Machine Learning for Networking

Introduction to Python

Andrea Pasini
Flavio Giobergia
Elena Baralis
Gabriele Ciravegna

DataBase and Data Mining Group

Python part – Summary

1. **Python engine and language**
   - Setup, data types, object oriented programming
2. **Numpy library**
   - Computation with multi-dimensional arrays
3. **Pandas library**
   - Tabular data and data preprocessing
4. **Matplotlib library**
   - Data visualization and graphics

Summary

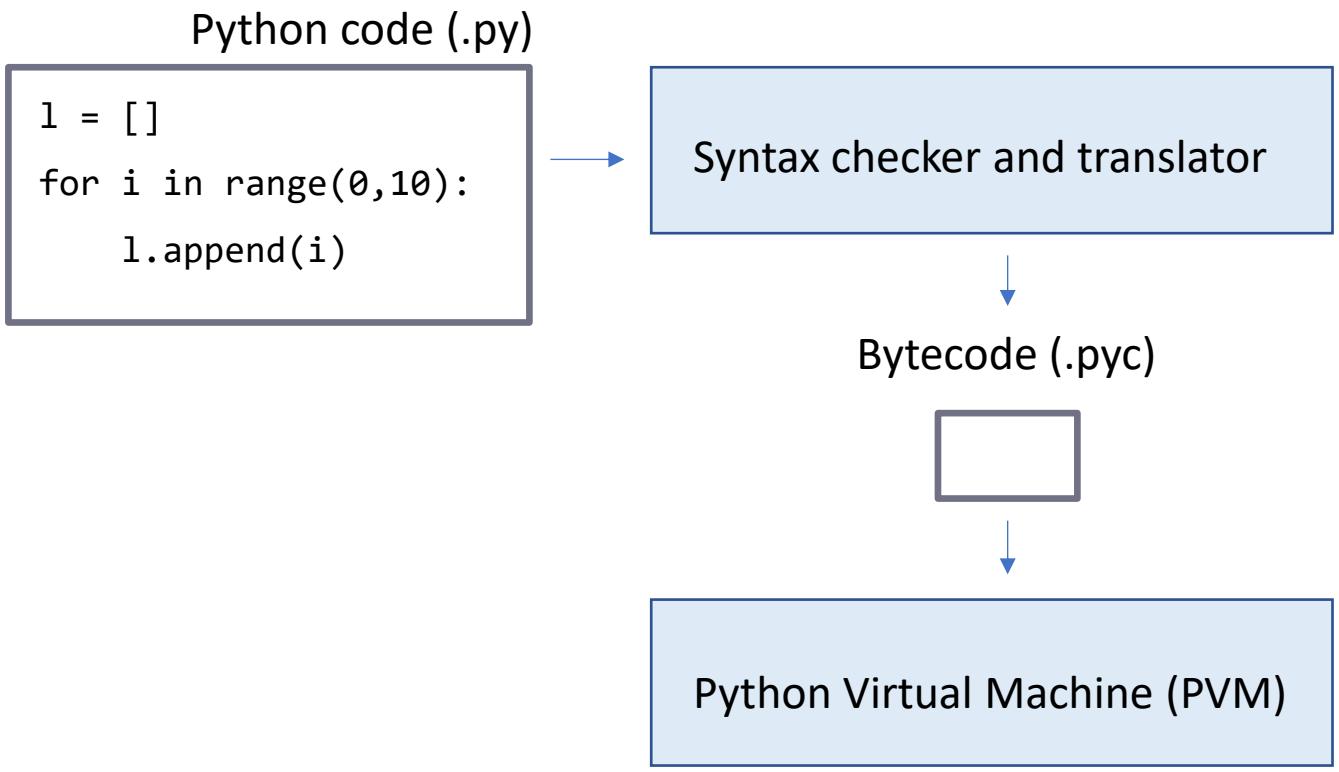
- **Executing Python programs**
  - **Python programs**
  - **Python setup**
- **Python language**
  - Python data types
  - Controlling program flow
  - Functions
  - Lambda functions
  - List comprehensions
  - Classes

Executing Python programs

- Python is an **interpreted** language
  - Code is not compiled to machine language
  - However the source code is compiled to an intermediate level, called **bytecode**
  - For this reason, to run Python programs, you need an **interpreter** that is able to execute the bytecode

Executing Python programs

- Sequence of operations executed by the interpreter



Executing Python programs

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- A common Python 3 setup on a **Linux** System
- Typically in the /usr/bin folder:
  - "**python3**" executable: run Python programs
  - "**ipython3**" executable: run programs line by line
  - "**jupyter**" executable: run a jupyter notebook
  - "**pip3**" executable: install Python packages
- To find where your python commands live:
  - $ which <command>

```
fgiobergia@localhost $ which python3
/usr/local/bin/python3
fgiobergia@localhost $
```

Executing Python programs

- Executing a Python program

my_script.py

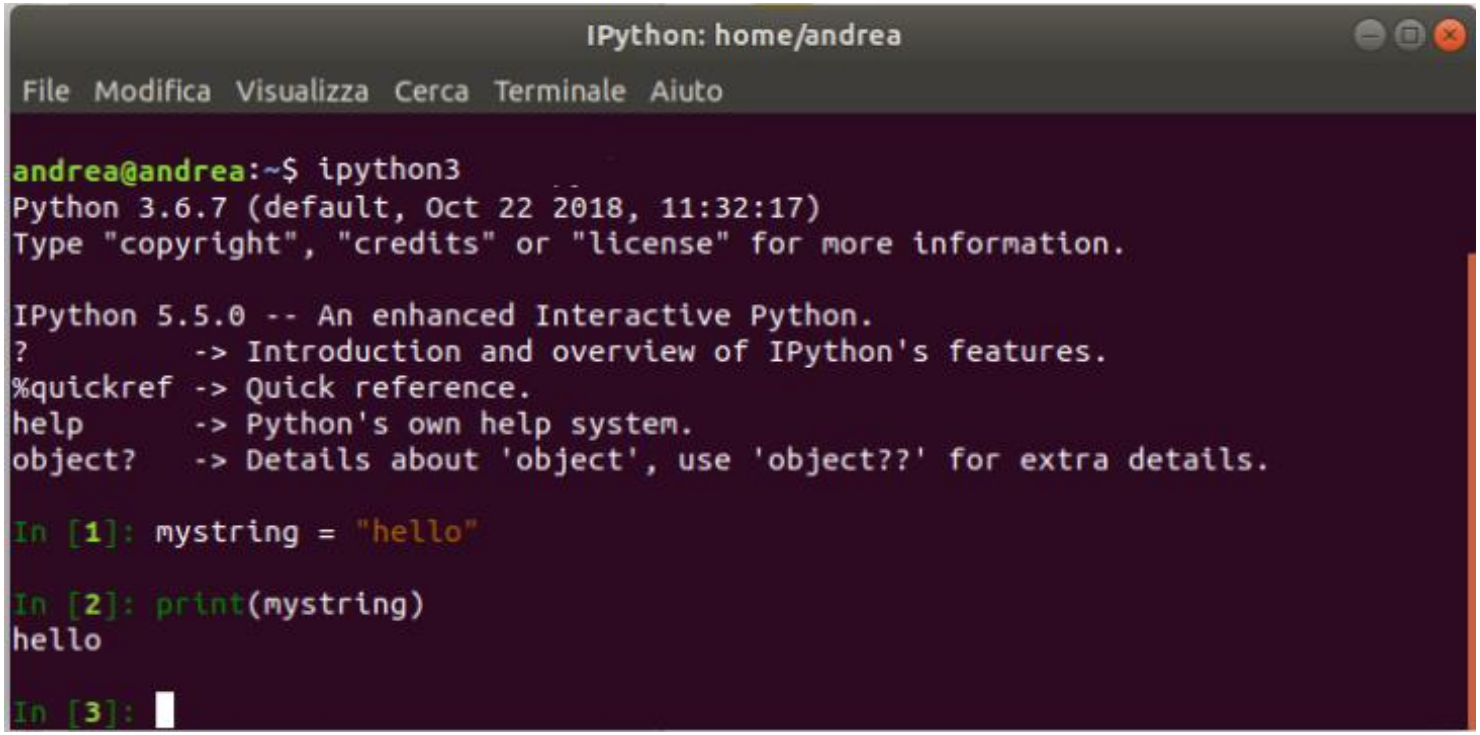
```
print("Hello")
```

~/Documents/MyScript

- Type in your terminal:
  - cd ~/Documents/MyScript
  - python3 my_script.py

Executing Python programs

- Running Python line by line with IPython
- Type in your terminal:
  - ipython3 (or ipython, depending on your installation)

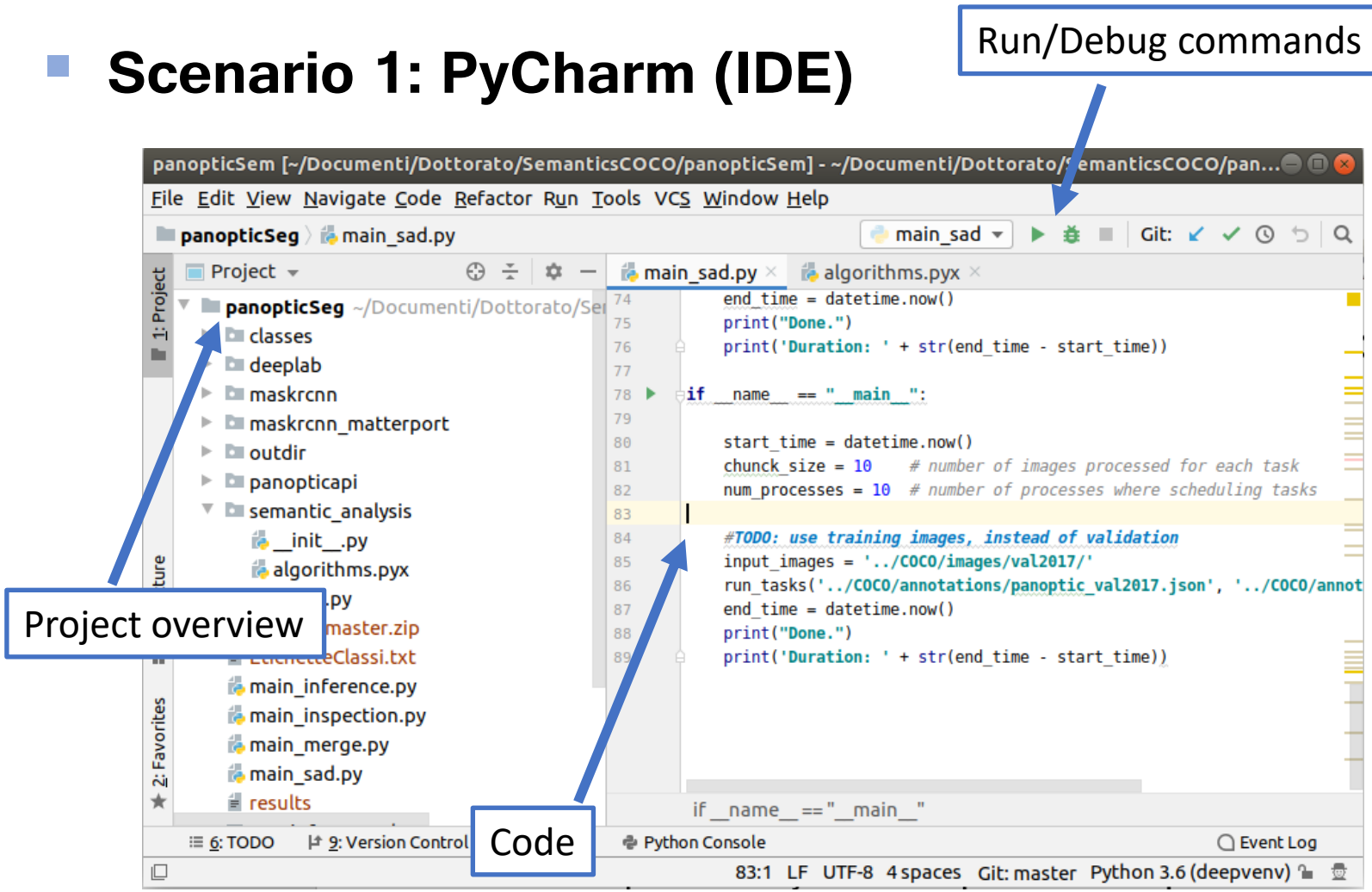


Executing Python programs

- **Development scenarios**, typically two:
  1. Develop your Python **project** with an **IDE**
     - Example: Visual Studio Code, PyCharm
     - **Debug** and **run** your code inside the IDE
  2. Develop and test a Python **script** with **Jupyter notebook**
     - Inspect **step by step** the results
     - Keep the history of the output of the script

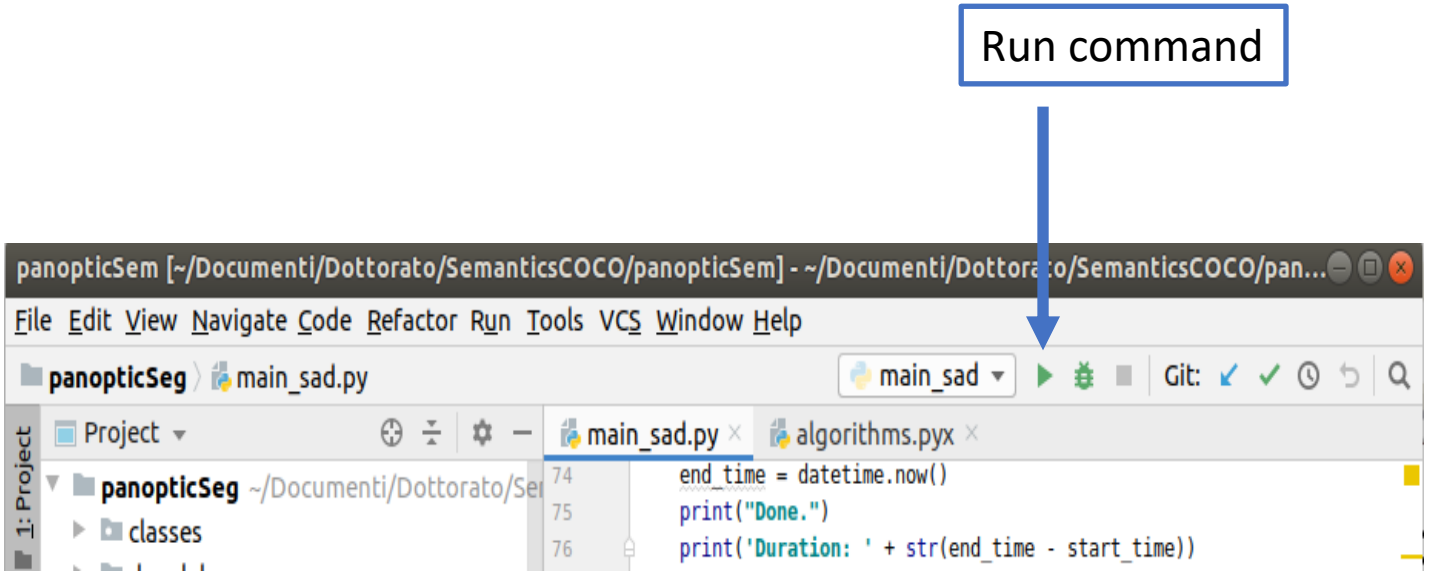
Executing Python programs

- **Scenario 1: PyCharm (IDE)**



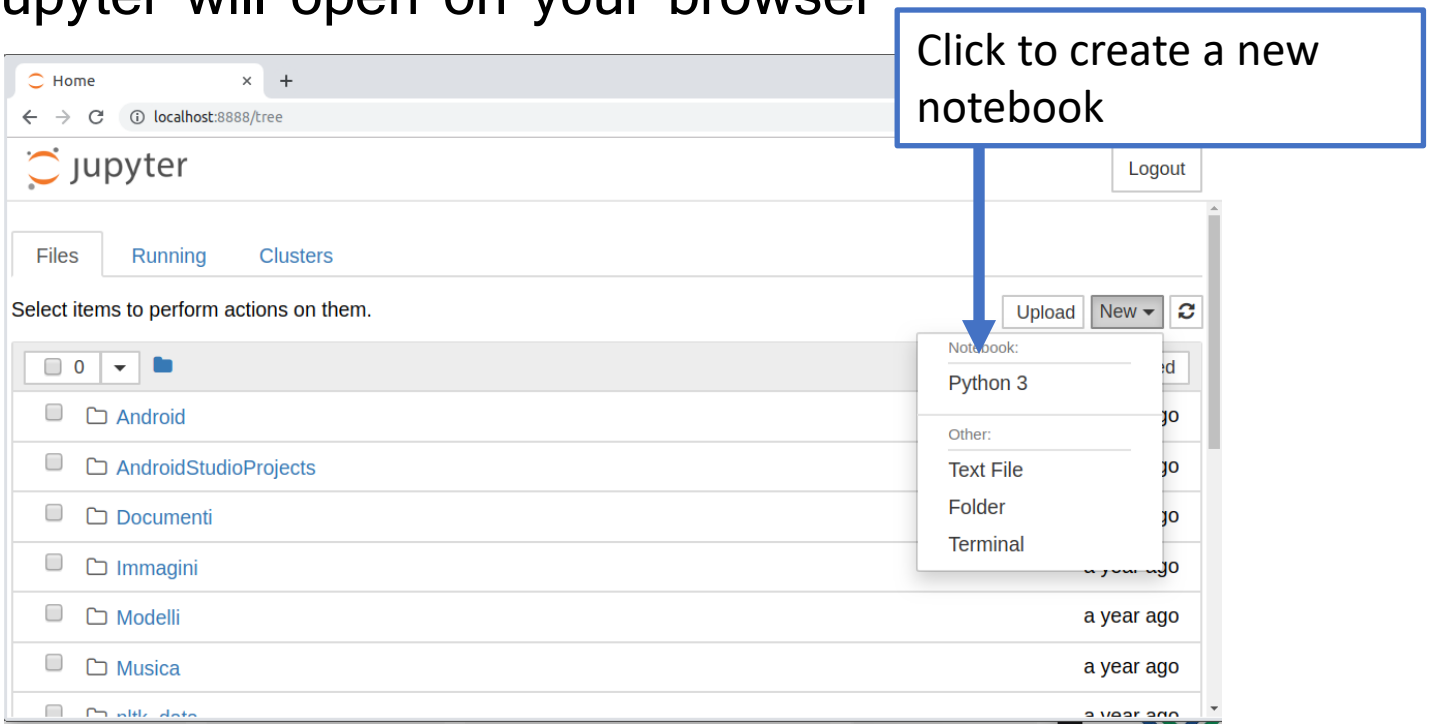
Executing Python programs

- **Scenario 1: PyCharm (IDE)**
  - When you click on the run button, the IDE will automatically call the "**python**" command to execute your script



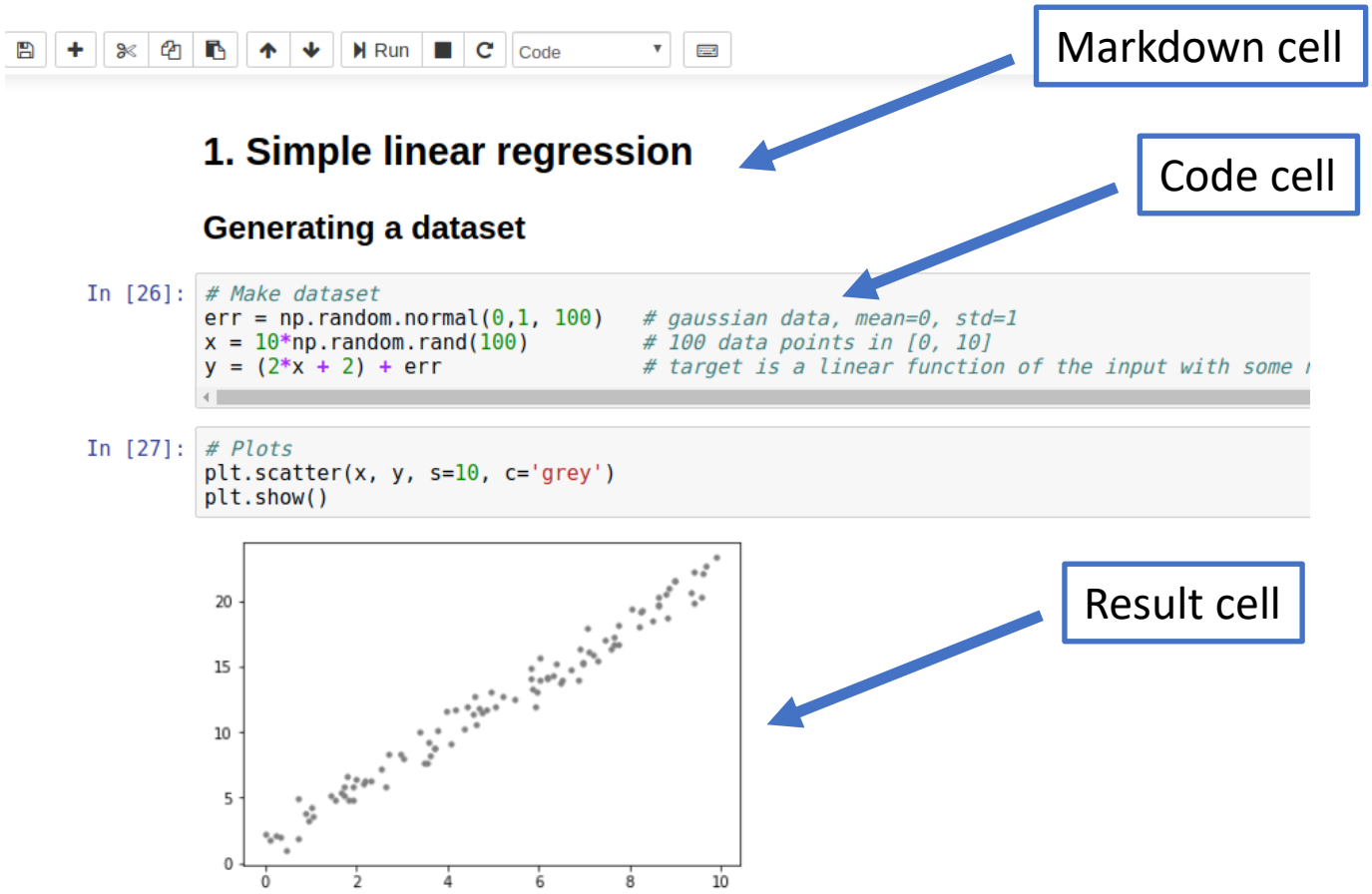
Executing Python programs

- **Scenario 2: Jupyter notebook**
  - Type in your terminal
    - jupyter notebook
  - Jupyter will open on your browser



Executing Python programs

- **Scenario 2: Jupyter notebook**



Executing Python programs

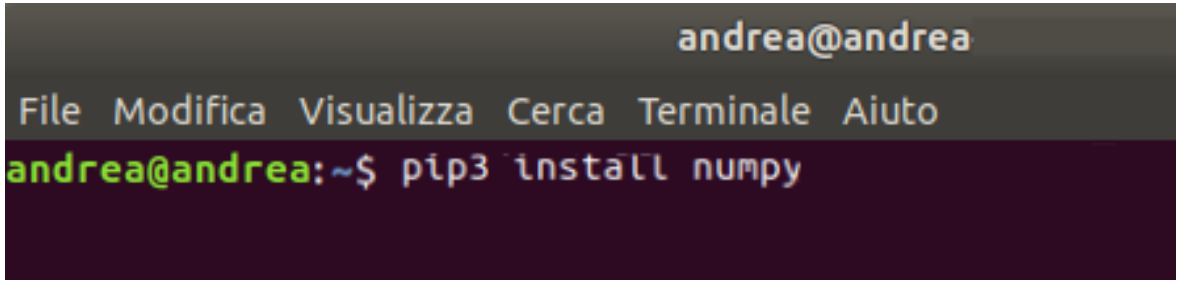
- **Scenario 2: Jupyter notebook**
  - Based on **IPython** command
  - Each code **cell** can be executed **separately** by pressing CTRL + ENTER

IDE vs Jupyter notebook

- **IDE**
  - For more **complex** projects (many files)
  - More powerful debug commands
  - More powerful code editing tools
- **Jupyter notebook**
  - For simple scripts and prototypes
  - Great **visualization** tool
    - Example: **report** with Python code and text for explanations

Executing Python programs

- **Installing libraries**
  - Python language is provided with many useful libraries:
    - Numpy, Pandas, Matplotlib, Scikit-learn, SciPy, …
  - To use any of them you first have to install it with the **pip** command: pip3 install <package>
    - pip3 install numpy
    - pip3 install pandas



Executing Python programs

- **Virtual environments**
  - The pip command will associate the libraries to your **default Python installation**
  - A more powerful way of managing libraries is to use a Python **environment (virtualenv or conda)**
    - Useful when you have **many projects** that use different libraries and **configurations (e.g. versions)**
      - Each projects is associated to a virtual environment

Python language

- Python language
  - Clean and concise syntax
    - No semi-colons to end instructions
    - No braces to define if clauses and for loops
    - No need to specify variable types
    - …

Java

```
List<String> l = new LinkedList<>();
for (int i=0; i<10; i++) {
    l.add(i);
}
```

Python

```
l = []
for i in range(0,10):
    l.append(i)
```

Python language

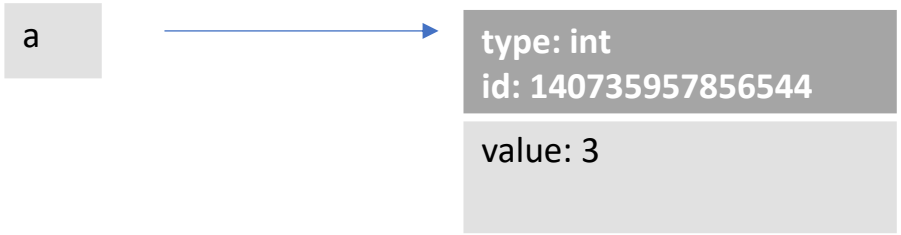
- Python is an **object-oriented** language
- Every piece of data in the program is an **Object**
  - Objects have **properties** and **functionalities**
  - Even a simple **integer** number is a Python **object**

Example of an integer object

type: int id: 140735957856544
value: 3

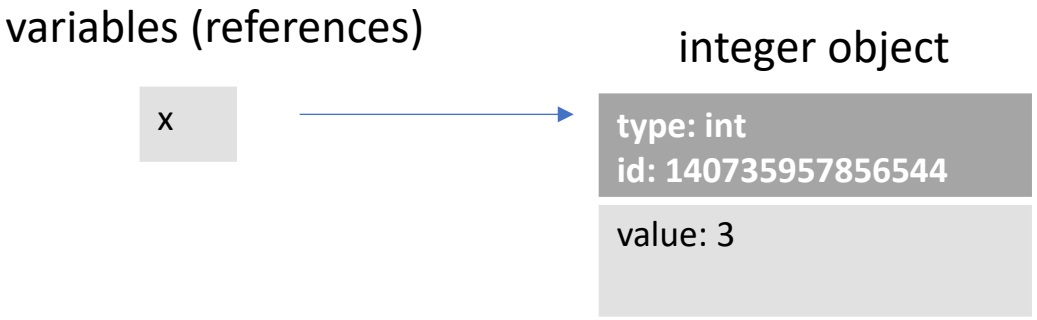
- **Defining a variable**
  - **No need** to specify its data type
  - **Just assign** a value to a new variable name

```
a = 3
```

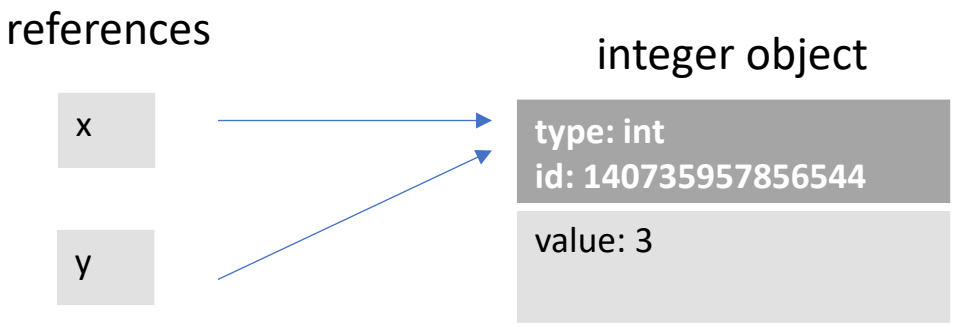


Python language

- In Python
  - **Variable** = **reference** to an object
- When you **assign** an object to a variable it becomes a **reference** to that object



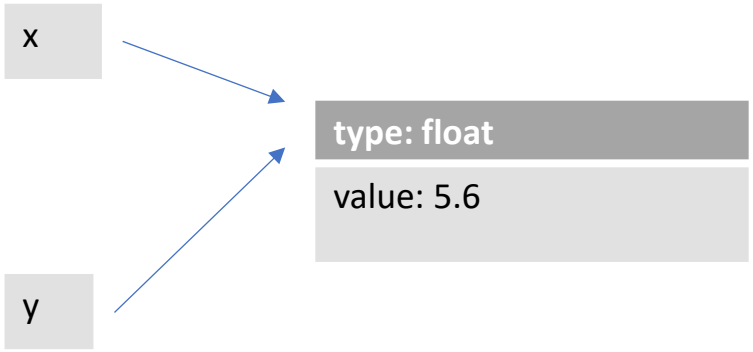
- A single Python object can have **multiple references (alias)**



Python data types

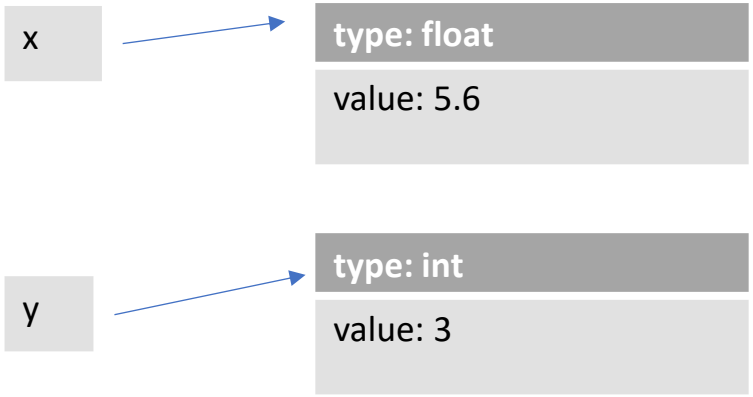
- Example

```
x = 5.6
y = x
```



  - If you assign y to a new value…

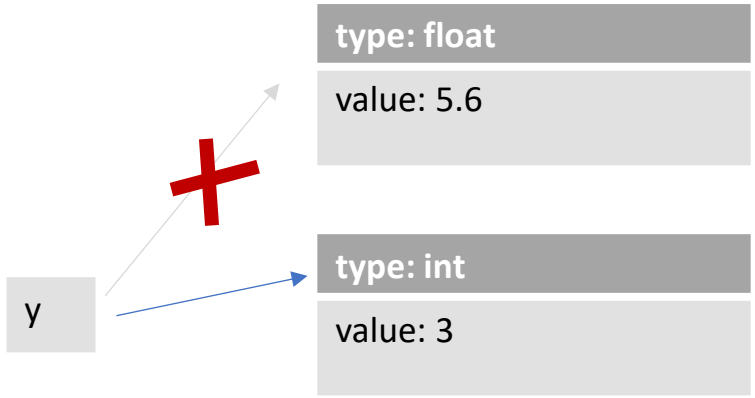
```
y = 3
```



Python data types

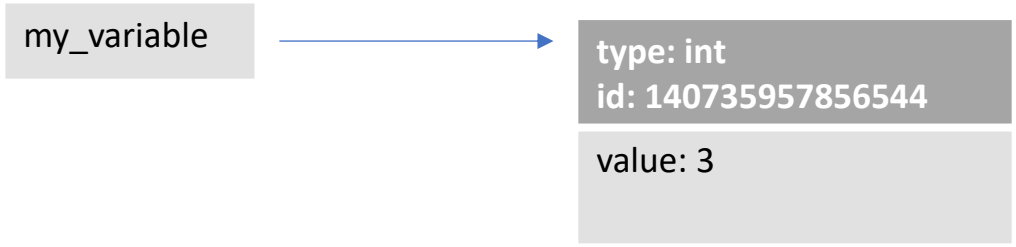
- From the previous example we learn that:
  - Basic data types, such as integer and float variables are **immutable**:
    - Assigning a new number will not change the value inside the object by rather create a new one

```
y = 5.6
y = 3
```



Python data types

- Verify this reasoning with id()
  - **id(my_variable)** returns the **identifier** of the object that the variable is referencing



Python data types

- **Jupyter example**
  - Type in your code

```
In [1]: x = 1
        y = x
        print(id(x))
        print(id(y))
```

  - Press CTRL+ENTER to run and obtain a result

```
Out[1]: 140735957856544
        140735957856544
```

Python data types

- **Basic data types**
  - *int*, *float*, *bool*, *str*
  - *None*
  - All of these objects are **immutable**
- **Composite data types**
  - *tuple* (**immutable** list of objects)
  - *list*, *set*, *dict* (**mutable** collections of objects)

Python data types

- **int, float**
  - No theoretical size limit
    - Effectively limited by memory available
  - Available operations
    - `+`, `-`, `*`, `/`, `//` (integer division), `%` remainder, `**` (exponentiation)
    - Example

```
In [1]: x = 9
        y = 5
        r1 = x // y          # r1 = 1
        r2 = x % y           # r2 = 4
        r3 = x / y           # r3 = 1.8
        r4 = x ** 2          # r4 = 81
```

    - Note that dividing 2 **integers** yields a **float**

Python data types

- **bool**
  - Can assume the values True, False
  - Boolean operators: **and, or, not**
    - Example

In [1]:

```
is_sunny = True
is_hot = False
is_rainy = not is_sunny                  # is_rainy = False
bad_weather = not (is_sunny or is_hot)   # bad_weather = False

temperature1 = 30
temperature2 = 35
raising = temperature2 > temperature1    # raising = True
```

Python data types

- **string**

In [1]:
```
string1 = "Python's nice"                # with double quotes
string2 = 'He said "yes"'                # with single quotes
print(string1)
print(string2)
```

Out[1]:
```
Python's nice
He said "yes"
```

- Definition with single or double quotes is equivalent

Python data types

- **Conversion** between types
  - Example

In [1]:

```
x = 9.8
y = 4
r1 = int(x)                    # r1 = 9
r2 = float(y)                  # r2 = 4.0
r3 = str(x)                    # r3 = '9.8'
r4 = float("6.7")              # r4 = 6.7
r5 = bool("True")              # r5 = True
r6 = bool(0)                   # r6 = False
```

- Only `0`, `“”`, `[]`, `{}`, `set()`, `()` convert to `False` through bool()

Python data types

- **Working with strings**
  - **len:** get string length
  - **strip:** remove leading and trailing spaces (tabs or newlines)
  - **upper/lower**: convert uppercase/lowercase

In [1]:

```
s1 = ' My string '
length = len(s1)            # length = 11
s2 = s1.strip()             # s2 = 'My string'
s3 = s1.upper()             # s3 = ' MY STRING '
s4 = s1.lower()             # s4 = ' my string '
```

Python data types

- **Sub-strings**
  - **str[start:stop]**
    - The start index is **included**, while stop index is **excluded**
    - Index of characters starts **from 0**
    - We can optionally specify a step str[start:stop:step] (*)
  - **Shortcuts**
    - **Omit start** if you want to start from the beginning
    - **Omit stop** if you want to go until the end of the string

In [1]:

```
s1 = "Hello"
charact = s1[0]              # charact = 'H'
s2 = s1[0:3]                 # s2 = 'Hel'
s3 = s1[1:]                  # s3 = 'ello'
s4 = s1[:3]                  # s4 = 'Hell'
s5 = s1[:]                   # s4 = 'Hello'
```

(*) see details in the upcoming "list" explanation

Python data types

- **Sub-strings**
  - **Negative indices:**
    - count characters **from the end**
    - **-1 = last character**

In [1]:

```
s1 = "MyFile.txt"


s2 = s1[:-1]                # s2 = 'MyFile.tx'
s3 = s1[:-2]                # s3 = 'MyFile.t'
s4 = s1[-3:]                # s4 = 'txt'
```

- **Strings: concatenation**
  - Use the **+** operator

```
In [1]:  string1 = 'Value of '
         sensor_id = 'sensor 1.'
         print(string1 + sensor_id)          # concatenation
         val = 0.75
         print('Value: ' + str(val))         # float to str
```

```
Out[1]:  Value of sensor 1.
         Value: 0.75
```

Python data types

- **Strings are immutable**

In [1]:

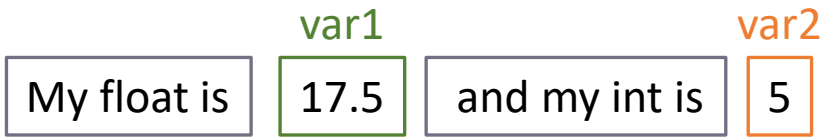
```
str1 = "example"
str1[0] = "E"                    # will cause an error
```

- Use instead:

In [1]:

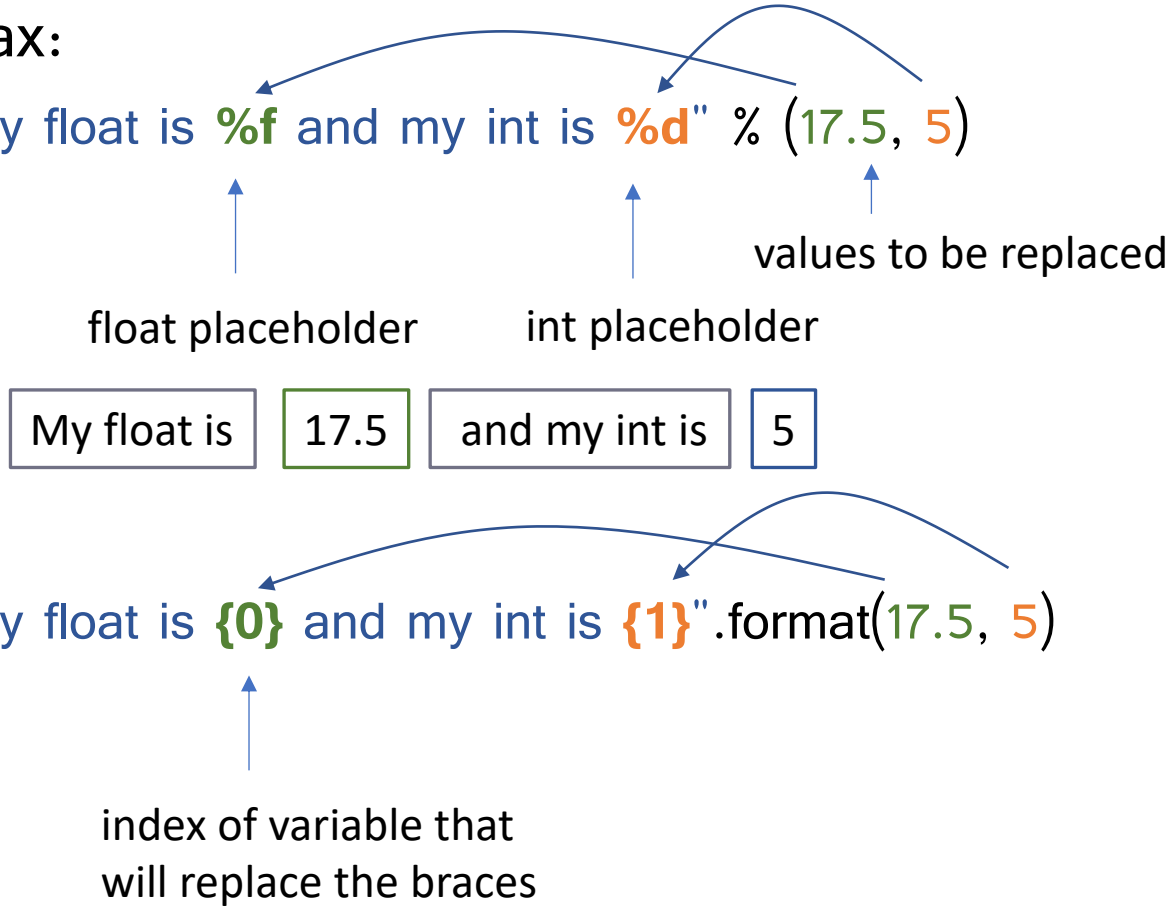
```
str1 = "example"
str1 = 'E' + str1[1:]
```

- **Formatted string literals (or f-strings)**
  - Introduced in Python 3.6
  - Useful pattern to build a string from one or more variables
  - E.g. suppose you want to build the string:



  - Syntax:
    - **f**"My float is **{var1}** and my int is **{var2}**"

- **Formatting strings (older versions)**
  - Syntax:
    - `"My float is %f and my int is %d" % (17.5, 5)`



Python data types

- **Example (>= Python 3.6)**

In [1]:

```
city = 'London'
temp = 19.23456
str1 = f"Temperature in {city} is {temp} degrees."
str2 = f"Temperature with 2 decimals: {temp:.2f}"
str3 = f"Temperature + 10: {temp+10}"
print(str1)
print(str2)
print(str3)
```

Out[1]:

```
Temperature in London is 19.23456 degrees.
Temperature with 2 decimals: 19.23
Temperature + 10: 29.23456
```

Python data types

- **Strings**
  - **Other methods:**
    - str1.capitalize()
      - Converts the first character to upper case(element)
    - str1.find("a") or str1.index("a")
      - Return the index of the given string
    - str1.count("a"):
      - Count the number of times a given string is found
    - str1.split("a"):
      - Returns a list of sub-strings separated by the given string
    - str1.replace("Mike", "Bob")
      - Returns a new string where all "Mike" substrings are replaced by "Bob"

Python data types

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- **None type**
  - Specifies that a reference does not contain data

In [1]:

```
my_var = None


if my_var is None:
    my_var = 10
```

  - Useful to:
    - Represent "missing data" in a list or a table
    - Initialize an empty variable that will be assigned later on
      - (e.g. when computing min/max)

Python data types

- **Tuple**
  - **Immutable** sequence of variables
  - Definition:

```
In [1]:  t1 = ('Turin', 'Italy')      # City and State
         t2 = 'Paris', 'France'       # optional parentheses

         t3 = ('Rome', 2, 25.6)       # can contain different types
         t4 = ('London',)             # tuple with single element
```

Python data types

- **Tuple unpacking**
  - **Assigning** a tuple to a set of variables

In [1]:

```
city_data = ('Turin', 'Italy', 12)
city, state, temperature = city_data

print(city)        # Turin
print(state)       # Italy
print(temperature) # 12
```

Python data types

- **Swapping** elements with tuples
  - This is an interesting case of unpacking

In [1]:

```
a = 1
b = 2
a, b = b, a
print(a)
print(b)
```

Out[1]:

```
2
1
```

Python data types

- **Tuple**
  - Tuples can be **concatenated**
  - A new tuple is generated upon concatenation

In [1]:

```
city = 'Turin', 'Italy'
temperatures = 6, 15
city_data = city + temperatures
print(city_data)
```

Out[1]:

```
('Turin', 'Italy', 6, 15)
```

Python data types

- **Tuple**
  - Accessing elements of a tuple
    - t [start:stop]
    - We can optionally specify a step str[start:stop:step] (*)

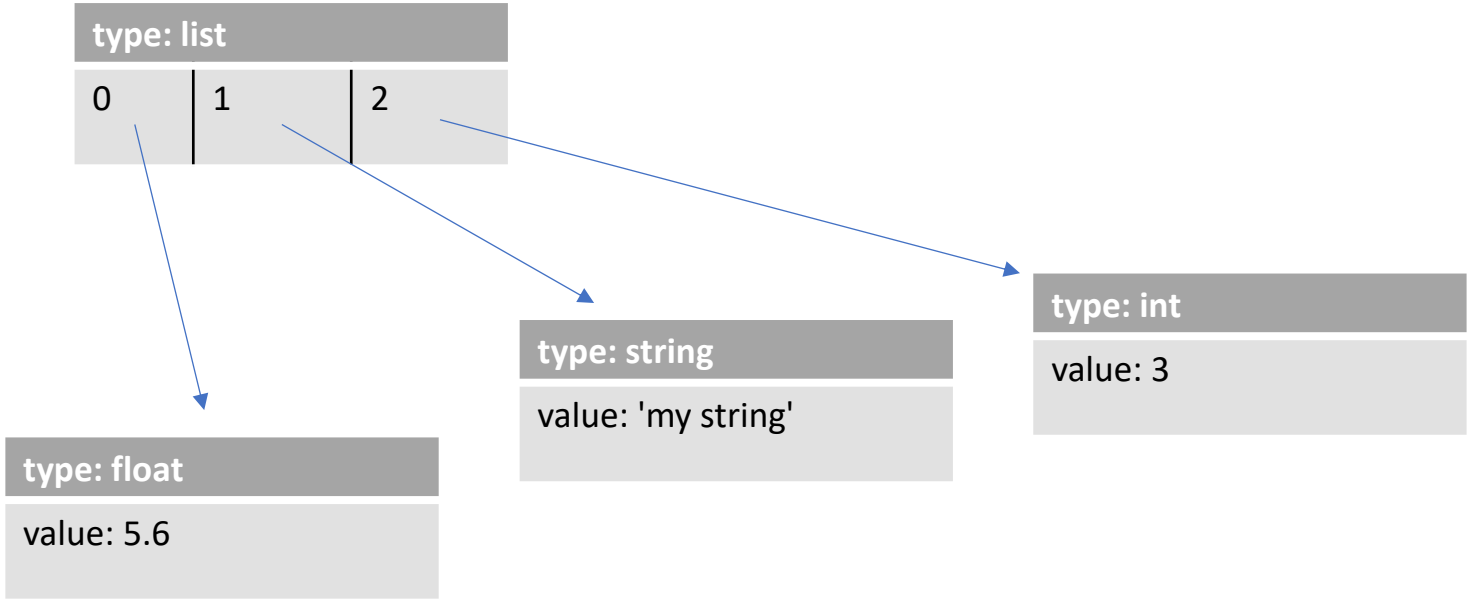
In [1]:

```
t1 = ('a', 'b', 'c', 'd')

val1 = t1[0]                # val1 = 'a'
t2 = t1[1:]                 # t2 = ('b', 'c', 'd')
t3 = t1[:-1]                # t3 = ('a', 'b', 'c')

t1[0] = 2                   # will cause an error
                            # (a tuple is immutable)
```


(*) see details in the upcoming “list” explanation

Python data types

- **List**
  - **Mutable** sequence of heterogeneous elements
  - Each element is a **reference** to a Python object



Python data types

- **List**
  - Definition

In [1]:

```
l1 = []                          # empty list
l2 = [1, 'str', 5.6, None]       # can contain different types

a, b, c, d = l2                  # can be assigned to variables
                                 # a=1, b='str', c=5.6, d=None
```

Python data types

- **List**
  - **Adding** elements and **concatenating** lists

In [1]:

```
l1 = [2, 4, 6]
l2 = [10, 12]
l1.append(8)                    # append an element to l1
l3 = l1 + l2                    # concatenate 2 lists
print(l1)
print(l3)
```

Out[1]:

```
[2, 4, 6, 8]
[2, 4, 6, 8, 10, 12]
```

Python data types

- **List**
  - **Other methods:**
    - list1.insert(index, element):
      - Insert element at position
    - list1.pop(index):
      - Remove element by position
    - list.index(element):
      - Returns position of *first* occurrence of element
    - list.count(element):
      - Number of occurrences of element
    - list1.extend(list2):
      - Extend list1 with another list list2

Python data types

- **List**
  - **Accessing** elements:
    - Same syntax as tuples, but this time assigment is allowed

In [1]:

```
l1 = [0, 2, 4, 6]
val1 = l1[0]                    # val1 = 0
a, b = l1[1:-1]                 # a=2, b=4
l1[0] = 'a'
print(l1)
```

Out[1]:

```
['a', 2, 4, 6]
```

Python data types

- **List**
  - **Accessing** elements
    - Can also specify a **step**: [start:stop:step]
      - **step = 2** skips 1 element
      - **step = -1** reads the list in reverse order
      - **step = -2** reverse order, skip 1 element

In [1]:

```
l1 = [0, 1, 2, 3, 4]
l2 = l1[::2]                # l2 = [0, 2, 4]
l3 = l1[::-1]               # l3 = [4, 3, 2, 1, 0]
l4 = l1[::-2]               # l3 = [4, 2, 0]
```

Python data types

- **List**
  - **Assigning** multiple elements

```
In [1]: l1 = [0, 1, 2, 3, 4]
        l1[1:4] = ['a', 'b', 'c']   # l1 = [0, 'a', 'b', 'c', 4]
```

  - **Removing** multiple elements

```
In [1]: l1 = [0, 1, 2, 3, 4]
        del l1[1:-1]        # l1 = [0, 4]
```

Python data types

- **"in" operator**
  - **Check** if element belongs to a list

In [1]:
```
l1 = [0, 1, 2, 3, 4]
myval = 2
myval in l1 # True, since 2 is in l1
```

  - **Iterate** over list elements

In [1]:
```
l1 = [0, 1, 2, 3, 4]
for el in l1:
    print(el)
```

Python data types

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- **List**
  - **Sum, min, max** of elements

In [1]:
```
l1 = [0, 1, 2, 3, 4]
min_val = min(l1)           # min_val = 0
max_val = max(l1)           # max_val = 4
sum_val = sum(l1)           # sum_val = 10
```

  - **Sort** list elements

In [1]:
```
l1 = [3, 2, 5, 7]
l2 = sorted(l1)             # l2 = [2, 3, 5, 7]
```

Python data types

- **Set**
  - **Unordered** collection of **unique** elements
  - Definition:

```
In [1]: s0 = set()                      # empty set
        s1 = {1, 2, 3}
        s2 = {3, 3, 'b', 'b'}           # s2 = {3, 'b'}
        s3 = set([3, 3, 1, 2])          # from list: s3 = {1,2,3}
```

Python data types

- **Set**
  - **Operators between two sets**
    - | (union), & (intersection), - (difference)
    - <, <= ((proper) subset), >, >= ((proper) superset)

In [1]:

```
s1 = {1, 2, 3}
s2 = {3, 'b'}
union = s1 | s2              # {1, 2, 3, 'b'}
intersection = s1 & s2       # {3}
difference = s1 - s2         # {1, 2}

{1,2} <= s1                  # True
{1,2,3} < s1                 # False (not a proper subset)
{1,2,3} <= s1                # True (same set)
```

Python data types

- **Set**
  - **Add/remove elements**

In [1]:

```
s1 = {1,2,3}
s1.add('4')                    # s1 = {1, 2, 3, '4'}
s1.remove(3)                   # s1 = {1, 2, '4'}
```

Python data types

PoliTo DBMG

- **"in" operator**
  - **Check** whether element belongs to a set

In [1]:
```
s1 = set([0, 1, 2, 3, 4])
myval = 2
myval in s1 # True, since 2 is in s1
```

  - **Iterate** over set elements

In [1]:
```
s1 = set([0, 1, 2, 3, 4])
for el in s1:
    print(el)
```

Python data types

PoliTo DBMG

- **"in" operator**
  - **Check** whether element belongs to a set

```
In [1]: s1 = set([0, 1, 2, 3, 4])
        myval = 2
        myval in s1 # True, since 2 is in s1
```

  - **Iterate** over set elements

```
In [1]: s1 = set([0, 1, 2, 3, 4])
        for el in s1:
            print(el)
```

Note

Sets are unordered – the order during iterations is not well-defined

```
In [1]: {1,2,3} == {3,2,1}
Out[1]: True

In [2]: for i in {1,2,3}:
   ...:     print(i)
   ...:
1
2
3

In [3]: for i in {3,2,1}:
   ...:     print(i)
   ...:
1
2
3
```

Python data types

PoliTo DBMG

- **Set example: removing list duplicates**

In [1]:
```
input_list = [1, 5, 5, 4, 2, 8, 3, 3]
out_list = list(set(input_list))

print(out_list)
```

- **Note:** order of original elements is not preserved

Out [1]:
```
[1, 2, 3, 4, 5, 8]
```

Python data types

- **Dictionary**
  - Collection of key-value pairs
  - Allows fast **access** of elements **by key**
    - Keys are **unique**
  - **Definition:**

```
In [1]: d1 = {'Name' : 'John', 'Age' : 25}
        d0 = {}                                  # empty dictionary
```

Python data types

- **Dictionary keys**
  - Must be **hashable** types
    - E.g. int, float, string, bool, **tuple**
    - Note: lists and dictionaries are not hashable
    - Hashable types are hashed with the hash() function
  - Example: itemsets and their support

```
In [1]: d1 = {('a','b') : 120, ('c','d','e') : 1000}
```

  - Note: the same applies for elements of sets!
- **Dictionary values**
  - Any Python object is allowed

Python data types

- **Dictionary**
  - **Access** by key:

In [1]:
```
images = {10 : 'plane.png', 25 : 'flower.png'}
img10 = images[10]          # img10 = 'plane.png'
img8 = images[8]            # Get an error if key does not exist
img8 = images.get(8)        # .get() returns None if the key does not exist
img8 = images.get(8, 'notfound.ong') # we can optionally specify a default value
```

  - Reading **keys** and **values**:
    - Note: keys() and values() return **views on original data**

In [2]:
```
occurrences = {'Car' : 33, 'Truck' : 55}
keys = list(occurrences.keys())      # keys = ['Car', 'Truck']
values = list(occurrences.values())  # values = [33, 55]
```

Python data types

- **Dictionary**
  - **Adding/updating** values:

```
In [1]: occur = {'Car' : 33, 'Truck' : 55}
        occur ['Car'] = 56          # Update existing value
        occur ['Road'] = 3          # Add a new key
```

  - **Deleting** a key:

```
In [2]: occur = {'Car' : 33, 'Truck' : 55}
        del d2['Truck']             # occur = {'Car':33}
```

Python data types

- **Dictionary**
  - **Check** whether a key exists:

```
In [1]: occur = {'Car' : 33, 'Truck' : 55}
        'Truck' in occur # True since “Truck” is in occur
```

Python data types

- **Dictionary**
  - **Iterating** keys and values
    - Note: Previous Python versions had no order guarantee
    - However, Python 3.7+ officially preserves insertion order (*)
  - E.g. get the cumulative price of items in a market basket

In [1]:

```
basket = {'Cola' : 0.99, 'Apples' : 1.5, 'Salt' : 0.4}
price = 0
for k, v in basket.items():
    price += v
    print(f"{k}: {price}")
```

Out [1]:

```
Cola: 0.99
Apples: 2.49
Salt: 2.89
```

(*) https://docs.python.org/3/whatsnew/3.7.html

Python data types

PoliTo DBMG

- **Default dictionary**
  - Access by key with **default value**:

In [1]:
```
from collections import defaultdict

experience = defaultdict(lambda: 1)
experience['Mario']=3
experience['Elena']+=1        # Even if key 'Elena' not defined
```

  - Instead of writing:

In [2]:
```
if 'Elena' in experience:
    experience['Elena']+=1
else:
    experience['Elena']=2
```

tuple vs list vs set vs dict

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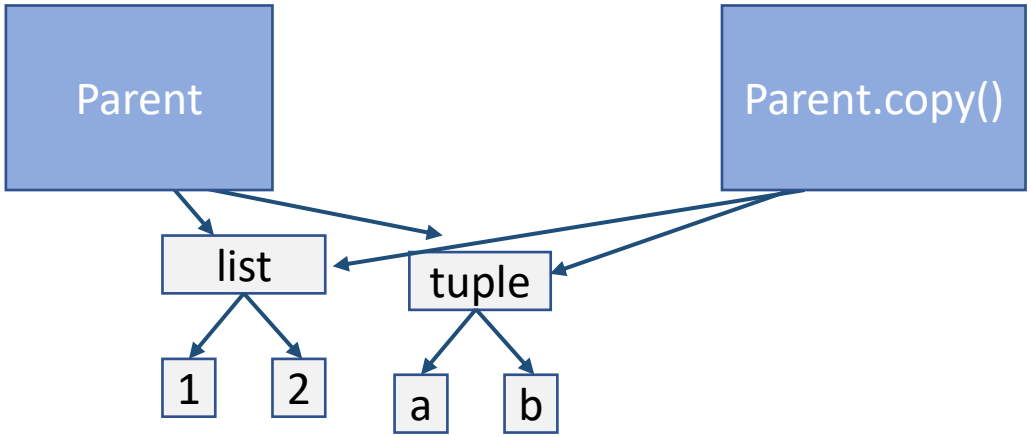
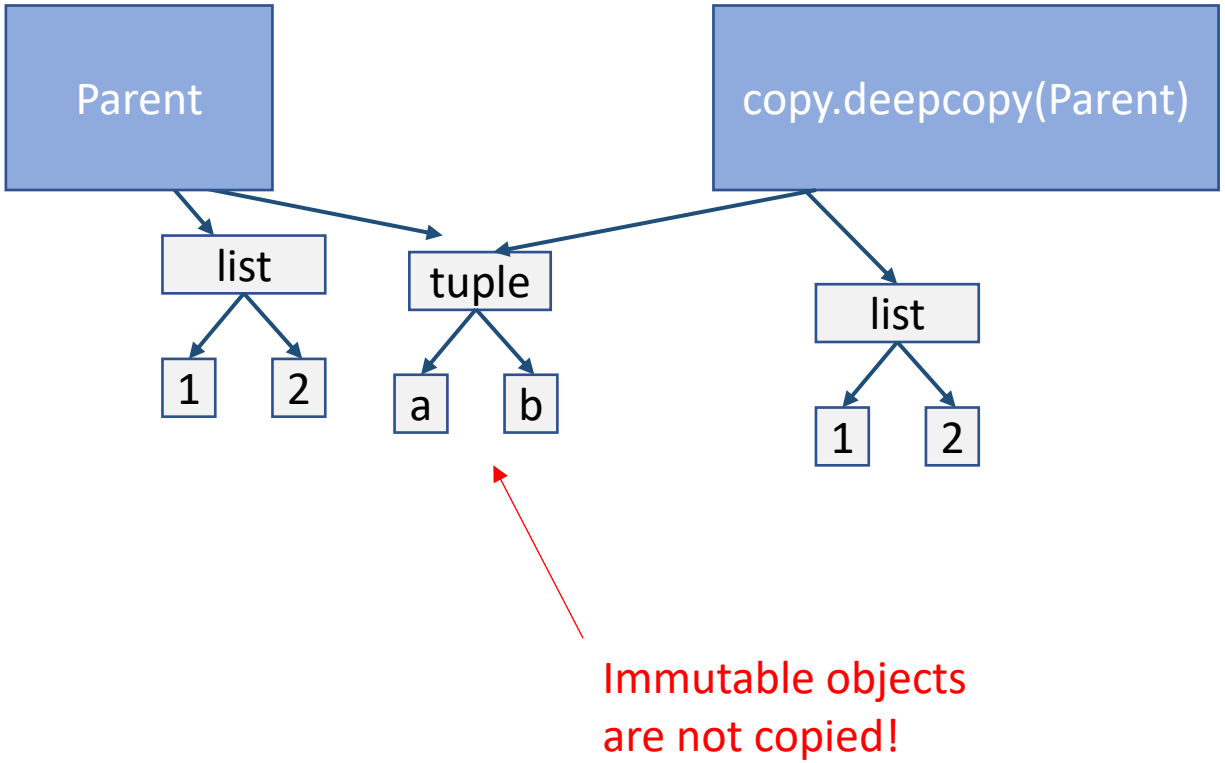
	tuple	list	set	dict
Mutable	No	Yes	Yes	Yes
Ordered	Yes	Yes	No*	No*
Unique values	No	No	Yes	Yes (keys)
Limitations on values	No	No	Must be hashable	Keys must be hashable
Search cost	O(n)	O(n)	O(1)	O(1)

* Implementation dependent – Since Python 3.7 dicts are ordered based on insertion order

- **Shallow vs deep copy**
  - Shallow: copies the parent object, shares references to children



- **Shallow vs deep copy**
  - Deep: recursively copies all children nodes of parent object



Python data types

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- **Shallow copies of Python objects**

In [1]:

```
temperatures = {'Turin':[10,12,10], 'Milan':[15,16,16]}
temp2 = temperatures.copy()
temp2['Turin'].append(13)            # Edit child node
temp2['Rome'] = [10, 11, 10]         # Edit parent node
print(temperatures)
print(temp2)
```

In [2]:

```
{'Turin': [10, 12, 10, 13], 'Milan': [16, 15]}
{'Turin': [10, 12, 10, 13], 'Milan': [16, 15], 'Rome': [10, 11, 10]}
```

Python data types

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Deep copy of Python objects

In [1]:
```
import copy
temperatures = {'Turin':[10,12,10], 'Milan':[15,16,16]}
temp2 = copy.deepcopy(temperatures)
temp2['Turin'].append(13)              # Edit child node
temp2['Rome'] = [10, 11, 10]           # Edit parent node
print(temperatures)
print(temp2)
```

In [2]:
```
{'Turin': [10, 12, 10], 'Milan’: [15,16,16]}
{'Turin': [10, 12, 10, 13], 'Milan’: [15,16,16], 'Rome': [10, 11, 10]}
```

Controlling program flow

PoliTo DBMG

- **if/elif/else**
  - Conditions expressed with >, <, >=, <=, ==, !=
    - Can include boolean operators (and, not, or)

In [1]:

```
if sensor_on and temperature == 10:
    print("Temperature is 10")
elif sensor_on and 10 < temperature < 20:
    in_range = True
    print("Temperature is between 10 and 20")
else:
    print("Temperature is out of range or sensor is off.")
```

indentation is mandatory

Controlling program flow

PoliTo DBMG

- **While loop**
  - Iterate while the specified condition is True

In [1]:

```
counter = 0
while counter < 5:
    print (f"The value of counter is {counter}")
    counter += 2    # increment counter of 2
```

Out [1]:

```
The value of counter is 0
The value of counter is 2
The value of counter is 4
```

Controlling program flow

- **Iterating** for a fixed number of times
  - Use: range(start, stop)

In [1]:

```
for i in range(5, 8):
    txt = f"The value of i is {i}"
    print(txt)
```

Out [1]:

```
The value of i is 5
The value of i is 6
The value of i is 7
```

Controlling program flow

- **Enumerating** list objects
  - Use: enumerate(my_list)

In [1]:

```
my_list = ['a', 'b', 'c']
for i, element in enumerate(my_list):
    print(f"The value of my_list[{i}] is {element}")
```

Out [1]:

```
The value of my_list[0] is a
The value of my_list[1] is b
The value of my_list[2] is c
```

Controlling program flow

PoliTo DBMG

- **Iterating on multiple lists**
  - Use: zip(list1, list2, …)

In [1]:

```
my_list1 = ['a', 'b', 'c']
my_list2 = ['A', 'B', 'C']
for el1, el2 in zip(my_list1, my_list2):
    print(f"El1: {el1}, el2: {el2}")
```

Out [1]:

```
El1: a, el2: A
El1: b, el2: B
El1: c, el2: C
```

Controlling program flow

PoliTo DBMG

- **Break/continue**
  - Alter the flow of a **for** or a **while** loop
  - Example

my_file.txt

```
car
skip
truck
end
van
```

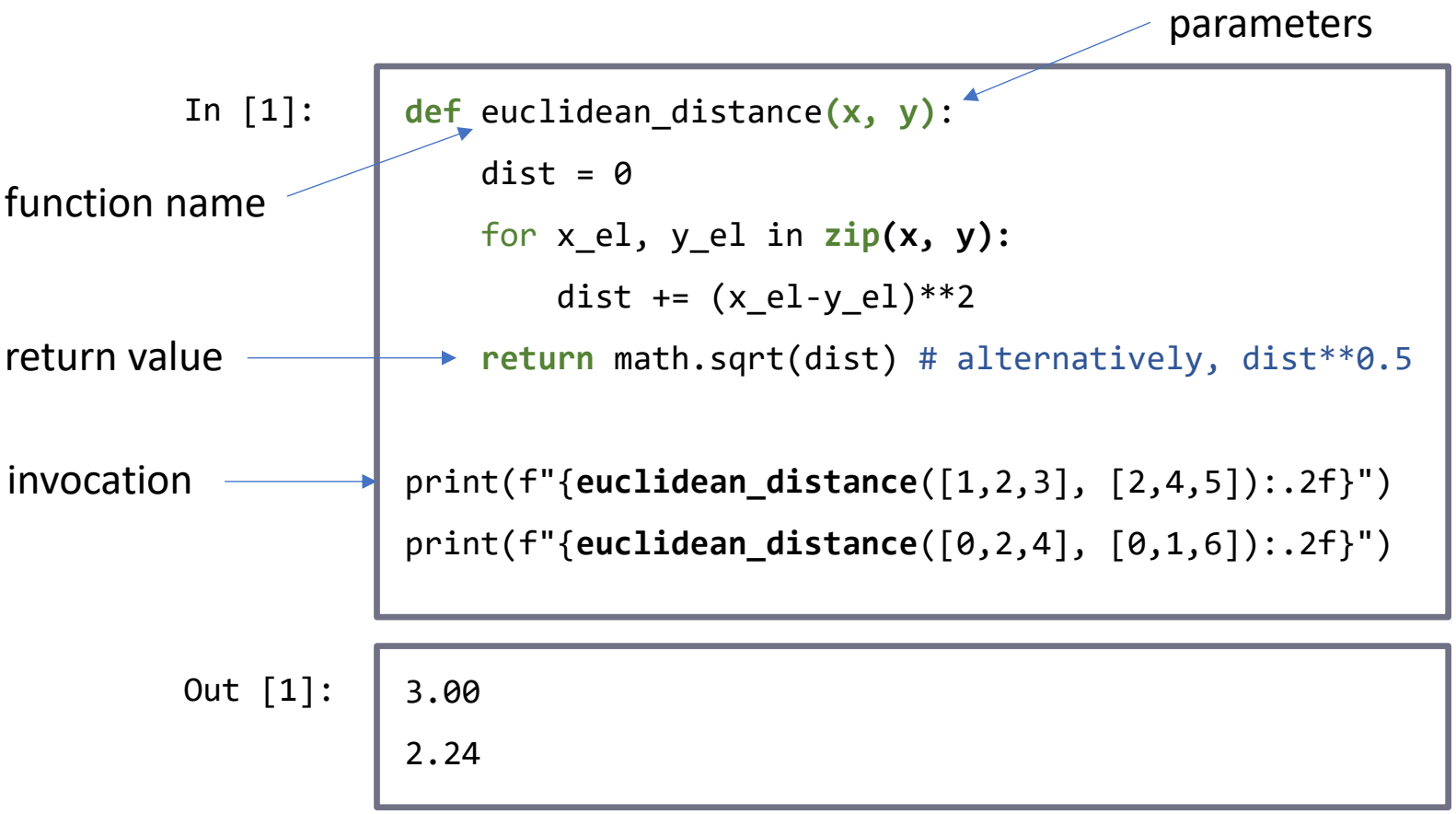
```
with open("./data/my_file.txt") as f:
    for line in f:          # read file line by line
        if line=='skip':
            continue        # go to next iteration
        elif line=='end':
            break           # interrupt loop
        print(line)
```

Out [1]:

```
car
truck
```

Functions

- **Essential** to organize code and avoid repetitions



- **Variable scope**
  - Rules to specify the **visibility** of variables
  - **Local scope**
    - Variables defined inside the function

In [1]:

```
def my_func(x, y):
    z = 5          <-- not accessible from outside
    return x + y + z

print(my_func(2, 4))
print(z)           <-- error: z undefined
```

- **Variable scope**
  - **Global scope**
    - Variables defined outside the function

In [1]:

```
def my_func(x, y):
    return x + y + z

z = 5
my_func(2, 4)
```

z can be read inside the function

Out [1]:

```
11
```

- **Variable scope**
  - **Global scope vs local scope**

In [1]:

```
def my_func(x, y):
    z = 2          <-- define z in local scope
    return x + y + z   <-- use z from local scope

z = 5              <-- define z in global scope
print (my_func(2, 4))
print (z)          <-- z in global scope is not modified
```

Out [1]:

```
8
5
```

- **Variable scope**
  - Force the usage of variables in the global scope

In [1]:

```
def my_func(x, y):
    global z          <-- now z refers to global scope
    z = 2             <-- this assigment is performed to z in the global scope
    return x + y + z
z = 5
print (my_func(2, 4))
print (z)
```

Out [1]:

```
8
2
```

- **Variable scope**
  - Force the usage of variables in the global scope

In [1]:

```
def my_func(x, y):
    global z          <-- now z ref
    z = 2             <-- this assig
    return x + y + z  in the glo
z = 5
print (my_func(2, 4))
print (z)
```

Note
Avoid mixing global-local variables if possible. Pass all variables needed as arguments!

Out [1]:

```
8
2
```

Functions

- Functions can **return tuples**

In [1]:

```
def add_sub(x, y):
    return x+y, x-y

summ, diff = add_sub(5, 3)
print(f"Sum is {summ}, difference is {diff}.")
```

Out [1]:

```
Sum is 8, difference is 2.
```

Functions

- Parameters with **default value**

In [1]:

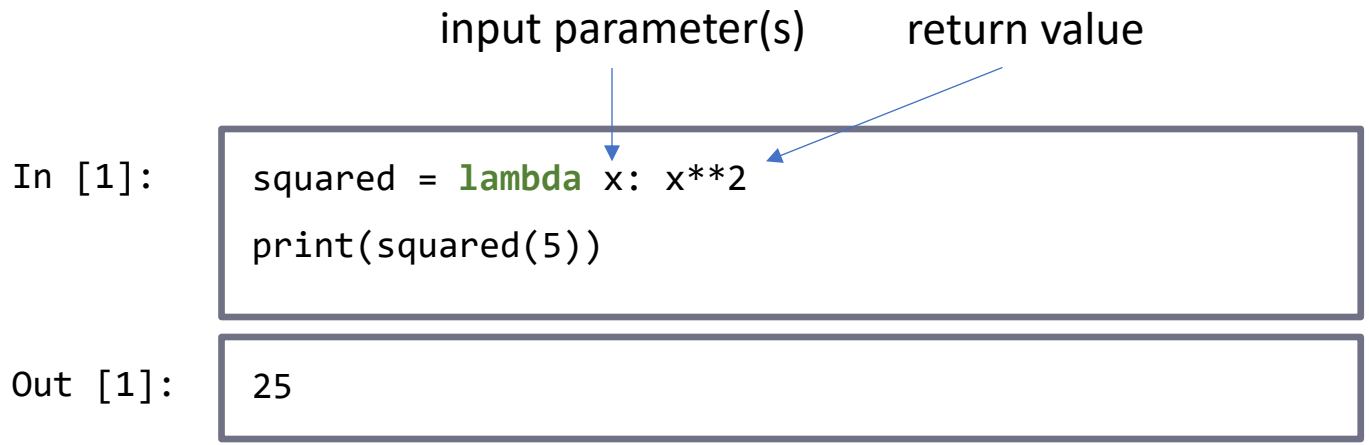
```
def func(a, b, c='defC', d='defD'):
    print(f"{a}, {b}, {c}, {d}")
func(1, 2)                  # use default for c, d
func(1, 2, 'a')             # use default for d, not for c
func(1, 2, d='b')           # passing keyword argument
func(b=2, a=1, d='b')       # keyword order does not matter
func(1, c='a')              # Error: b not specified
```

Out [1]:

```
1, 2, defC, defD
1, 2, a, defD
1, 2, defC, b
1, 2, defC, b
```

Lambda functions

- Functions that can be defined **inline** and **without a name**
- Example of lambda function definition:



Lambda functions

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- **These patterns are useful shortcuts…**
  - Example: **filter** negative numbers from a list:

```
In [1]: numbers = [1, -8, 5, -2, 5]
        negative = []
        for x in numbers:
            if x < 0:
                negative.append(x)
```

  - This code can be completely rewritten with lambda functions…

Lambda functions

PoliTo DBMG

- **Filter and map patterns**
  - Both apply a function element-wise to the elements of a list (iterable)
  - **Filter** the elements of a list based on a condition
  - **Map** each element of a list with a new value

In [1]:

```
numbers = [1, -8, 5, -2, 5]
negative = list(filter(lambda x: x<0, numbers))
squared = list(map(lambda x: x**2, negative))
print(negative)
print(squared)
```

Out [1]:

```
[-8, -2]
[64, 4]
```

Lambda functions

- **Lambda functions and conditions**
  - Example **conditional mapping**:

In [1]:
```
numbers = [1, 1, 2, -2, 1]
sign = list(map(lambda x: '+' if x>0 else '-', numbers))
print(sign)
```

Out [1]:
```
['+', '+', '+', '-', '+']
```

Lambda functions

PoliTo DBMG

- **Sort/min/max by key**

In [1]:

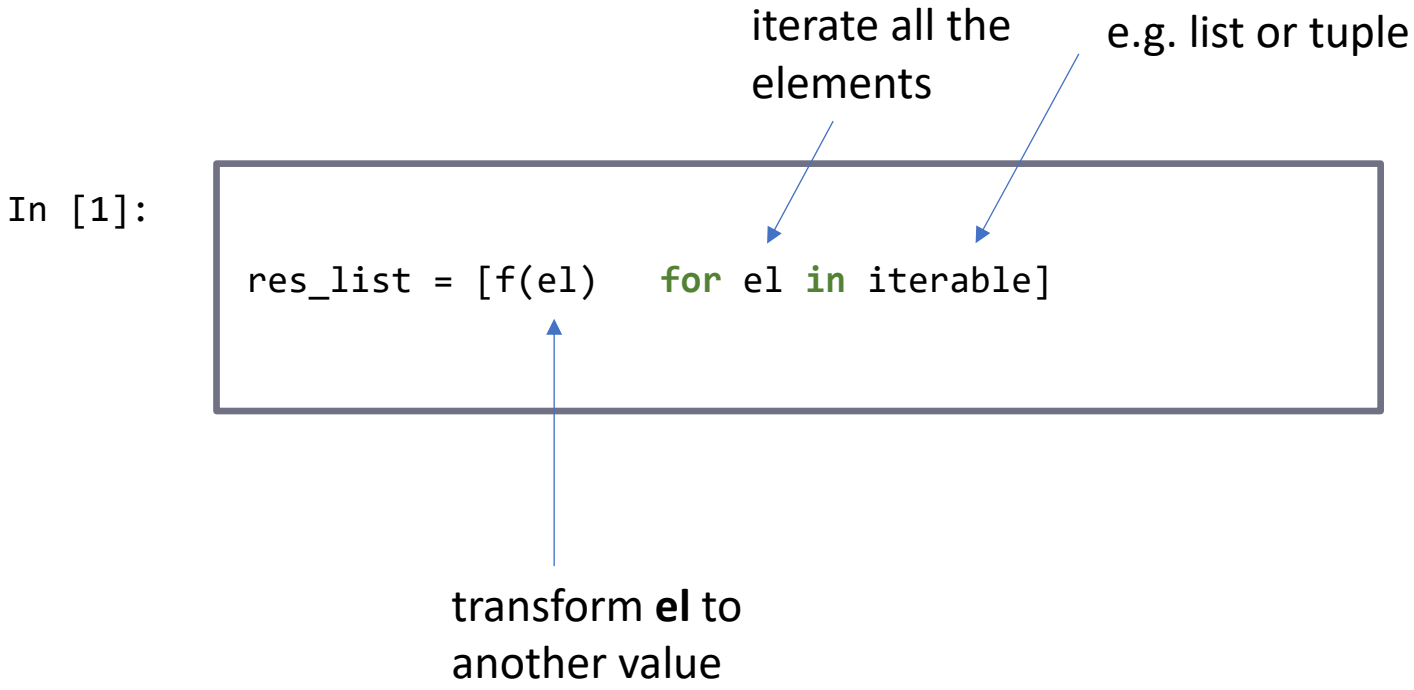
```
records = [{'name':'v1', 'val':5}, {'name':'v2', 'val':1},
           {'name':'v3', 'val':6}]
min_val = min(records, key=lambda r: r['val'])
sorted_records = sorted(records, key=lambda r: r['val'])

print(f"Min: {min_val}")
print(f"Sorted: {sorted_records}")
```

Out [1]:

```
Min: {'name':'v2', 'val':1}
Sorted: [{'name':'v2', 'val':1}, {'name':'v1', 'val':5},
           {‘name':'v3', 'val':6}]
```

List comprehensions

- Allow creating **lists** from other **iterables**
  - Useful for implementing the **map pattern**
  - Syntax:



List comprehensions

- Example: convert to uppercase dictionary keys
  - (**map** pattern)

```
In [1]:
dct = {'a':10, 'b':20, 'c':30}

my_list = [s.upper() for s in dct.keys()]
print(my_list)
```

```
Out [1]:
['A', 'B', 'C']
```

List comprehensions

- Allow specifying **conditions** on elements
  - Example: **square positive** numbers in a list
    - **Filter** + **map** patterns

```
In [1]: my_list1 = [-1, 4, -2, 6, 3]

        my_list2 = [el**2 for el in my_list1 if el>0]
        print(my_list2)
```

```
Out [1]: [16, 36, 9]
```

List comprehensions

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- Example: euclidean distance

```
def euclidean_distance(x, y):
    dist = 0
    for x_el, y_el in zip(x, y):
        dist += (x_el-y_el)**2
    return math.sqrt(dist)
```

```
def euclidean_distance(x, y):
    dist = sum([(x_el-y_el)**2 for x_el, y_el in zip(x, y)])
    return math.sqrt(dist)
```

Other comprehensions

- Dictionary comprehensions
  - Similarly to lists, allow building dictionaries

In [1]:

```
keys = ['a','b','c']
values = [-1, 4, -2]

my_dict = {k:v for k, v in zip(keys, values)}
print(my_dict)
```

Out [1]:

```
{'a': -1, 'b': 4, 'c': -2}
```

- Set comprehensions

```
In [1]: { v ** 2 for v in [ 4, 3, 2, -2, 1 ] }
Out[1]: {1, 4, 9, 16}
```

List comprehensions

- List comprehensions and lambda functions can shorten your code, but …
  - Pay attention to **readability**!!
  - **Comments** are welcome!!

Classes

- A class is a model that specifies a collection of
  - attributes (= variables)
  - methods (that interact with attributes)
  - a constructor (a special method called to initialize an object)
- An object is an **instance** of a specific class

- Example:
  - class: Triangle (all the triangles have 3 edges)
  - object: a specific instance of Triangle

Classes

- Simple class example:

In [1]:

```
class Triangle:
    num_edges = 3

triangle1 = Triangle()
print(triangle1.num_edges)
```

class name

attribute definition

class instantiation

access to attribute

Out [1]:

```
3
```

- In this example all the object instances of Triangle have the same attribute value for num_edges: 3

Classes

- Constructor and initialization:

```
In [1]: class Triangle:
            num_edges = 3
            def __init__(self, a, b, c):
                self.a = a
                self.b = b
                self.c = c

        triangle1 = Triangle(2, 4, 3)
        triangle2 = Triangle(2, 5, 2)
```

self is always the first parameter

constructor parameters

self is a reference to the current object

initialize attributes

invoke constructor and instantiate a new Triangle

Classes

- Methods
  - Equivalent to Python functions, but defined inside a class
  - The first argument is always **self** (reference to current object)
    - **self** allows accessing the object attributes
  - Example:

```
class MyClass:
    def my_method(self, param1, param2):
        ...
        self.attr1 = param1
        ...
```

- Example with methods

In [1]:

```
class Triangle:
    def __init__(self, a, b, c):
        self.a, self.b, self.c = a, b, c
    def get_perimeter(self):
        return self.a + self.b + self.c

triangle1 = Triangle(2,4,3)
triangle1.get_perimeter()
```

method

use **self** for referring to attributes

method invocation (**self** is passed to the method automatically)

Out [1]:

```
9
```

Classes

- **Private** attributes
  - Methods or attributes that are **available only inside the object**
  - They are **not accessible** from outside
  - Necessary when you need to define elements that are useful for the class object but must not be seen/modified from outside

Classes

- **Private** attributes

In [1]:

```
class Triangle:
    def __init__(self, a, b, c):
        self.a, self.b, self.c = a, b, c
        self.__perimeter = a + b + c
    def get_perimeter(self):
        return self.__perimeter

triangle1 = Triangle(2,4,3)
print(triangle1.get_perimeter())
print(triangle1.__perimeter)
```

2 leading underscores make variables private

Error! Cannot access private attributes

Out [1]:

```
9
```

File Handling

- Use `open(filename, 'w'/'r')` to **read/write** a file

```
f = open("my_file.txt", "r")
…
f.close()
```

Watch out the strategy!
"r" - reading
"w" - writing
"a" - append

- We always need to remember `f.close()`. Unless…
- Use `with` statement!

```
with open("my_file.txt", "r") as f:
    …
```

  - It avoids remembering to close the file
  - Even in case of errors it guarantees a correct closure

File Handling

- How to **read**?

```
with open("my_file.txt", "r") as f:
    lines = f.readlines()
    for line in f:
        print(line)
```

`readlines()` read all the lines in once

Same as reading one line at a time

```
line = True
while(line):
    line = f.readline()
```

- What if the file is too big?
  - Chunk it!

```
with open("my_file.txt", "r") as f:
    for chunk in f.read(5):
        print(chunk)
```

`read(n)` reads n characters at a time (default n=1)

File Handling

PoliTo DBMG

- How to **write**?

```
with open(“my_file.txt”, “w”) as f:
    f.write(“Ops I deleted everything!”)
```

When you open a file with “w” you cancel all the existing content

- Example: make a copy of a file

```
with open(“my_file.txt”, “r”) as f1:
    with open(“my_file_copy.txt”, “w”) as f2:
        for line in f1:
            f2.write(line)
```

Exception handling

- To track errors during program execution

In [1]:

```
try:
    res = my_dict['key1']
    res += 1
except:
    print("Exception during execution")
```

In [2]:

```
try:
    res = a/b
except ZeroDivisionError:
    print("Denominator cannot be 0.")
```

can specify exception type →

Exception handling

PoliTo DBMG

- The **finally** block is executed in any case after try and except
  - It tipically contains cleanup operations
  - Example: reading a file

In [1]:

```
try:
    f = open('./my_txt','r')     # open a file
    ...                          # work with file
except:
    print("Exception while reading file")
finally:
    f.close()
```

Exception handling

- The try/except/finally program in the previous slide can also be written as follows:

In [1]:
```
try:
    with open('./my_txt', 'r') as f:
        for line in f:
            ... # do something with line
except:
    print("Exception while reading file")
```

- If there is an **exception** while reading the file, the with statement ends
- In any case, when the with statement ends the file is automatically closed (similarly to the finally statement)

Home exercises

- (1.0 Setup an environment)
- 1.1 Python Examples.ipynb
- 1.2 Python Tuples and Lists.ipynb
- 1.3 Python Dictionaries and Sets.ipynb
- 1.4 Python Lambda functions, Functions and Classes.ipynb
- 1.5 Python Files and Exceptions.ipynb