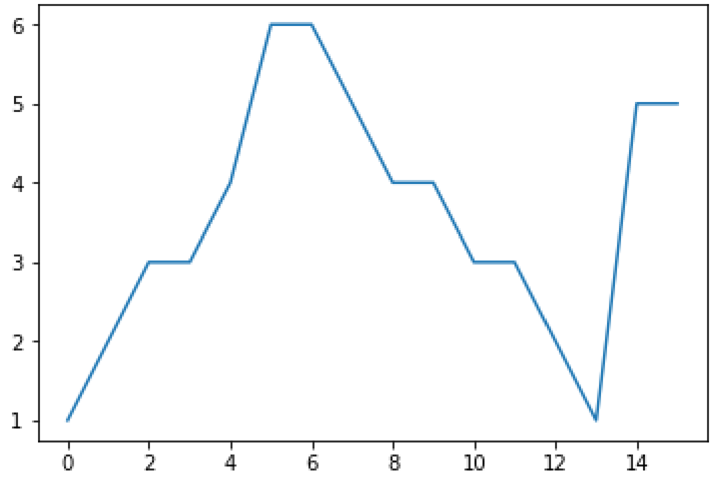
(中文版)

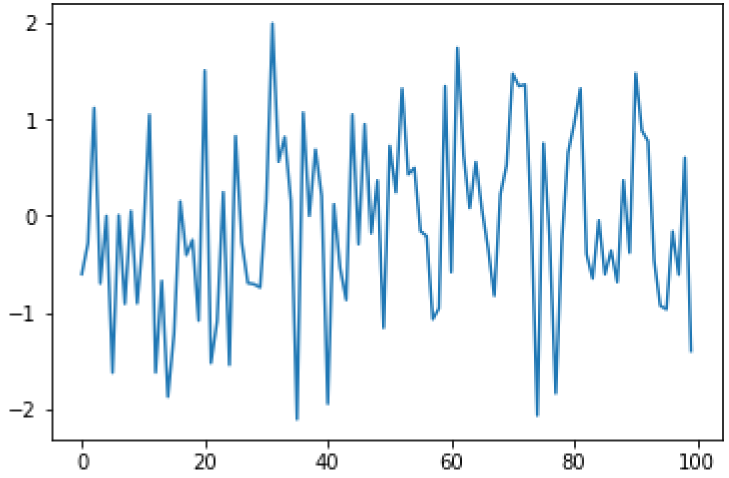
References and Recommended Materials

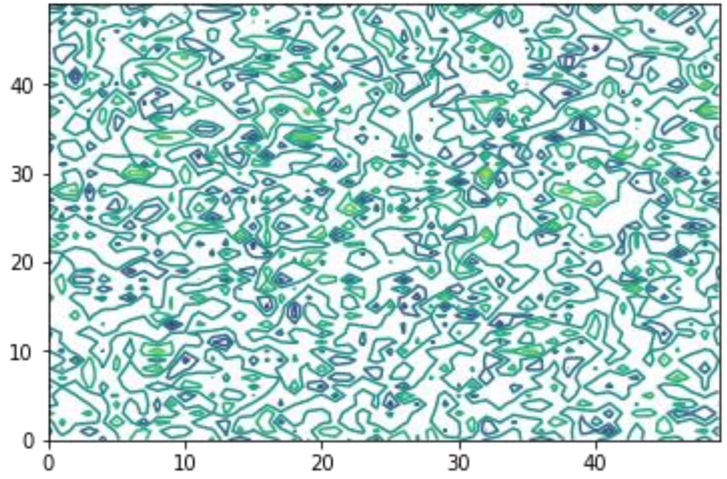
- Automate the Boring Stuff with Python (online book)
- Think Python: How to Think Like a Computer Scientist (online book)
- Dive into Python 3 (中文版)
- Python Cookbook 3rd Edition (中文版)

Start with an Example

- 000_the_first_example.ipynb



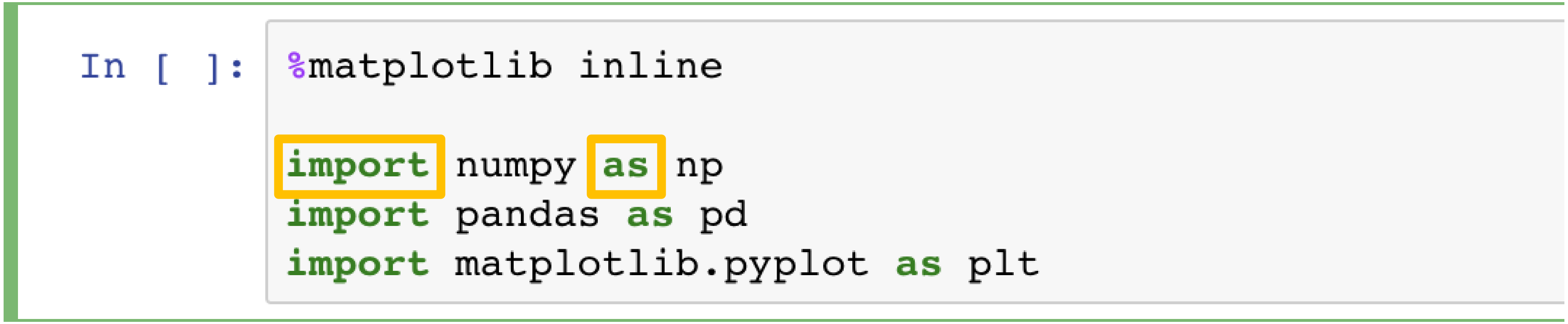




```
# symmetric difference: items appearing in only one set primes ^ odds # with an operator primes.symmetric_difference(odds) # equivalently with a method
```

Start with an Example

- Loading libraries

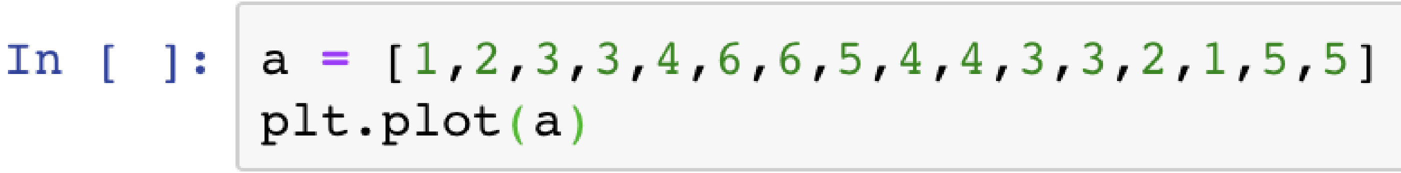


```
In [ ]: %matplotlib inline

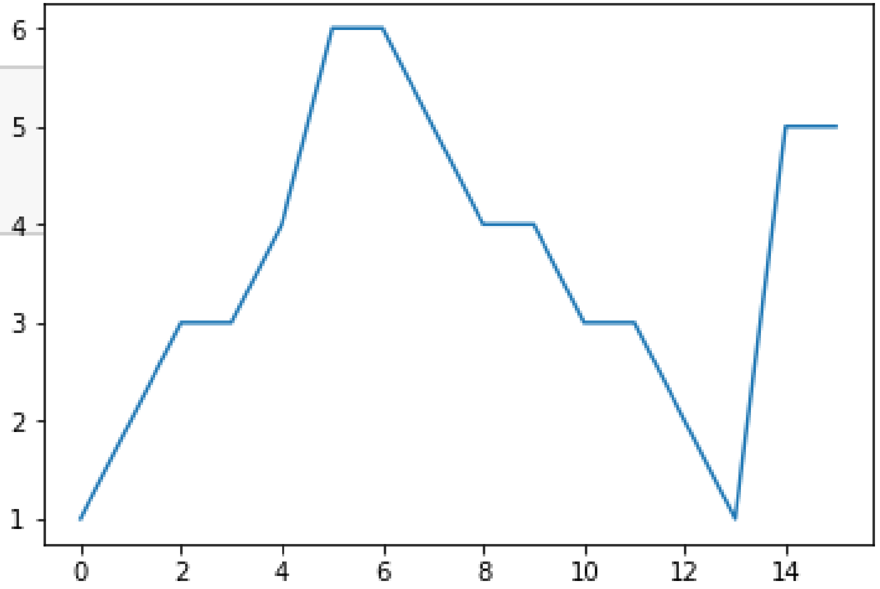
        import numpy as np
        import pandas as pd
        import matplotlib.pyplot as plt
```

Start with an Example

- Python built-in data structures: list
- **List** is a collection which is ordered and changeable. Allows duplicate members.
- In python, you can plot a vector with one line of code

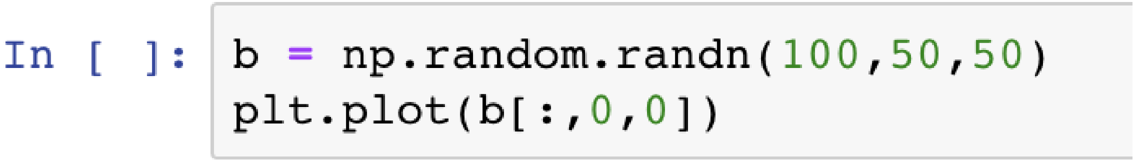


```
In [ ]: a = [1,2,3,3,4,6,6,5,4,4,3,3,2,1,5,5]
        plt.plot(a)
```

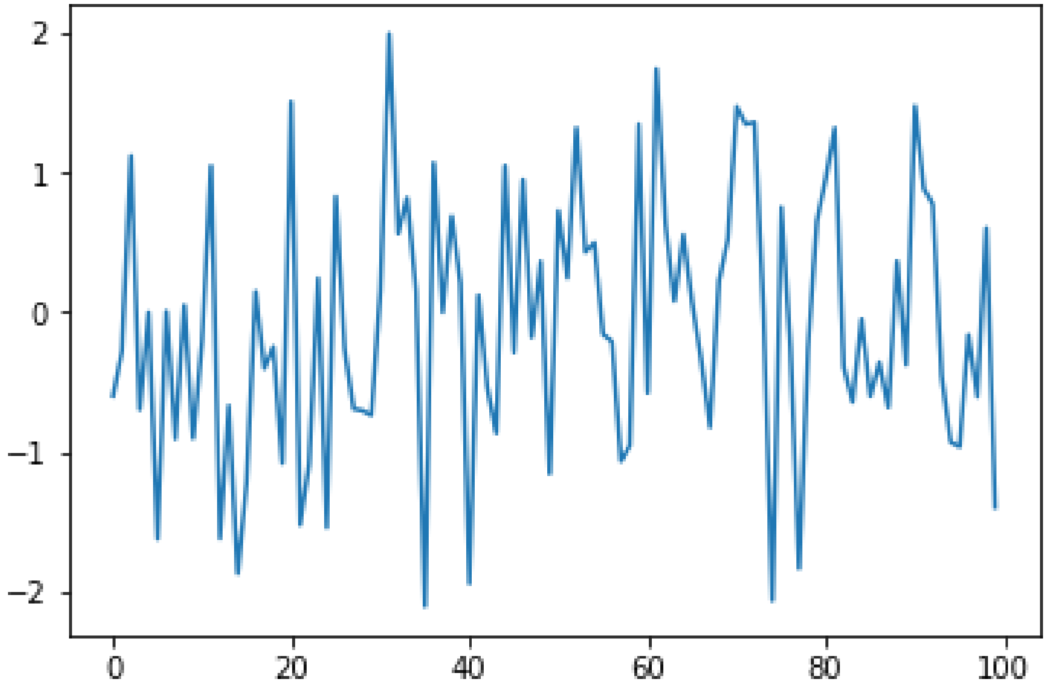


Start with an Example

- Want some random numbers? Simply specify how many you want.
- You can access n-dimensional numpy array easily.

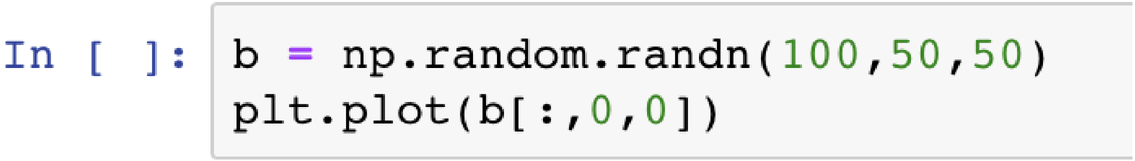


```
In [ ]: b = np.random.randn(100,50,50)
        plt.plot(b[:,0,0])
```

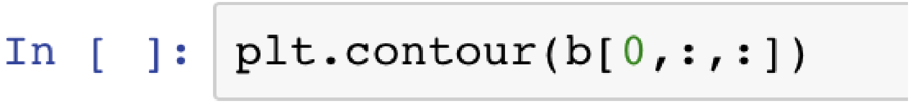


Start with an Example

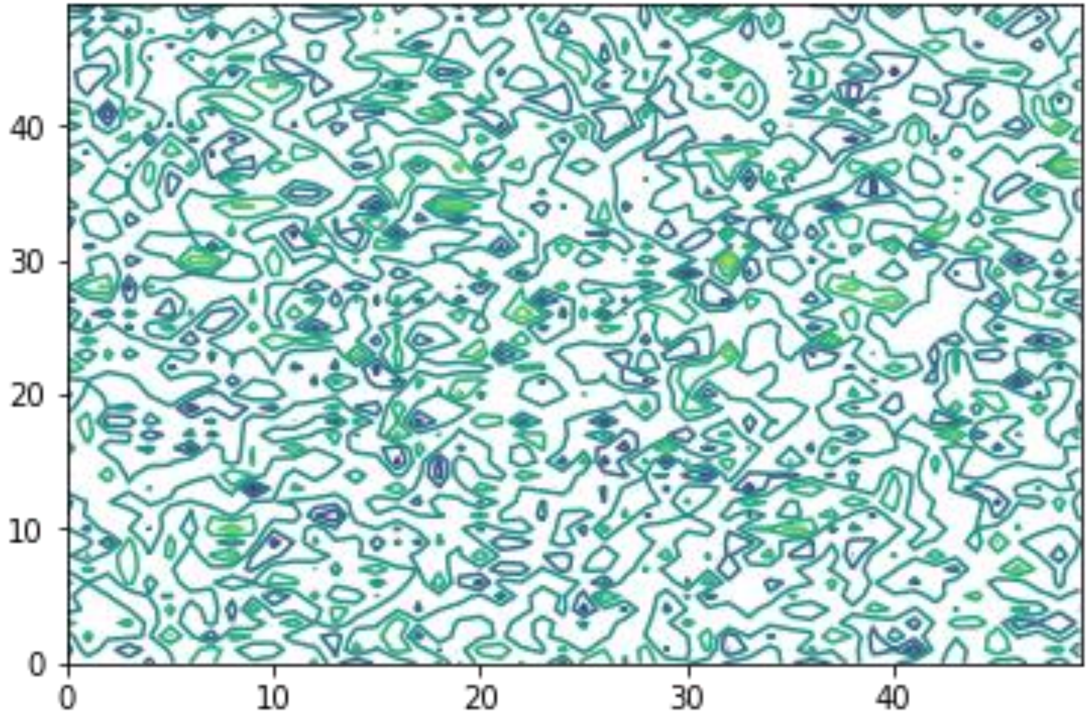
- Want some random numbers? Simply specify how many you want.
- You can access n-dimensional numpy array easily.



```
In [ ]: b = np.random.randn(100,50,50)
        plt.plot(b[:,0,0])
```



```
In [ ]: plt.contour(b[0,:,:])
```

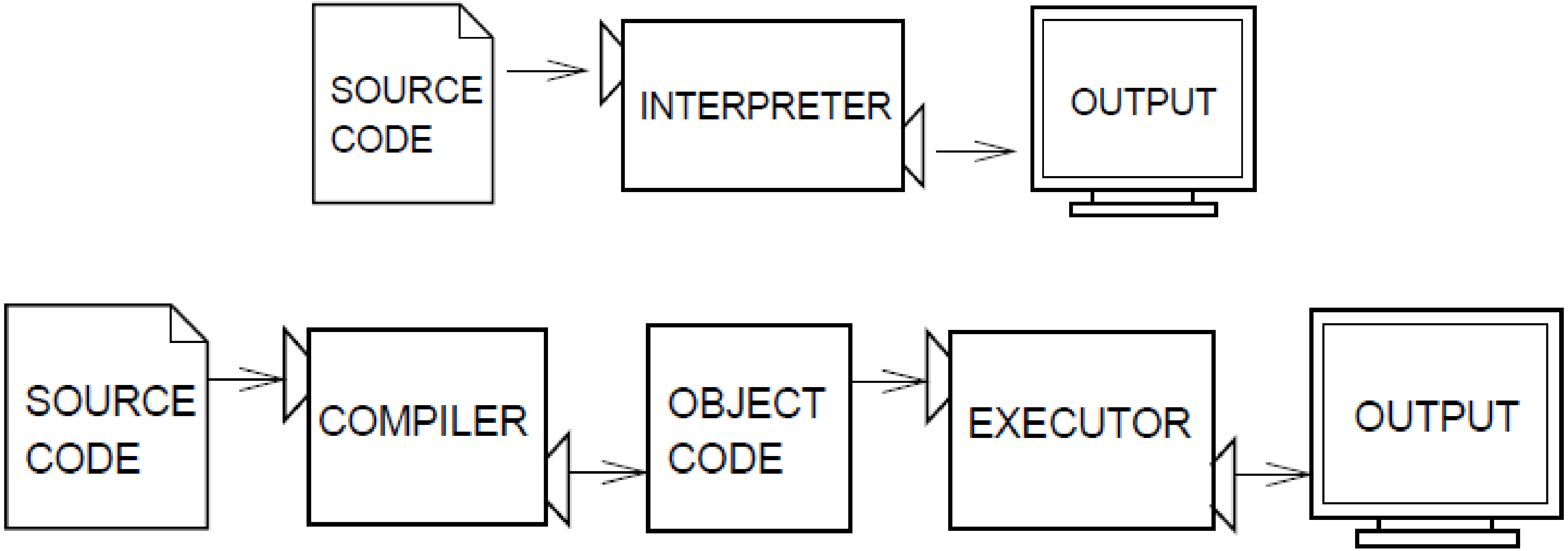


Outline of Python Basics

- Python Core
  - Variables and Controls
  - Function
  - Built-in Data Structures
  - Input / Output
  - Classes and Objects
- NumPy
- Pandas
- Matplotlib

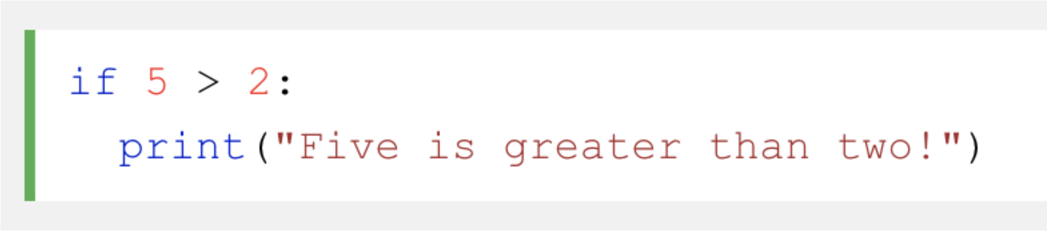
Before you code in Python

- Python is a interpreted language



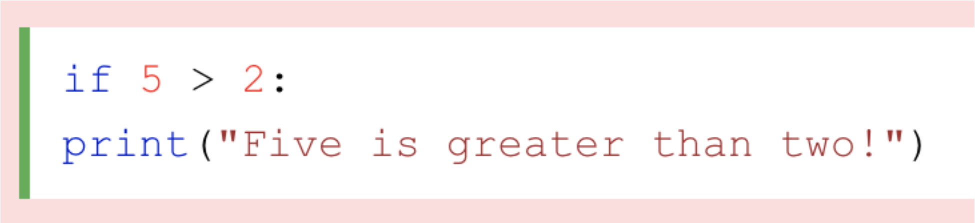
Before you code in Python

- Indentation is strictly enforced in python
  - Correct



```
if 5 > 2:
  print("Five is greater than two!")
```

  - Error



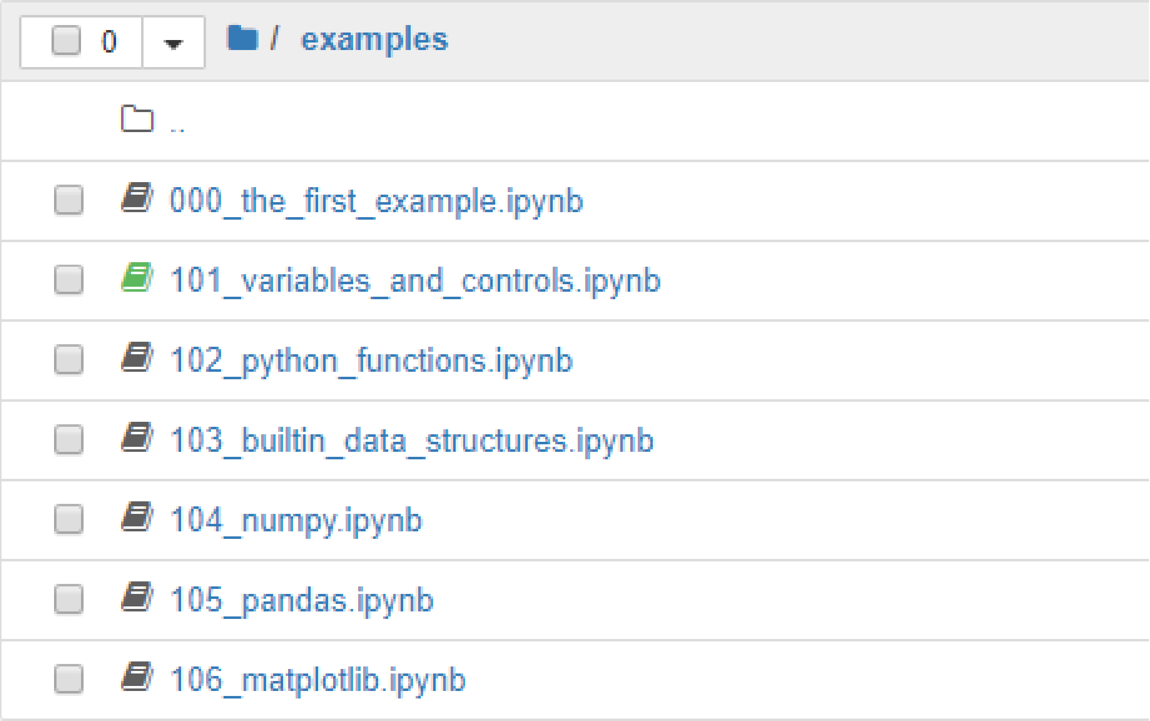
```
if 5 > 2:
print("Five is greater than two!")
```

- Tab is different from space.
- Setup your text editor carefully.

Python Variables and Controls

(1/12)

- Live demo: 101_variables_and_controls.ipynb
- Variables
- Casting
- Operators
- Controls:
  - `if…else…`
  - `while` loop
  - for loop



□ 0 ▾ / examples

..

□ 000_the_first_example.ipynb

□ 101_variables_and_controls.ipynb

□ 102_python_functions.ipynb

□ 103_builtin_data_structures.ipynb

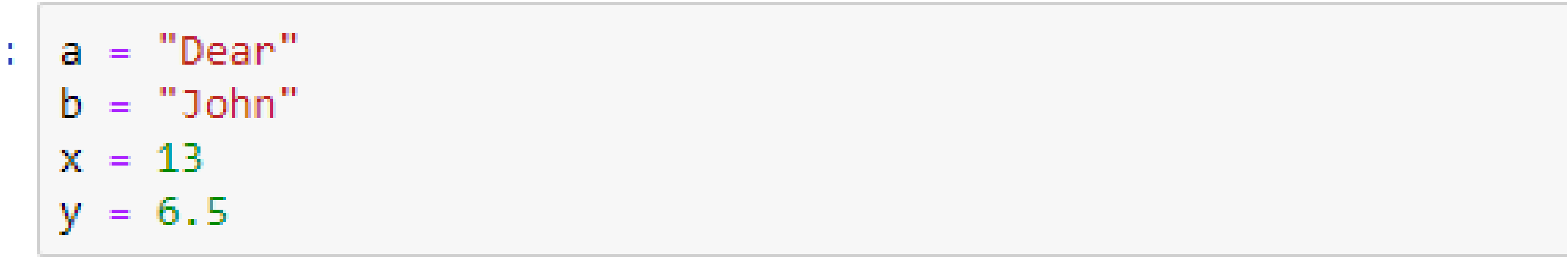
□ 104_numpy.ipynb

□ 105_pandas.ipynb

□ 106_matplotlib.ipynb

Python Variables and Controls

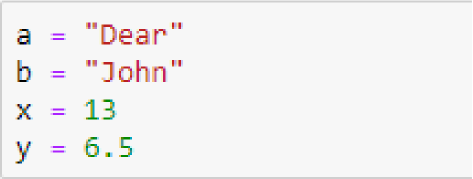
- Creating Variables
  - Unlike other programming languages, Python has no command for declaring a variable. A variable is created the moment you first assign a value to it.



```
a = "Dear"
b = "John"
x = 13
y = 6.5
```

Python Variables and Controls

- Output Variables
  - Use `print()` statement to output variables.



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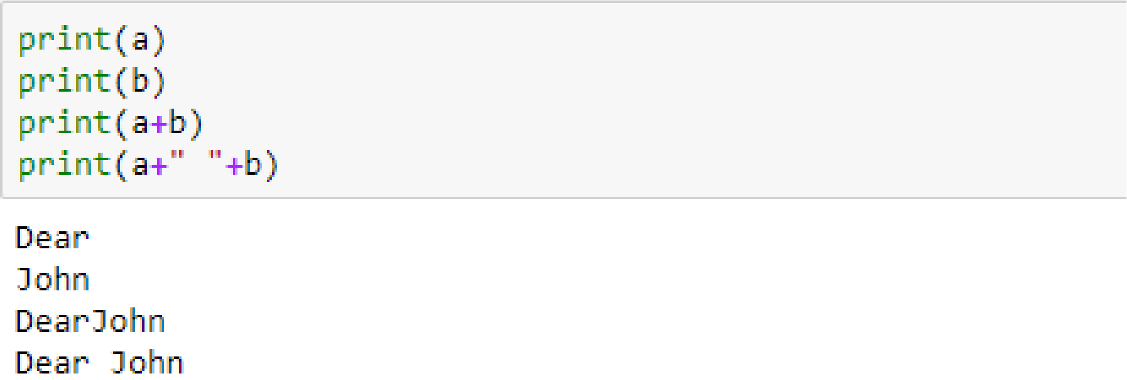
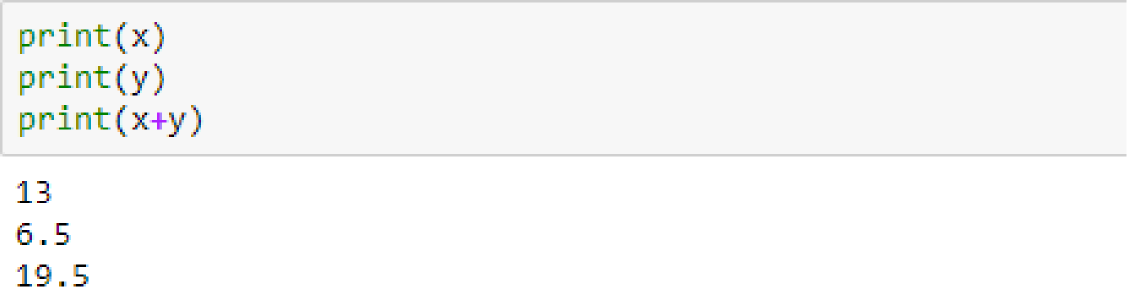


```
print(a)
print(b)
print(a+b)
print(a+" "+b)
```

```
Dear
John
DearJohn
Dear John
```

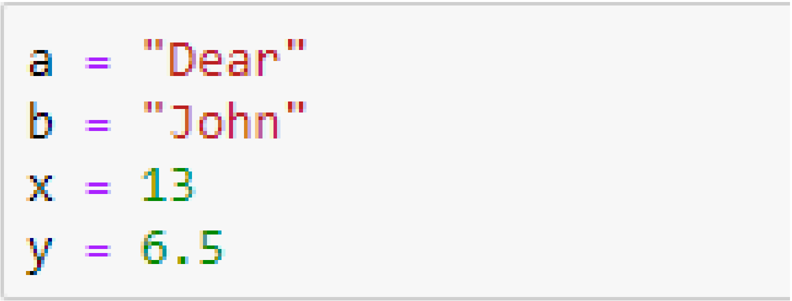


```
print(x)
print(y)
print(x+y)
```

```
13
6.5
19.5
```

Python Variables and Controls (4/12)

- Variable Types
  - Most commonly used variable types: strings, integers, and float point numbers.



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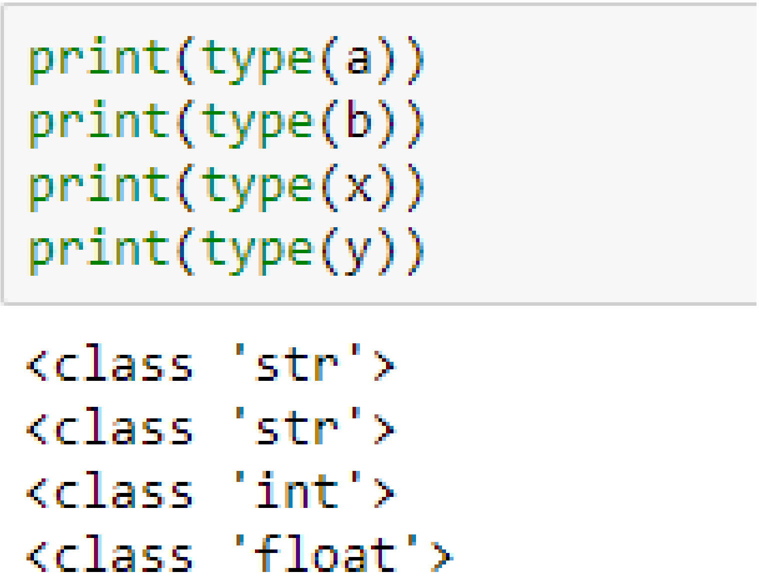
```



```
print(type(a))
print(type(b))
print(type(x))
print(type(y))
```

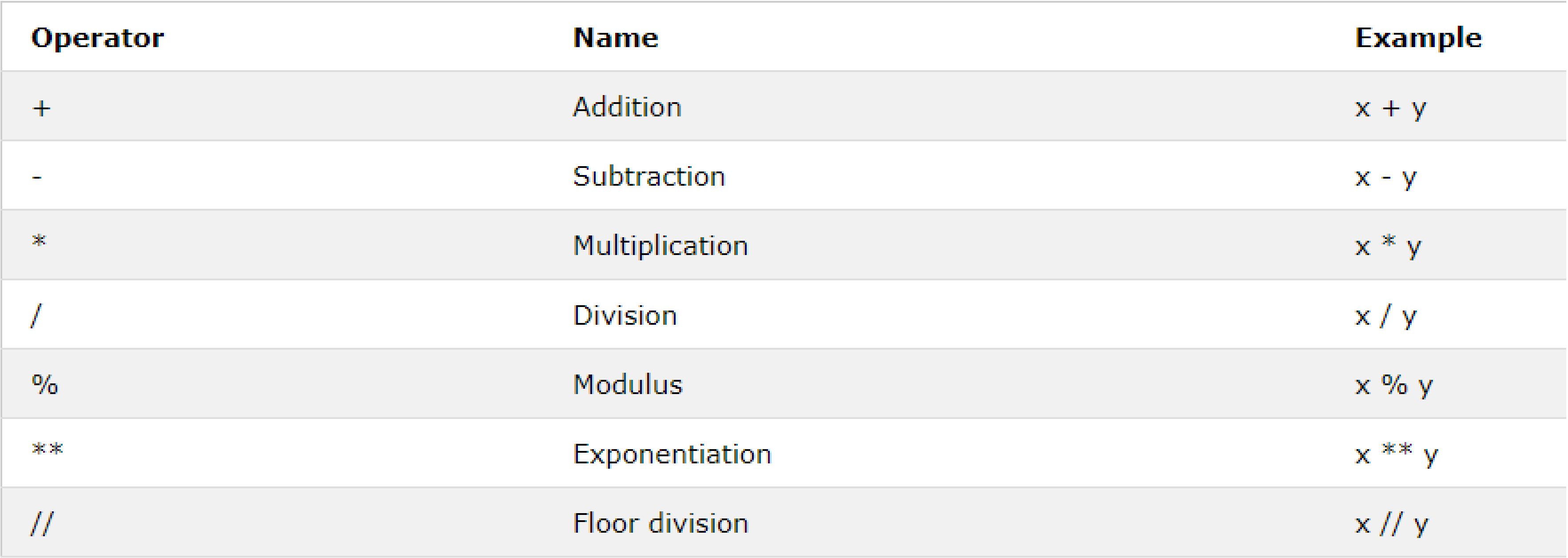
```
<class 'str'>
<class 'str'>
<class 'int'>
<class 'float'>
```

Python Variables and Controls

- Specify a Variable Type (Casting)
  - `int()`
    - constructs an integer number from an integer literal, a float literal (by rounding down to the previous whole number), or a string literal (providing the string represents a whole number)
  - `float()`
    - constructs a float number from an integer literal, a float literal or a string literal (providing the string represents a float or an integer)
  - `str()`
    - constructs a string from a wide variety of data types, including strings, integer literals and float literals

Python Variables and Controls (6/12)

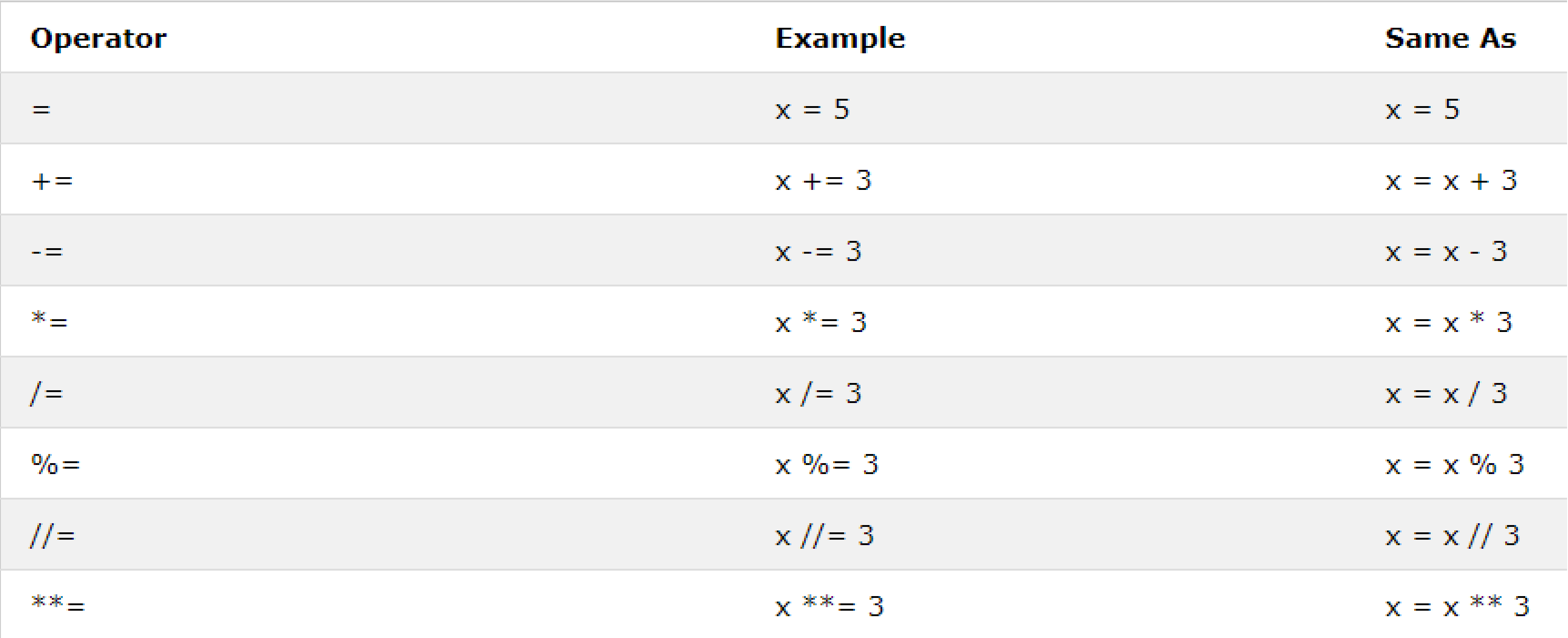
- Python Operators
  - Arithmetic Operators



Operator	Name	Example
+	Addition	x + y
-	Subtraction	x - y
*	Multiplication	x * y
/	Division	x / y
%	Modulus	x % y
**	Exponentiation	x ** y
//	Floor division	x // y

Python Variables and Controls (7/12)

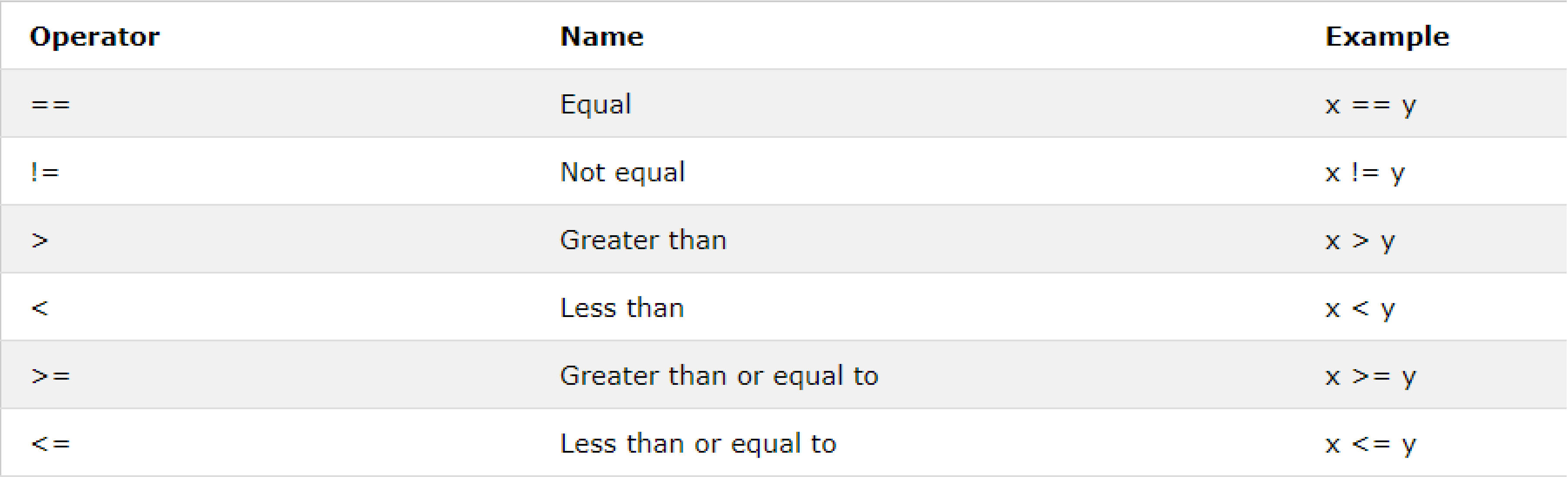
- Python Operators
  - Assignment Operators



Operator	Example	Same As
=	x = 5	x = 5
+=	x += 3	x = x + 3
-=	x -= 3	x = x - 3
*=	x *= 3	x = x * 3
/=	x /= 3	x = x / 3
%=	x %= 3	x = x % 3
//=	x //= 3	x = x // 3
**=	x **= 3	x = x ** 3

Python Variables and Controls (8/12)

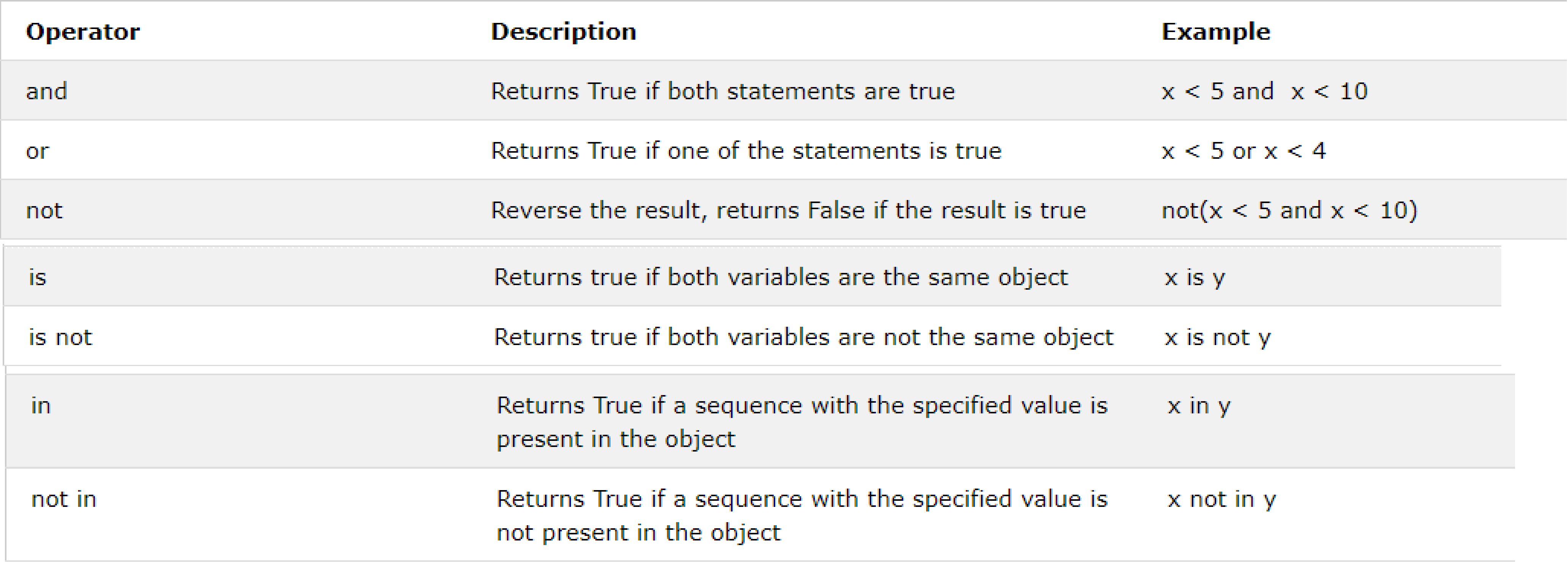
- Python Operators
    - Comparison Operators



Operator	Name	Example
==	Equal	x == y
!=	Not equal	x != y
>	Greater than	x > y
<	Less than	x < y
>=	Greater than or equal to	x >= y
<=	Less than or equal to	x <= y

Python Variables and Controls

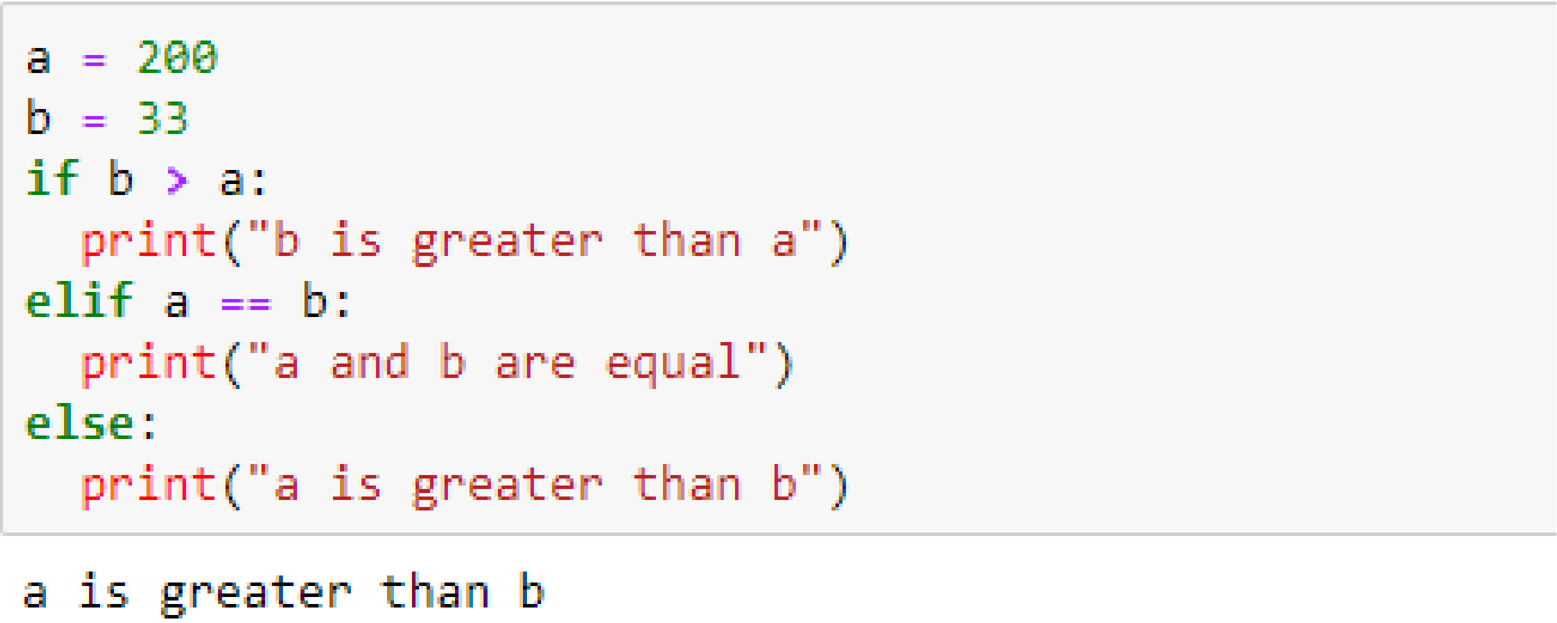
- Python Operators
  - Logical Operators



Operator	Description	Example
and	Returns True if both statements are true	x < 5 and x < 10
or	Returns True if one of the statements is true	x < 5 or x < 4
not	Reverse the result, returns False if the result is true	not(x < 5 and x < 10)
is	Returns true if both variables are the same object	x is y
is not	Returns true if both variables are not the same object	x is not y
in	Returns True if a sequence with the specified value is present in the object	x in y
not in	Returns True if a sequence with the specified value is not present in the object	x not in y

Python Variables and Controls

- Python Controls
  - If…else…
    - `if`
    - `elif`
    - `else`
    - Indentation!

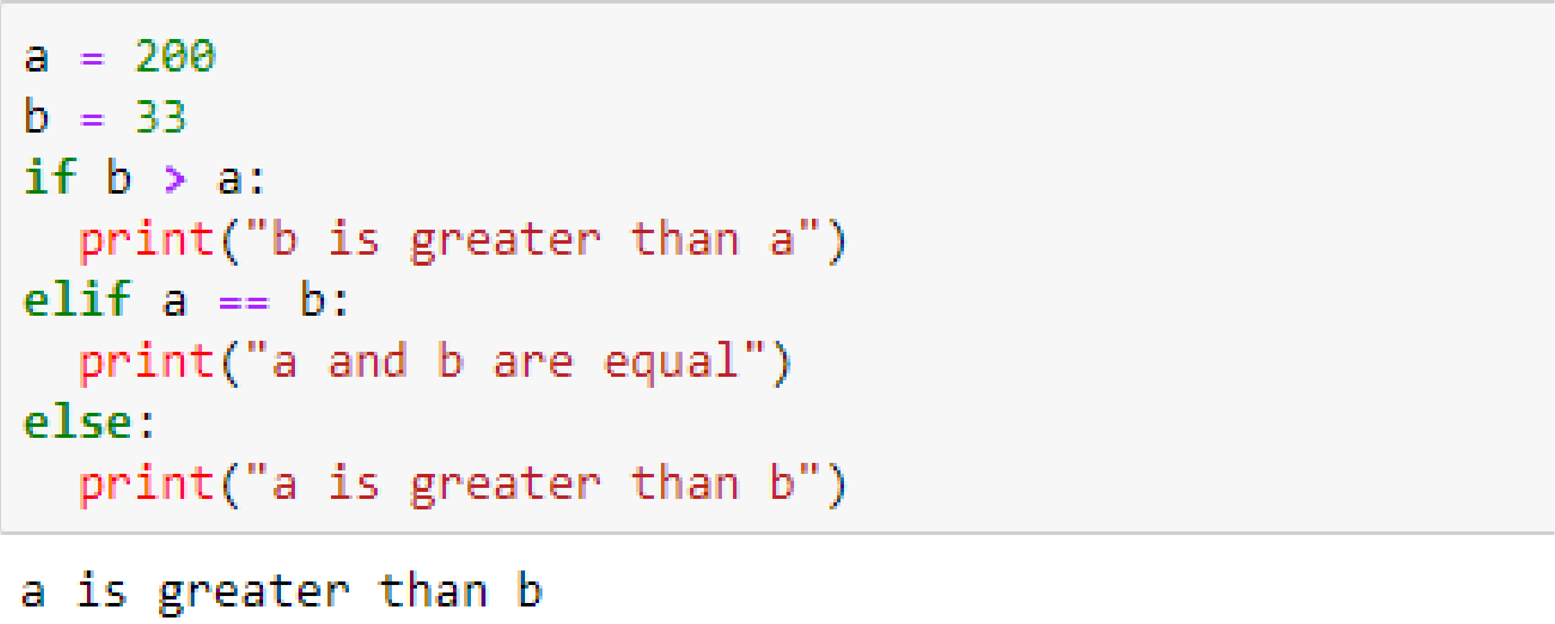


```
a = 200
b = 33
if b > a:
  print("b is greater than a")
elif a == b:
  print("a and b are equal")
else:
  print("a is greater than b")
```

```
a is greater than b
```

Python Variables and Controls

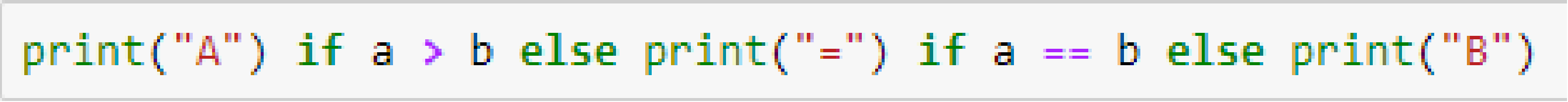
- Python Controls
  - If…else…
    - `if`
    - `elif`
    - `else`
    - Indentation!



```
a = 200
b = 33
if b > a:
  print("b is greater than a")
elif a == b:
  print("a and b are equal")
else:
  print("a is greater than b")
```

```
a is greater than b
```

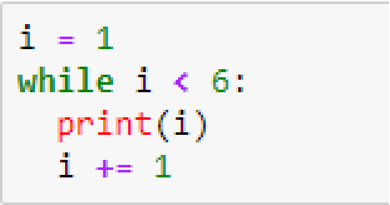
- Short version:



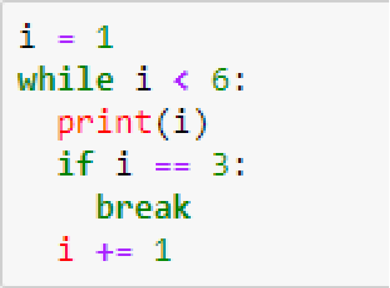
```
print("A") if a > b else print("=") if a == b else print("B")
```

Python Variables and Controls (12/12)

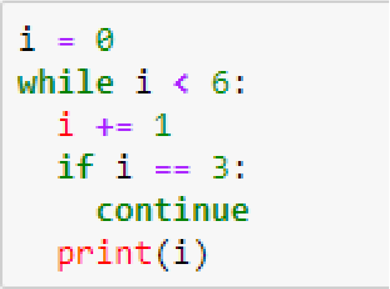
- Python Controls
  - Loops
    - The `while` loop
    - The `for` loop
    - Stop the loop: `break`
    - Skip some loop: `continue`



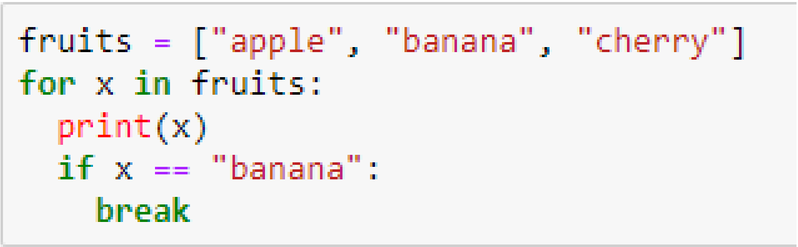
```
i = 1
while i < 6:
  print(i)
  i += 1
```



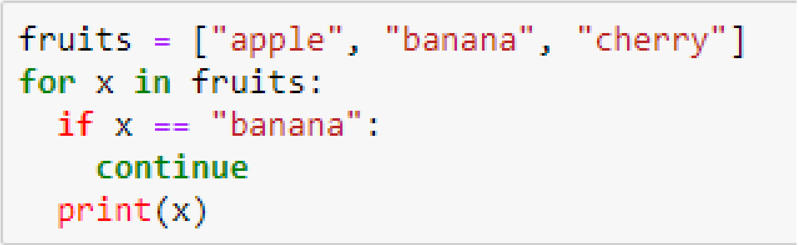
```
i = 1
while i < 6:
  print(i)
  if i == 3:
    break
  i += 1
```



```
i = 0
while i < 6:
  i += 1
  if i == 3:
    continue
  print(i)
```



```
fruits = ["apple", "banana", "cherry"]
for x in fruits:
  print(x)
  if x == "banana":
    break
```



```
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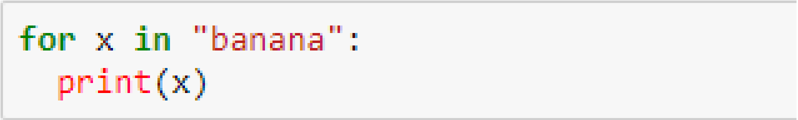
for x in fruits:
  if x == "banana":
    continue
  print(x)
```



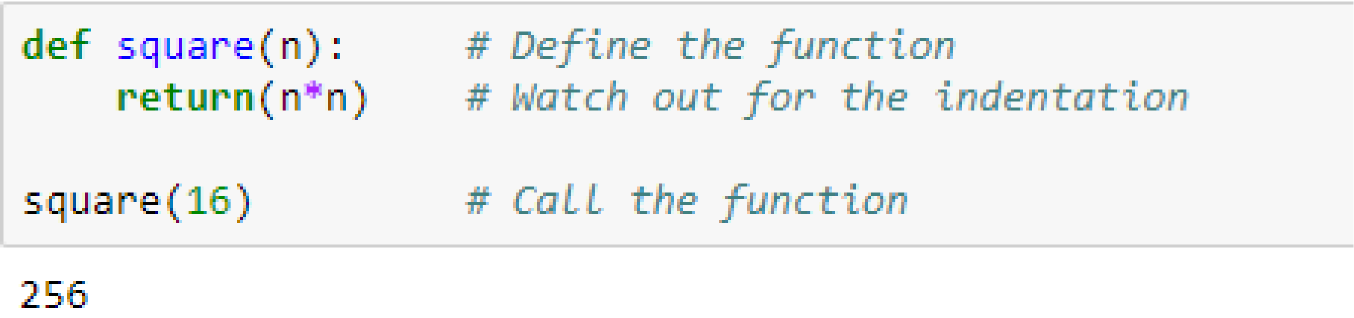
```
for x in "banana":
  print(x)
```

Python Functions

Python Functions

(1/8)

- What is a function?
  - A function is **a block of code** which only runs when it is called.
  - You can pass data, known as **parameters / arguments**, into a function.
  - A function can **return** data as a result.
- A simple example



```
def square(n):      # Define the function
    return(n*n)     # Watch out for the indentation

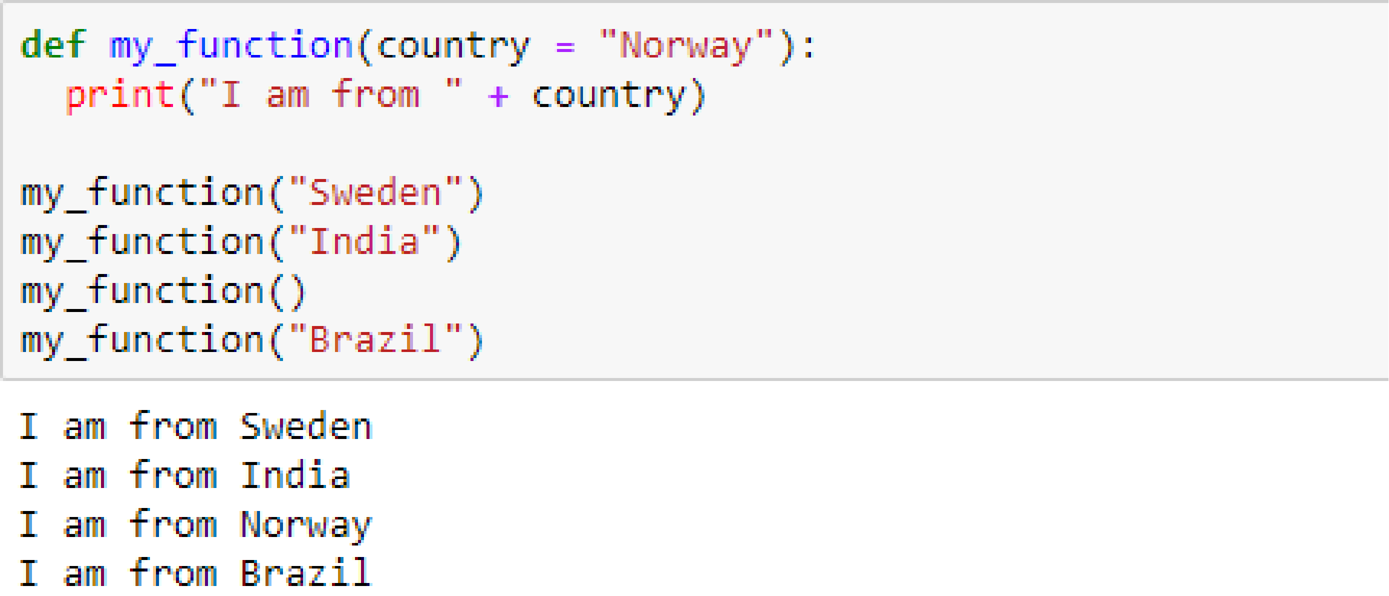
square(16)          # Call the function
```

```
256
```

Python Functions

(2/8)

- Default Parameter Value
  - A set of pre-defined values can be assigned to the parameters, so that the function can be called without specified parameters.



```
def my_function(country = "Norway"):
  print("I am from " + country)

my_function("Sweden")
my_function("India")
my_function()
my_function("Brazil")
```

```
I am from Sweden
I am from India
I am from Norway
I am from Brazil
```

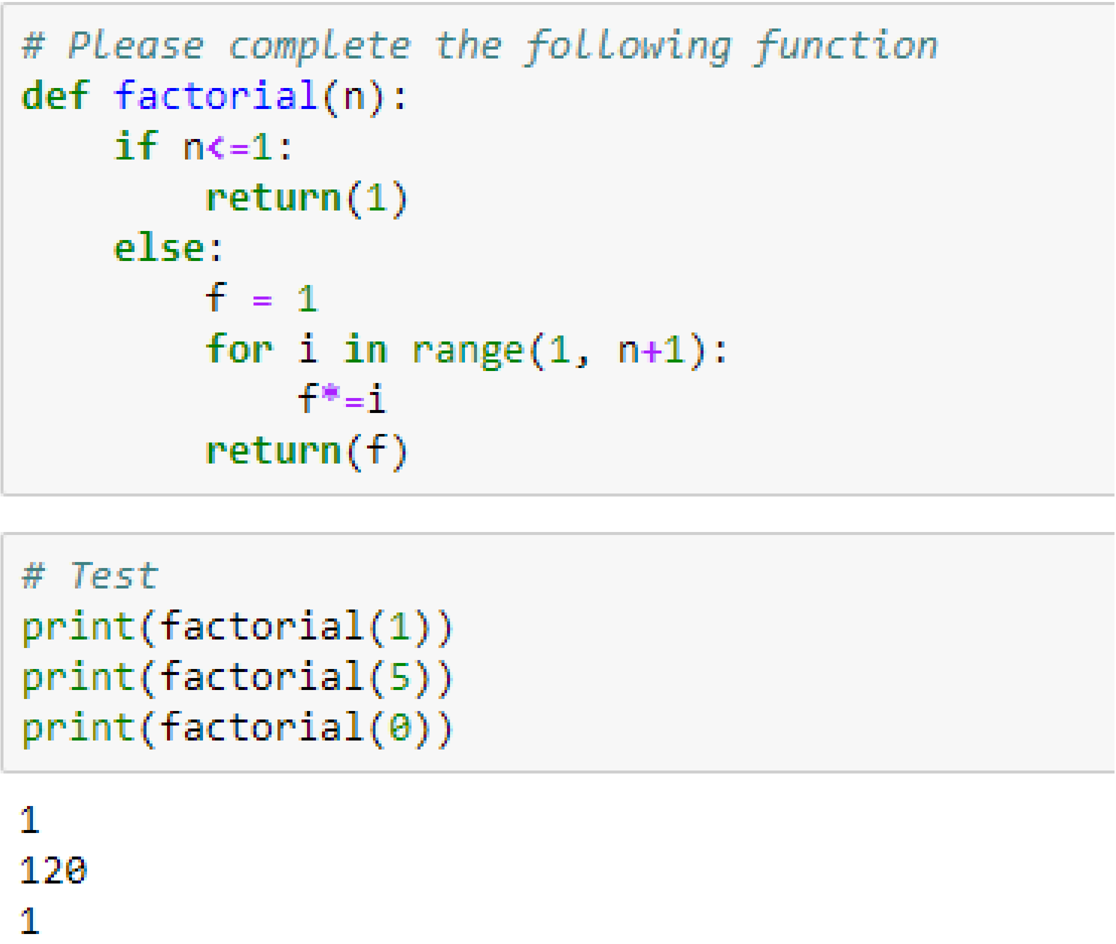
Python Functions

- **Exercise 1 Factorial**
  - In mathematics, the factorial of a non-negative integer n, denoted by n!, is the product of all positive integers less than or equal to n. For example:
  - `5! = 5 * 4 * 3 * 2 * 1 = 120`
  - By definition, `0! = 1`.
  - Please compose a function named `factorial`, which takes in one integer parameter and return the factorial of the integer.

Python Functions

(4/8)

- Exercise 1



```
# Please complete the following function
def factorial(n):
    if n<=1:
        return(1)
    else:
        f = 1
        for i in range(1, n+1):
            f*=i
        return(f)
```

```
# Test
print(factorial(1))
print(factorial(5))
print(factorial(0))
```

```
1
120
1
```

Python Functions

- **Exercise 2 Combination**
  - In mathematics, a combination is a selection of items from a collection, such that the order of selection does not matter.
  - More formally, a **k-combination of a set S** is a subset of k distinct elements of S. If the set has n elements, the number of k-combinations is equal to the binomial coefficient.

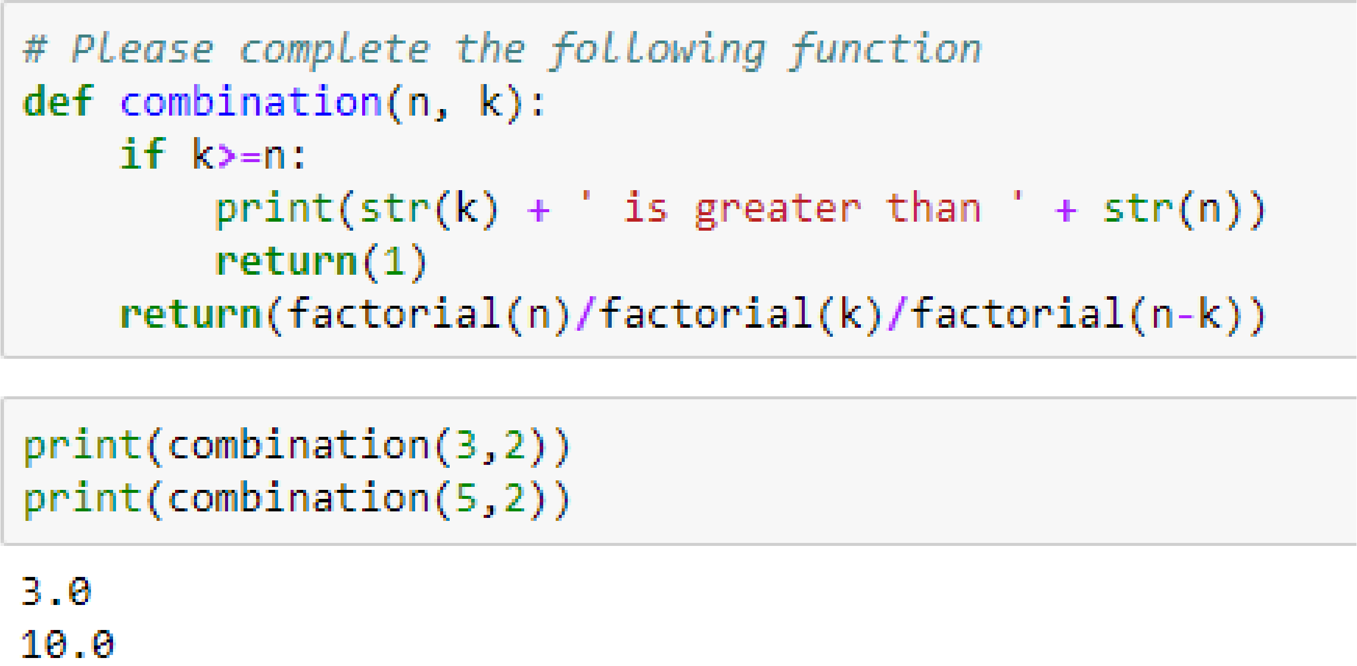
$$combination(n,k) = \frac{n(n-1)\ldots(n-k+1)}{k(k-1)\ldots1} = \frac{n!}{k!(n-k)!}$$

  - Please compose a function named `combination` which takes two integer parameters and return the number of combinations. Please use the `factorial` function you just completed.

Python Functions

(6/8)

- Exercise 2 Combination



```
# Please complete the following function
def combination(n, k):
    if k>=n:
        print(str(k) + ' is greater than ' + str(n))
        return(1)
    return(factorial(n)/factorial(k)/factorial(n-k))
```

```
print(combination(3,2))
print(combination(5,2))
```

```
3.0
10.0
```

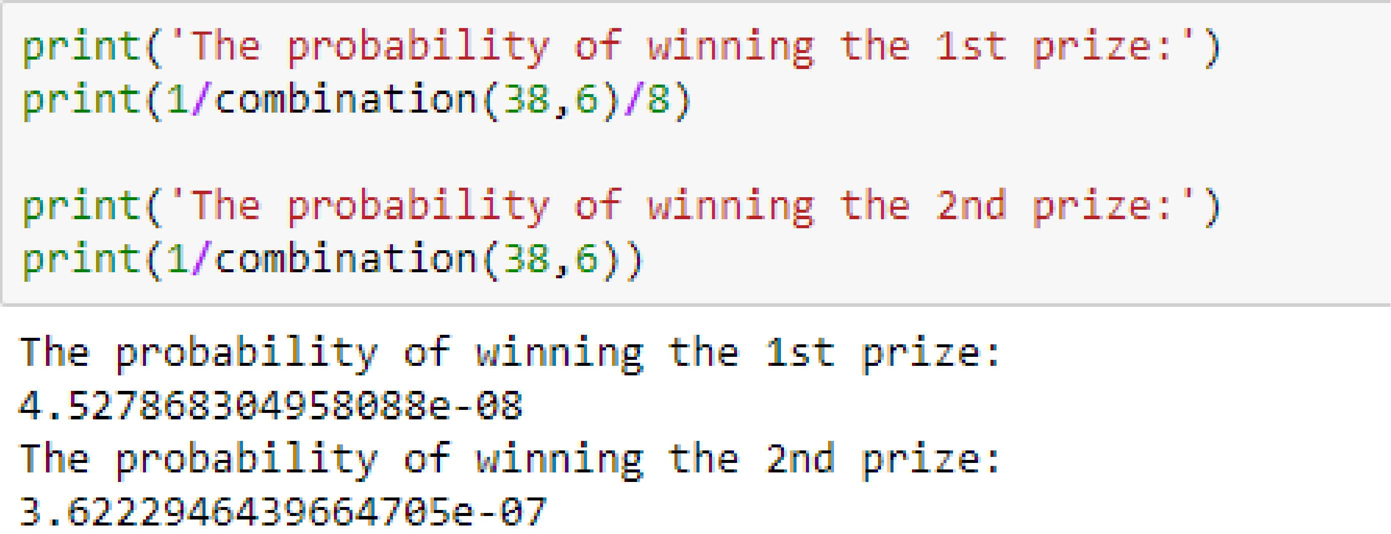
Python Functions

- **Exercise 3 Lottery Time!**
  - 威力彩是一種樂透型遊戲，其選號分為兩區，您必須從第1個選號區中的01~38 的號碼中任選6個號碼，並從第2個選號區中的01~08的號碼中任選1個號碼進行投注，這六個+一個號碼即為您的投注號碼。
    - **頭獎**：第1區六個獎號全中，且第2區亦對中獎號
    - **貳獎**：第1區六個獎號全中，但第2區未對中
  - Please use the `combination` function you completed earlier, to estimate the probability of winning the 1st and 2nd prize.

Python Functions

(8/8)

- **Exercise 3 Lottery Time!**



```
print('The probability of winning the 1st prize:')
print(1/combination(38,6)/8)

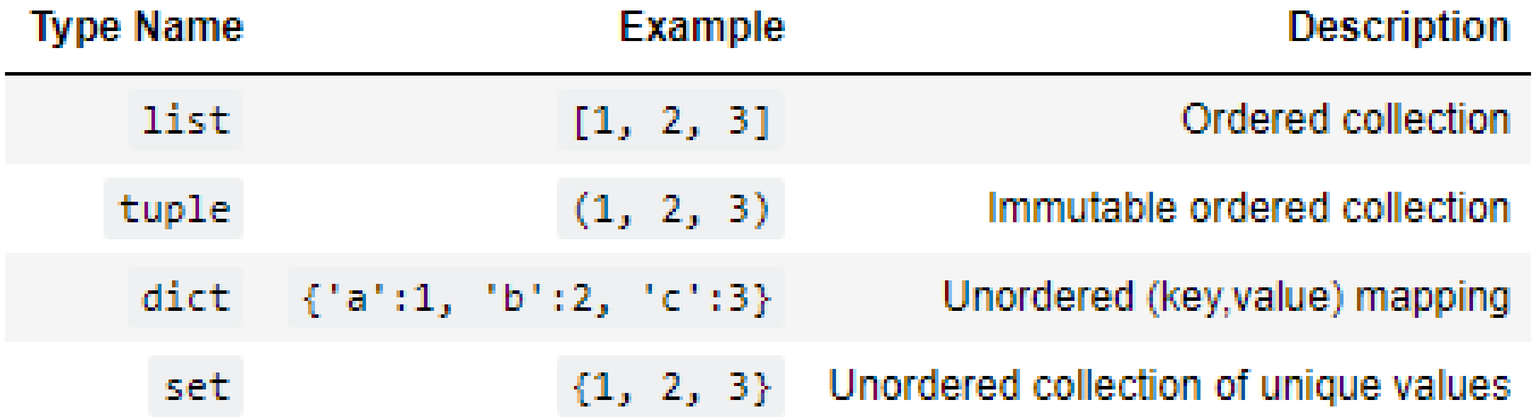
print('The probability of winning the 2nd prize:')
print(1/combination(38,6))
```

```
The probability of winning the 1st prize:
4.527868304958088e-08
The probability of winning the 2nd prize:
3.6222946439664705e-07
```

Python Built-in Data Structures

Python Built-in Data Structures

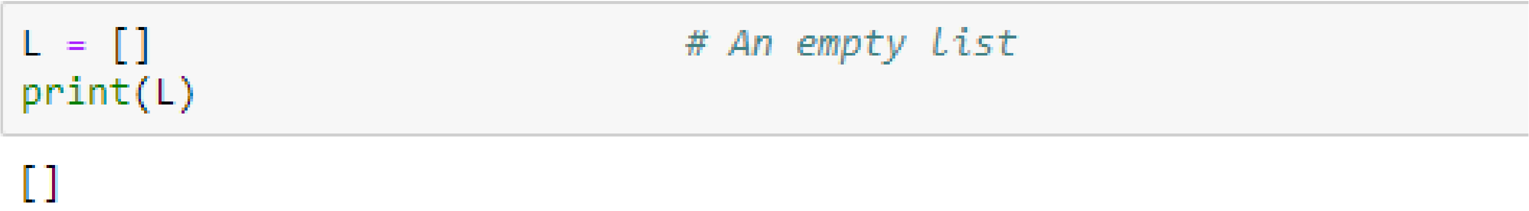
- Earlier we introduced some basic data types in python, such as `int`, `float`, `str`. Python also has several built-in compound types, which act as containers for other types.



Type Name	Example	Description
`list`	`[1, 2, 3]`	Ordered collection
`tuple`	`(1, 2, 3)`	Immutable ordered collection
`dict`	`{'a':1, 'b':2, 'c':3}`	Unordered (key,value) mapping
`set`	`{1, 2, 3}`	Unordered collection of unique values

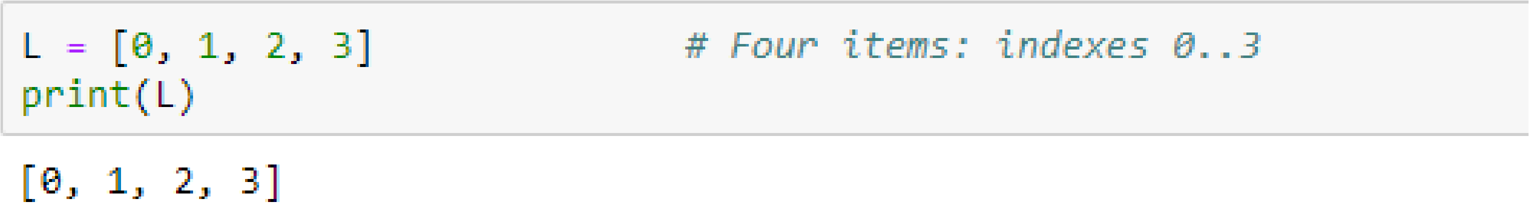
Python Built-in Data Structures

- Lists
  - The lists can contain any sort of object: numbers, strings, and even other lists.
  - Lists may be changed in-place by assignment to offsets and slices, list method calls, deletion statements.



```
L = []                              # An empty list
print(L)
```

```
[]
```

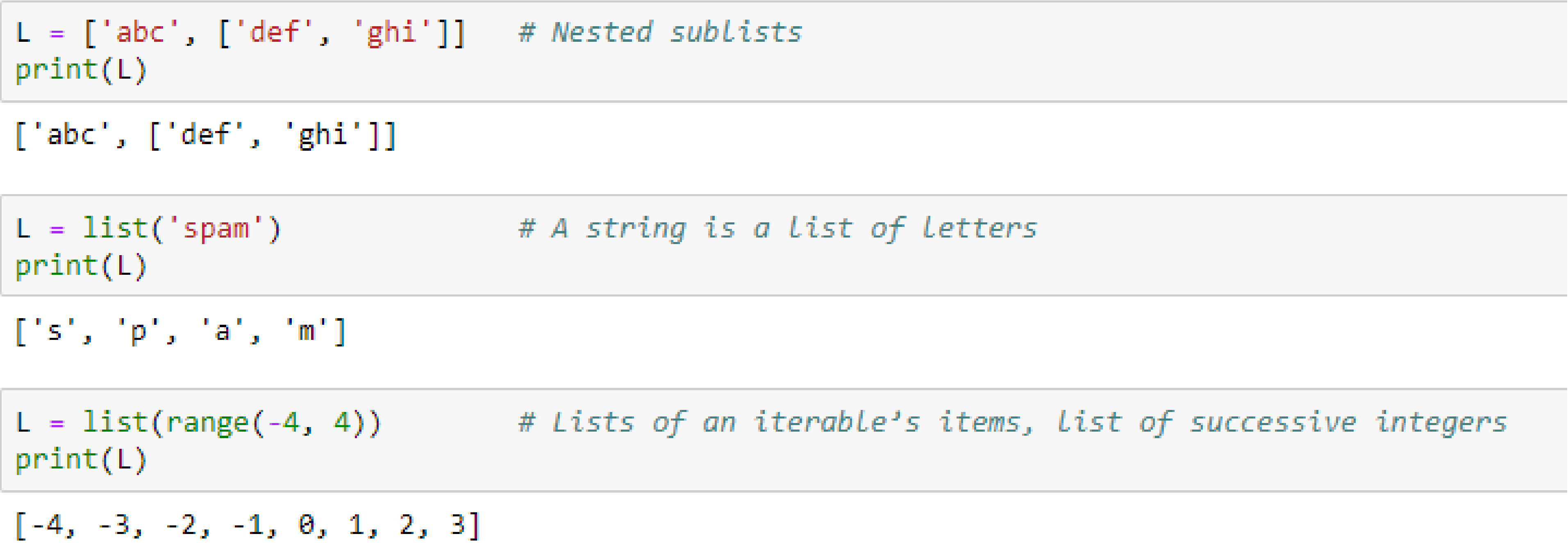


```
L = [0, 1, 2, 3]                    # Four items: indexes 0..3
print(L)
```

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

Python Built-in Data Structures

- Lists



```
L = ['abc', ['def', 'ghi']]    # Nested sublists
print(L)
```

```
['abc', ['def', 'ghi']]
```

```
L = list('spam')               # A string is a list of letters
print(L)
```

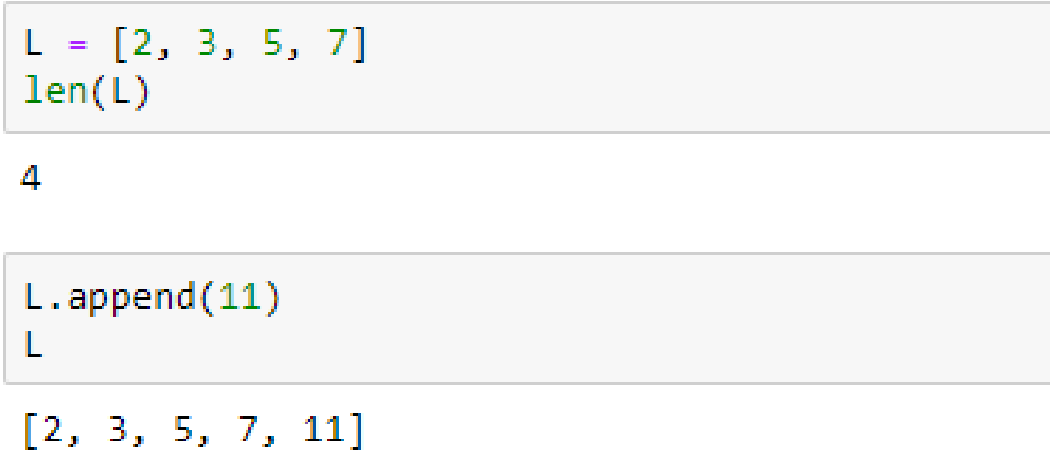
```
['s', 'p', 'a', 'm']
```

```
L = list(range(-4, 4))         # Lists of an iterable’s items, list of successive integers
print(L)
```

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

Python Built-in Data Structures

- Basic operation of lists
  - `len(L)`: the length of a list
  - `list.append(e)`: append `e` to the end of the list



```
L = [2, 3, 5, 7]
len(L)
```

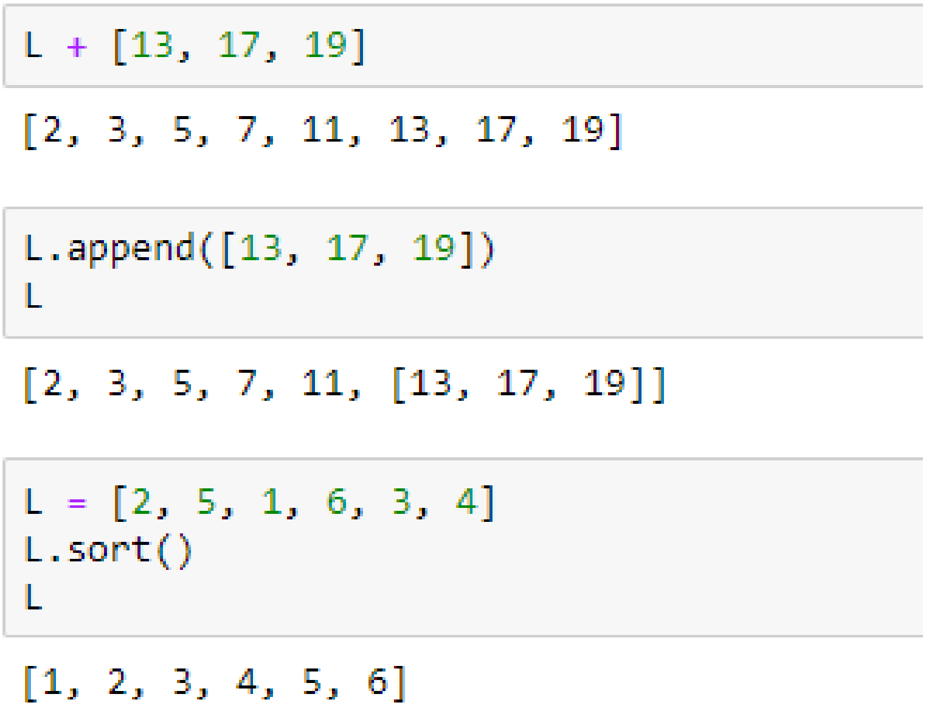
```
4
```

```
L.append(11)
L
```

```
[2, 3, 5, 7, 11]
```

Python Built-in Data Structures

- Basic operation of lists
  - `list.append(e)`: append `e` to the end of the list
  - `+`: concatenate two lists
  - `list.sort()`: in-place sorting of a list



```
L + [13, 17, 19]
```

```
[2, 3, 5, 7, 11, 13, 17, 19]
```

```
L.append([13, 17, 19])
L
```

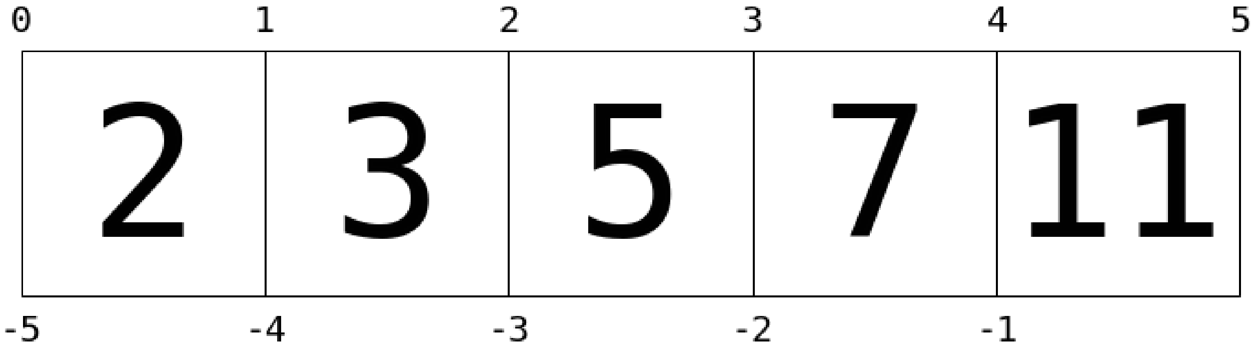
```
[2, 3, 5, 7, 11, [13, 17, 19]]
```

```
L = [2, 5, 1, 6, 3, 4]
L.sort()
L
```

```
[1, 2, 3, 4, 5, 6]
```

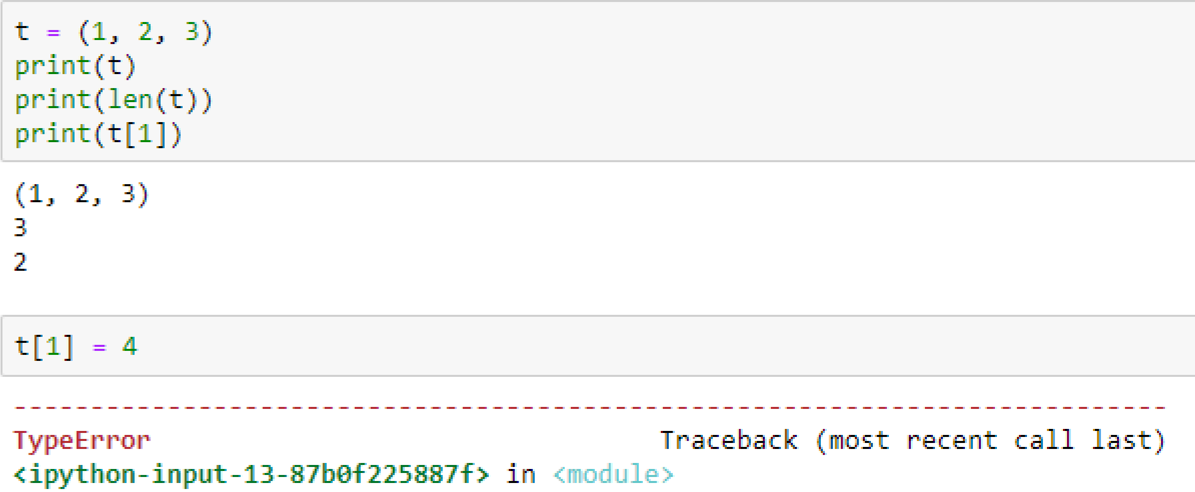
Python Built-in Data Structures

- Indexing the members in a list
  - `L[i]`: the *i*-th member
  - `L[i][j]`: index a member in a 2D list
  - `L[i:j]`: range indexing
  - `L[-1]`: the last element of the inde



Python Built-in Data Structures

- Tuples are in many ways similar to lists, but
  - they are defined with () rather than [].
  - tuples have a length, and can be indexed like a list.
  - Touples are **immutable**:
    - once they are created, their size and contents **cannot be changed**.



```
t = (1, 2, 3)
print(t)
print(len(t))
print(t[1])
```

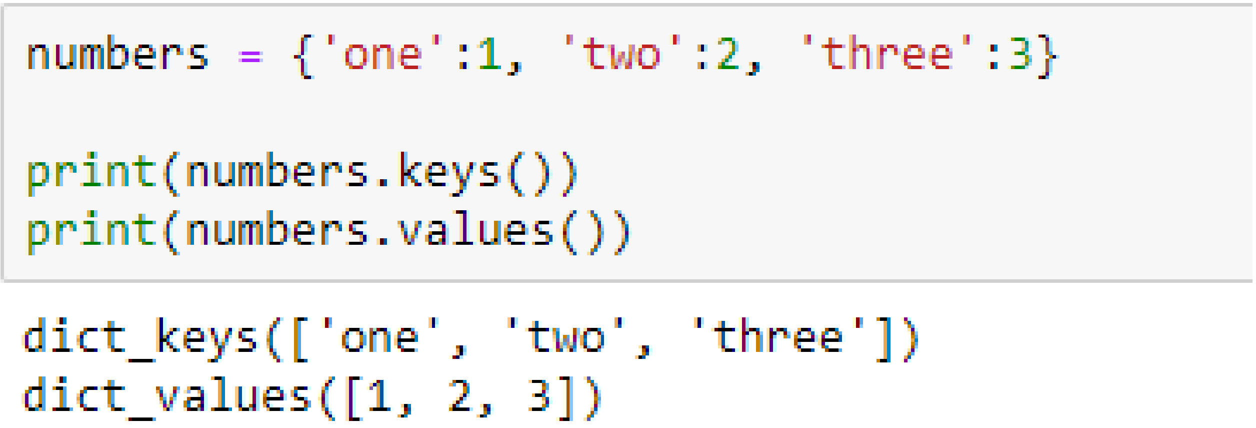
```
(1, 2, 3)
3
2
```

```
t[1] = 4
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-13-87b0f225887f> in <module>
```

Python Built-in Data Structures

- Dictionary
  - Dictionaries are extremely flexible mappings of ***keys to values***
  - The basis of much of Python's internal implementation



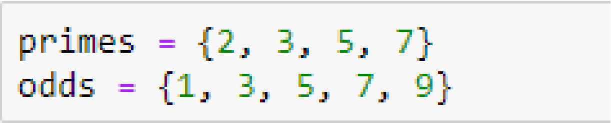
```
numbers = {'one':1, 'two':2, 'three':3}

print(numbers.keys())
print(numbers.values())
```

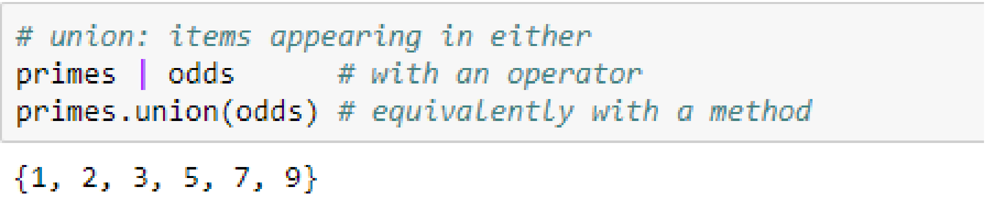
```
dict_keys(['one', 'two', 'three'])
dict_values([1, 2, 3])
```

Python Built-in Data Structures

- Set
  - The set contains unordered collections of unique items.
  - They are defined with the curly brackets.

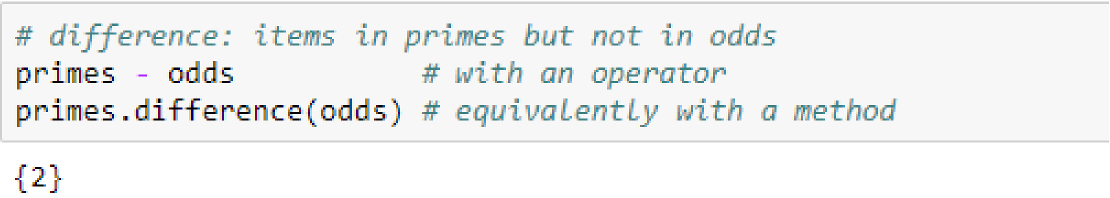


```
primes = {2, 3, 5, 7}
odds = {1, 3, 5, 7, 9}
```



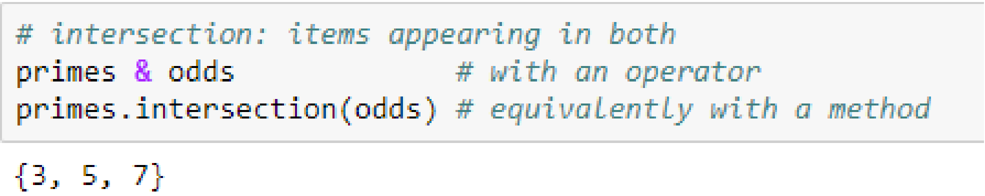
```
# union: items appearing in either
primes | odds      # with an operator
primes.union(odds) # equivalently with a method
```

```
{1, 2, 3, 5, 7, 9}
```



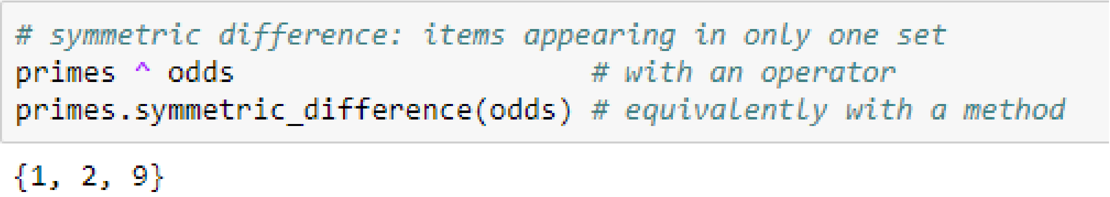
```
# difference: items in primes but not in odds
primes - odds           # with an operator
primes.difference(odds) # equivalently with a method
```

```
{2}
```



```
# intersection: items appearing in both
primes & odds             # with an operator
primes.intersection(odds) # equivalently with a method
```

```
{3, 5, 7}
```



```
# symmetric difference: items appearing in only one set
primes ^ odds                     # with an operator
primes.symmetric_difference(odds) # equivalently with a method
```

```
{1, 2, 9}
```

More Data Structures

- The lists, tuples, dictionaries, and sets are very useful.
- But for data analysis, we need some advanced data structures with functions to speed up the processing.

NumPy

SciPy.org

scikit learn

matplotlib

pandas

$y_{it} = \beta' x_{it} + \mu_i + \epsilon_{it}$

Python Libraries for Data Science

Python Libraries for Data Science

NumPy:

- Introduces new objects such as **multi-dimensional arrays** and matrices
- Introduces functions for advanced **mathematical** and **statistical** operations
- Provides **vectorization** of mathematical operations (significant performance gain)

Link: http://www.numpy.org/

Python Libraries for Data Science

SciPy:

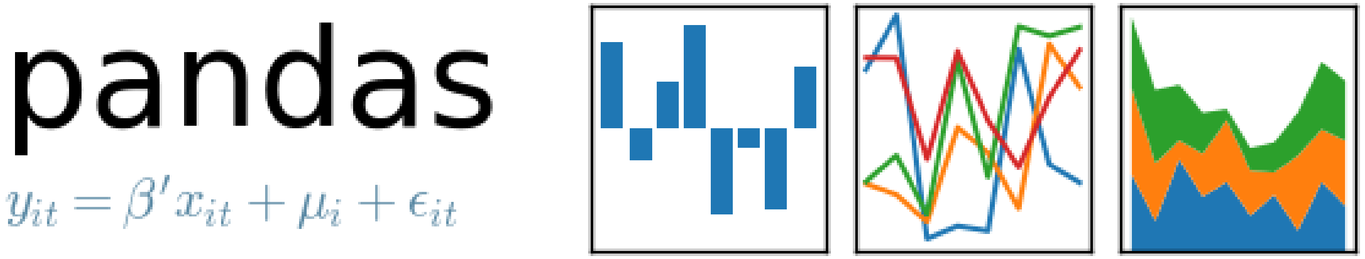
- Provides algorithms for linear algebra, differential equations, numerical integration, optimization, statistics and more.

Link: https://www.scipy.org/scipylib/

Python Libraries for Data Science

Pandas:

- Adds **DataFrame** designed to work with table-like data
- Provides **data manipulation** tools such merging, sorting, slicing, and aggregation
- Provides tools for **missing data** processing



Link: http://pandas.pydata.org/

Python Libraries for Data Science

SciKit-Learn:

- Provides implementations of classical **machine learning** algorithms such as classification, regression, clustering, and model validation

Link: http://scikit-learn.org/

Python Libraries for Data Science

matplotlib:

- A python **2D plotting library** which produces publication quality figures in a variety of hardcopy formats

Link: https://matplotlib.org/

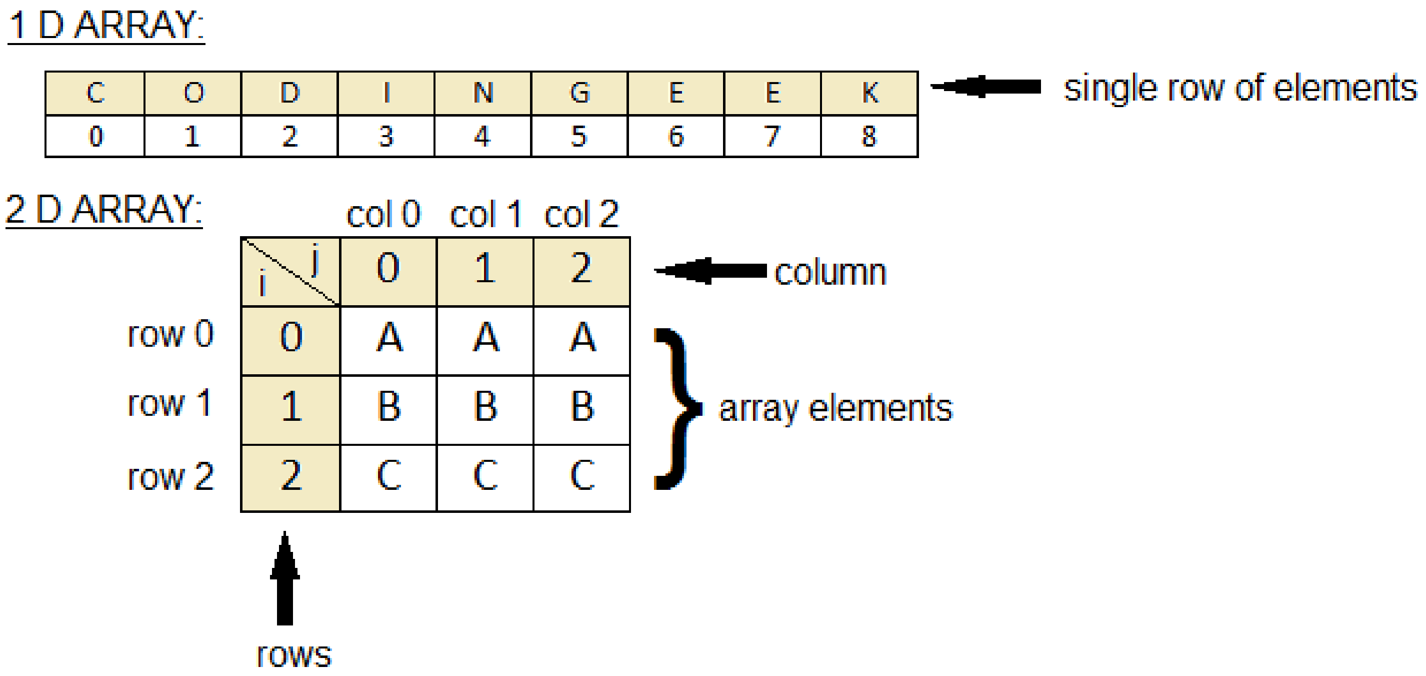
NumPy

NumPy is the fundamental package for scientific computing with Python. It contains among other things:

- a powerful **N-dimensional array object**
- sophisticated (broadcasting) functions
- tools for integrating C/C++ and Fortran code
- useful **linear algebra**, **Fourier transform**, and **random number** capabilities

NumPy Array Structures

- Key attributes
  - dtype
  - shape
  - ndim
  - strides
  - data



1 D ARRAY:

C	O	D	I	N	G	E	E	K
0	1	2	3	4	5	6	7	8

single row of elements

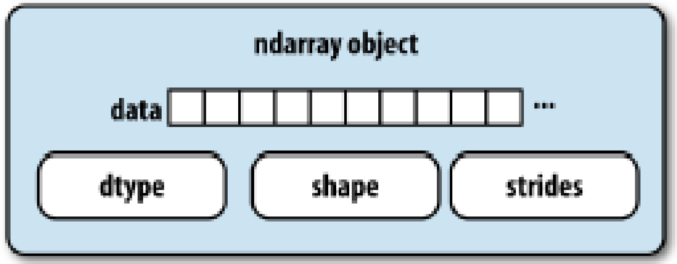
2 D ARRAY:

		col 0	col 1	col 2
	i \ j	0	1	2
row 0	0	A	A	A
row 1	1	B	B	B
row 2	2	C	C	C

column

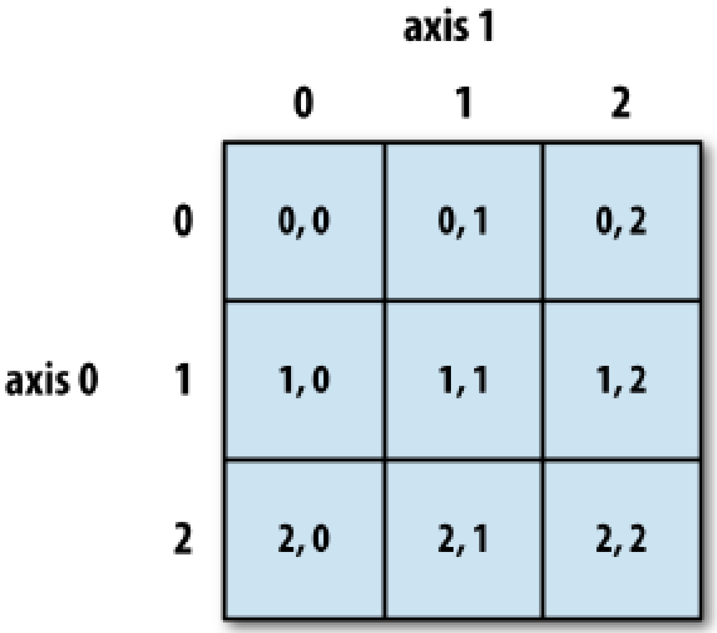
array elements

rows

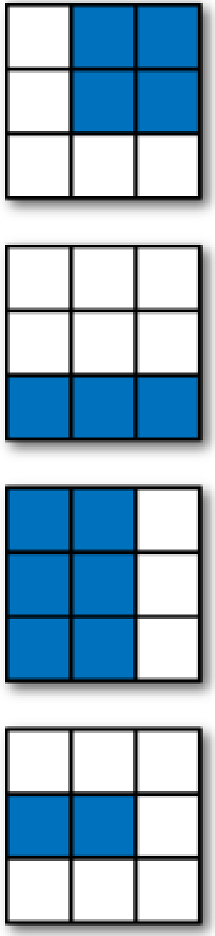


NumPy Array Examples

- Array indexing and shape



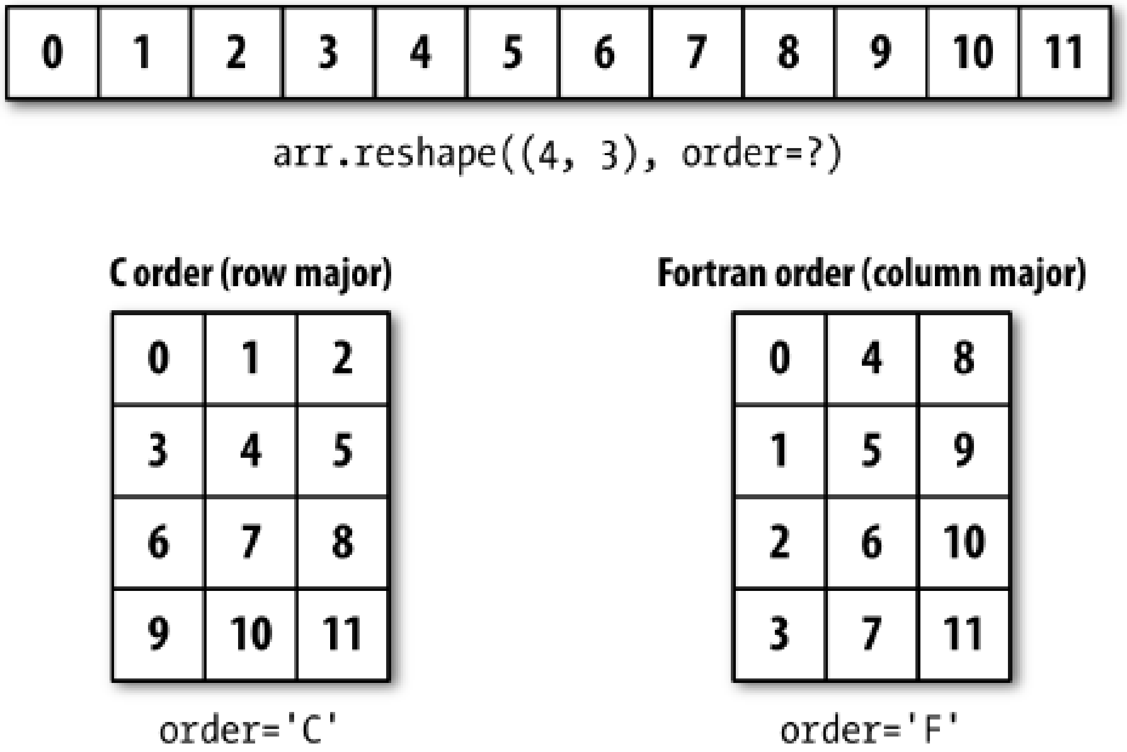
		axis 1		
		0	1	2
	0	0,0	0,1	0,2
axis 0	1	1,0	1,1	1,2
	2	2,0	2,1	2,2



Expression	Shape
arr[:2, 1:]	(2, 2)
arr[2] arr[2, :] arr[2:, :]	(3,) (3,) (1, 3)
arr[:, :2]	(3, 2)
arr[1, :2] arr[1:2, :2]	(2,) (1, 2)

NumPy Array Operations

- `.reshape`: change the dimension of arrays



0	1	2	3	4	5	6	7	8	9	10	11

```
arr.reshape((4, 3), order=?)
```

C order (row major)

0	1	2
3	4	5
6	7	8
9	10	11

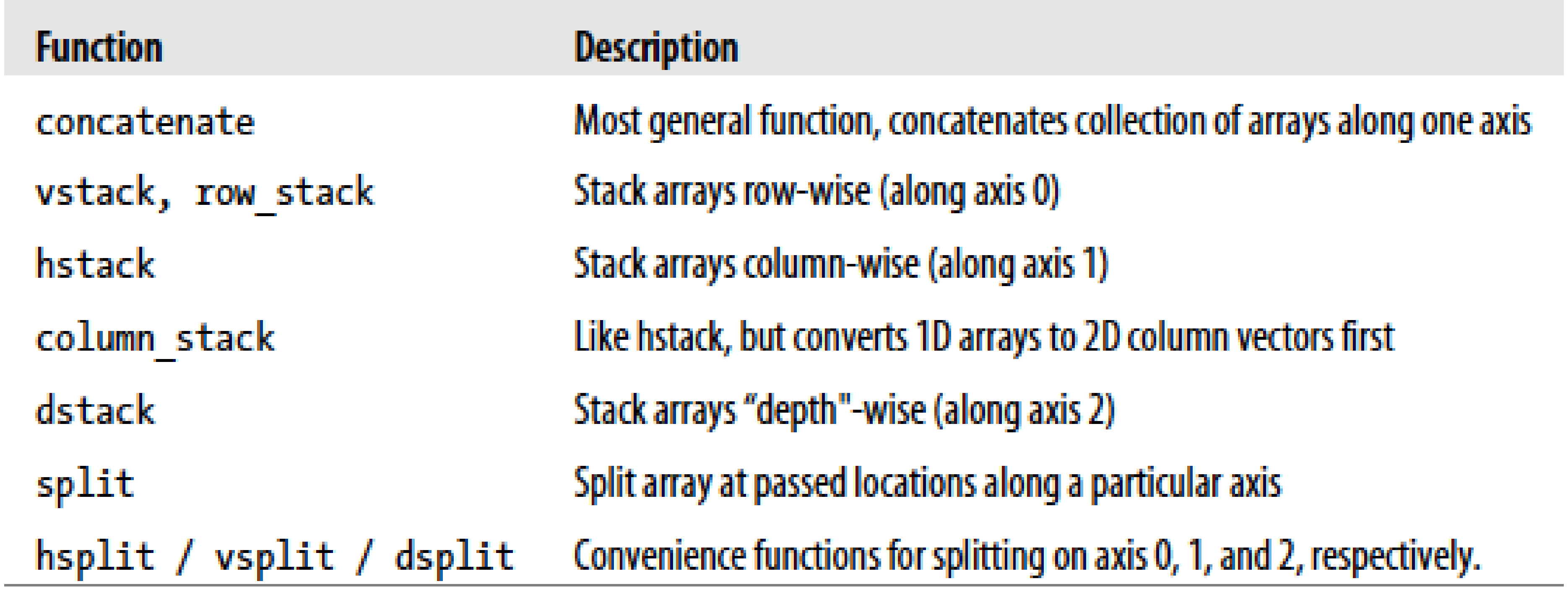
order='C'

Fortran order (column major)

0	4	8
1	5	9
2	6	10
3	7	11

order='F'

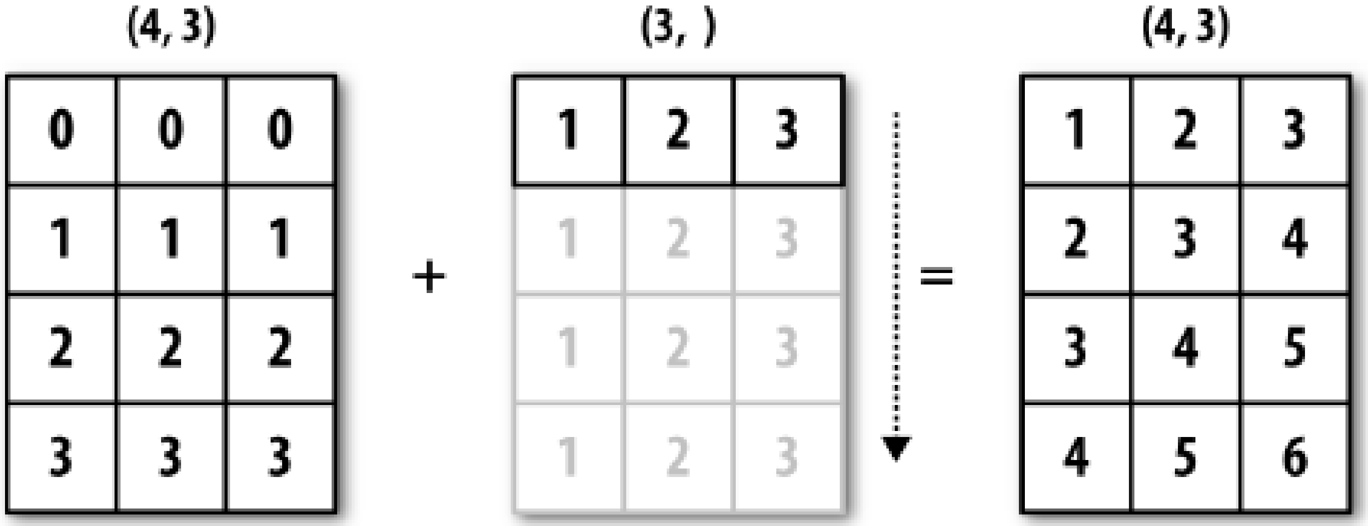
NumPy Array Operations



Function	Description
`concatenate`	Most general function, concatenates collection of arrays along one axis
`vstack, row_stack`	Stack arrays row-wise (along axis 0)
`hstack`	Stack arrays column-wise (along axis 1)
`column_stack`	Like hstack, but converts 1D arrays to 2D column vectors first
`dstack`	Stack arrays "depth"-wise (along axis 2)
`split`	Split array at passed locations along a particular axis
`hsplit / vsplit / dsplit`	Convenience functions for splitting on axis 0, 1, and 2, respectively.

NumPy Array Broadcasting

- Broadcasting describes how arithmetic works **between arrays of different shapes**.
- It is a very powerful feature, but one that can be easily misunderstood, even by experienced users.



(4, 3)

0	0	0
1	1	1
2	2	2
3	3	3

+

(3,)

1	2	3
1	2	3
1	2	3
1	2	3

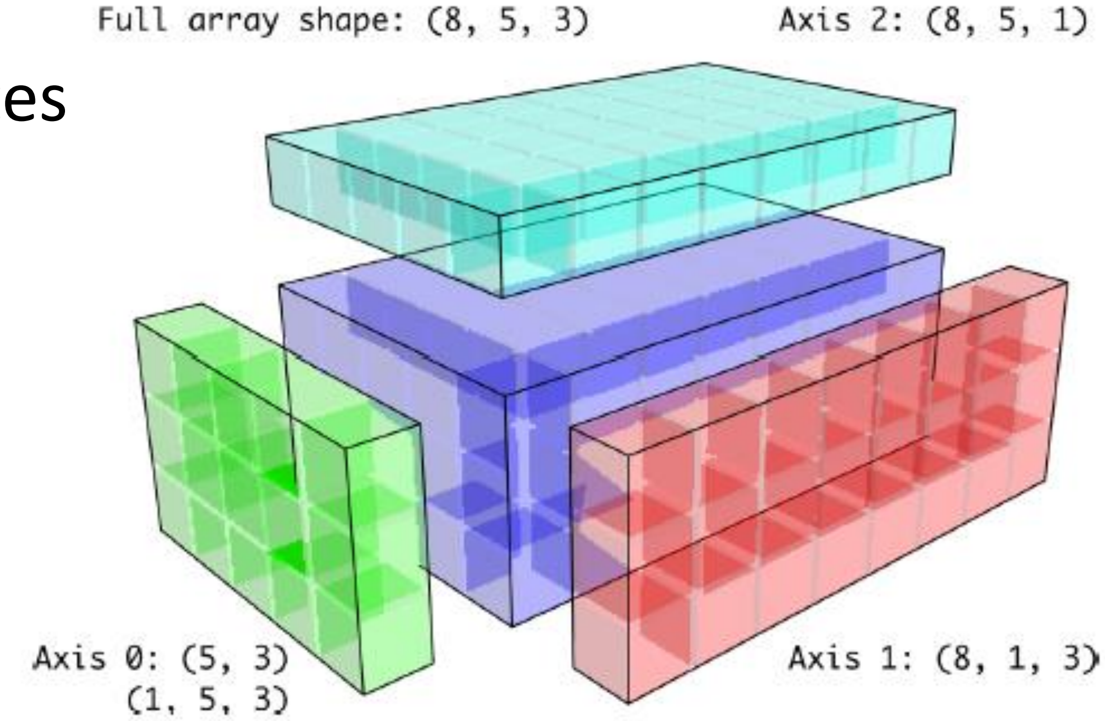
=

(4, 3)

1	2	3
2	3	4
3	4	5
4	5	6

NumPy Array Broadcasting

- Broadcasting can be applied to 3D arrays as well.
- We can easily calculate composites and anomalies of maps.

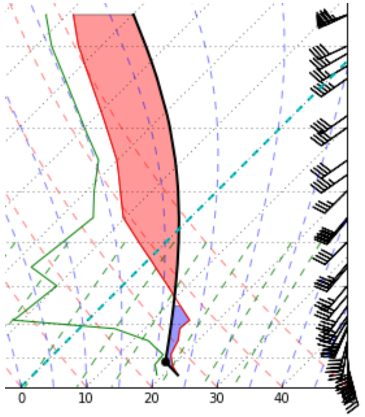


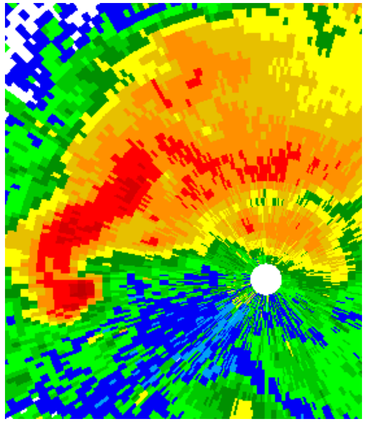
Pandas

- Pros:
  - Pandas provides powerful tools for processing **table-like data**.
  - Pandas adds **indexes and labels** to 1d and 2d NumPy arrays.
  - Easy handling of **missing data**.
  - Pandas **DataFrame** object can now be directly used by R.
- Cons:
  - However, most meteorological data is not in table-form.
- Bottom line:
  - We will use Pandas for its rich **data input/output** capability.
  - Pandas can serve as a good data cleaning tool.

Matplotlib

- Visualization is an important part of data analytics.
- MetPy
  - meteorology-focused plotting (e.g. skew-T, hodograph, station plot)
  - a growing list of meteorological calculations (e.g. advection, dewpoint, mixing_ratio, etc.)
  - reading common meteorological file formats (e.g. GINI satellite images, NEXRAD Level 2 and 3)
  - gridding and interpoloation tools
  - color table manipulation

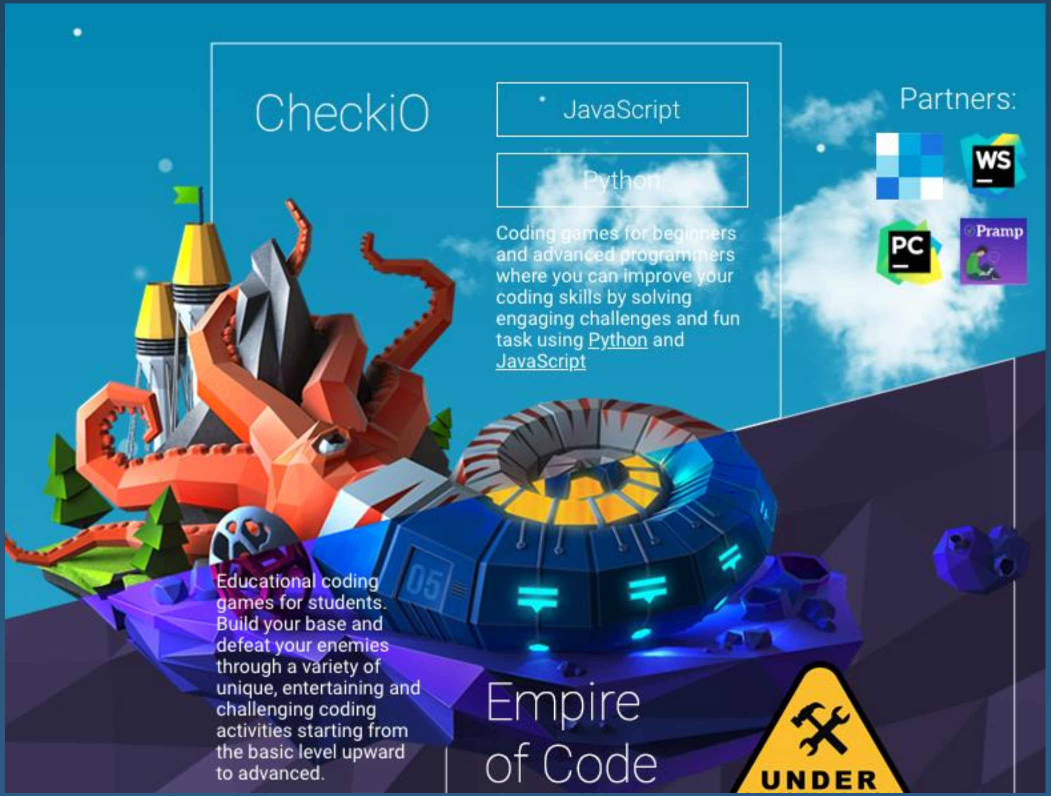




Exercises

- 練習範例
    - 107_week1_exercise.ipynb
- 習題
    - https://goo.gl/forms/JMu5PdM3DO3fxqtK2

Recommended Resources



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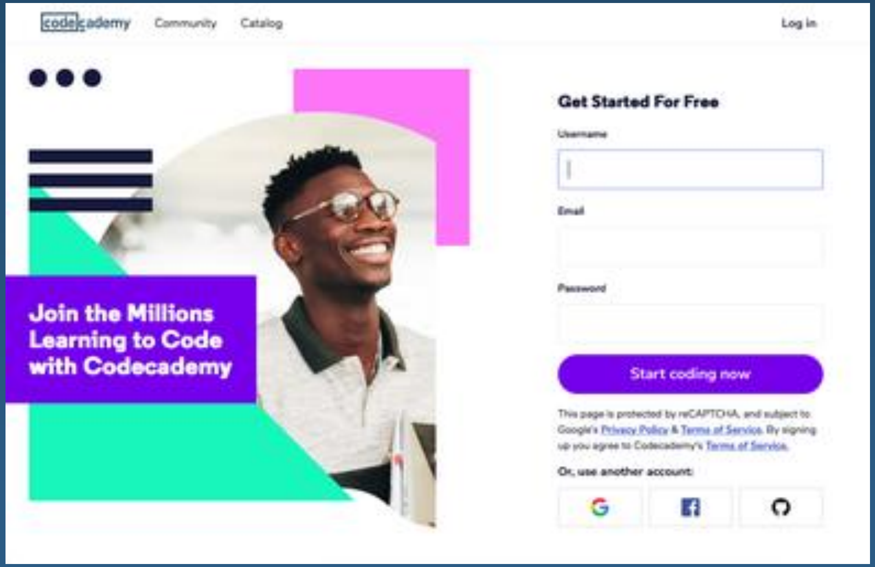

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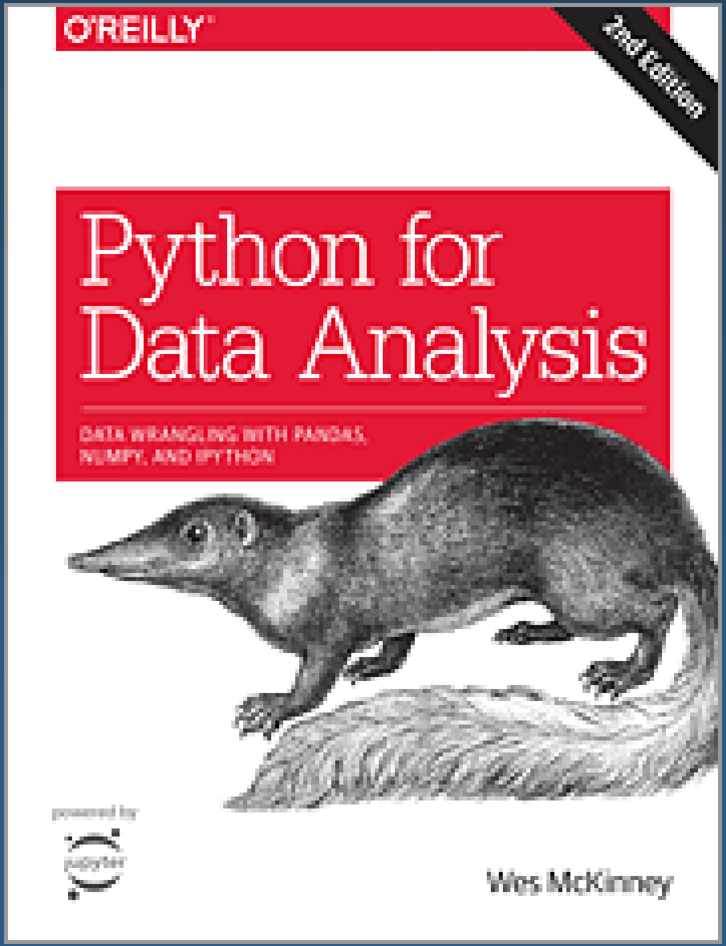

Python for Data Analysis, 2nd Edition

Data Wrangling with Pandas, NumPy, and IPython

By William McKinney

Publisher: O'Reilly Media
Release Date: October 2017
Pages: 550

Get complete instructions for manipulating, processing, cleaning, and crunching datasets in Python. Updated for Python 3.6, the second edition of this hands-on guide is packed with practical case studies that show you how to solve a broad set of data analysis problems effectively. You'll learn the latest versions of pandas, NumPy, IPython, and Jupyter in the process.

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