Python Basics

Python and R for Data Science

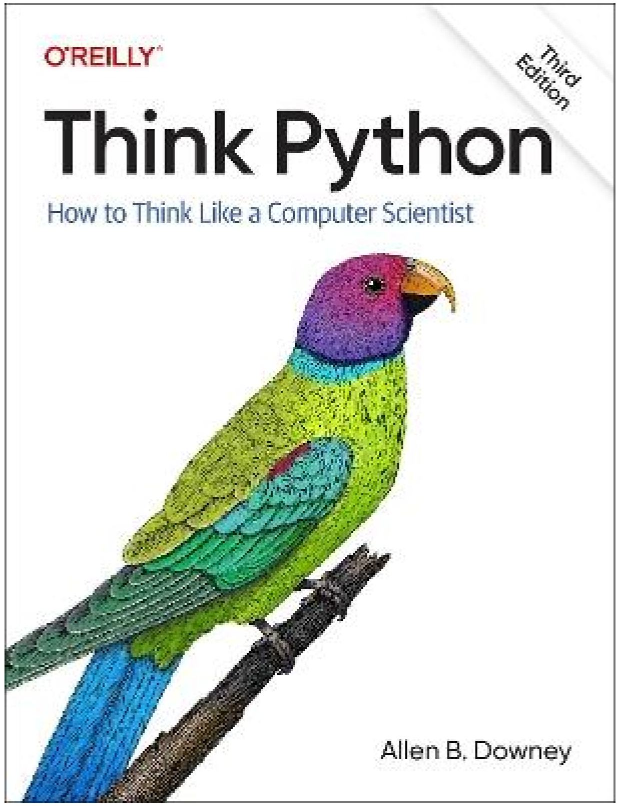
Data Science and Management

LUISS

Python: from zero to hero

Preliminaries

Reference Book: Think Python (3rd ed.)



Think Python is an introduction to Python for people who have never programmed before – or for people who have tried and had a hard time.

Freely available: https://allendowney.github.io/ThinkPython/

Programs manipulate data

Given input data, compute output data.

Data can be anything:

- text file
- something on the web
- click of a mouse (input)
- text on the screen (output)

Two main categories of data

Data types can be either:

- **scalar**: a single value
- **non scalar**: a collection of values

Scalar data types in Python

Type	Python type	Examples
Number > integers	`int`	`5`, `-2`
Number > floating point	`float`	`5.0`, `-2.0`
boolean	`bool`	`True`, `False`
invalid value	`NoneType`	`None`

Non-scalar data types in Python

Type	Python type	Examples
textual	`string`	`"Hello, World!"`, `'Bazinga123'`
list	`List`	`[1, 2, 3]`
tuple	`Tuple`	`("a", 2, 3.0)`
set	`Set`	`set("a", 1, 3.0)`
dictionary	`Dict`	`{"name": "Francesco", "surname" : "Totti"}`

Printing data

We can print on the screen (output) using `print(<data>)`:

In [1]:

```
print(5)
print(5.0)
print(True)
print("Hello, Word!")
print(None)
```

```
5
5.0
True
Hello, Word!
None
```

Variables

Programs manipulate non *constant* data

Real-world programs take the data from the external world (e.g., data from the web):

- **no assumptions on data *value***
- **assumptions on data *type***

Hence, programs must be correct, i.e., compute the correct result, regardless of the data value for which they were initially written and tested.

Notice that:

- if a program only works on constant data then it is enough to run it once and then use its result(s), without the need to run it again.
- if the program works on non-constant data then we have it from scratch every time the data has changed.

Non-constant data: **variables**

To represent data for which we cannot determine its constant value, we use **variables**:

In [2]:
```python
# let us suppose the current temperature is 35
# we can now store this value into a variable
current_temp = 35   # we call it current_temp
print(current_temp) # we now print the variable _current_ value

# after a bit of time, we measure the temperature again
# and we find that the temperature has increased to 40
current_temp = 40   # we change the value of the variable
print(current_temp) # we now print the variable _current_ value

# ragardless of the current value, our code has not changed
# i.e., the instruction performing the print is the same
```

```
35
40
```

Variables

- a variable is defined by using the assignment operatore `=`:
  `<name> = <data value>`

- `<name>` can be a mix of letters, numbers, and underscore (`_`)

- `<name>` cannot start with a number

- `<name>` cannot be equal to a Python keyword, i.e., reserved words (we will see them while introducing the language)

- `<name>` should be something meaningful for the human: **Python does not care about the variable name as long as it is valid and unique**.

- PEP-8, which defines several style guidelines, suggests to use lowercase descriptive words separated by one underscore

Variables can... vary

- A variable will have a specific **data type**, e.g., `int` or `bool`
- We **cannot** make assumptions on its value when writing the code but we **have to know its data type** to write code that can handle it.
- Python allows us to re-assign the same variable name:

In [3]:
```
current_temp = 35 # initial value
current_temp = 40 # new value!
```

When re-assigning a variable, tha previous value is lost.

- Python allows us to change the data type when doing a re-assignment:

In [4]:
```
current_temp = 35 # here, the variable is an int
current_temp = "IT IS (TOO) HOT" # now, it is a string
```

How to retrieve the data type?

Given a piece of data, we can retrieve its data type using `type(<data>)`:

In [5]:

```
print(type(5))
print(type(5.0))
print(type(True))
print(type("Hello, Word!"))
print(type(None))
```

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

In [6]:

```
current_temp = 35 # here, the variable is an int
print(type(current_temp))
current_temp = "IT IS (TOO) HOT" # now, it is a string
print(type(current_temp))
```

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

```
None
```

`None`: informal definition

The `NoneType` has only the value `None`.
We use it when we do not know yet our data value.

For instance:

In [7]:
```python
temp = None # we do not know the temperature
print(temp)
```

```
None
```

`None`: operators

Given a variable, we can check whether it is (not) assigned to `None` using the `is` (`is not`) operator:

In [8]:
```
temp = None
print(temp is None)
print(temp is not None)
```

```
True
False
```

In [9]:
```
temp = 35
print(temp is None)
print(temp is not None)
```

```
False
True
```

Integers (`int`)

Integers (`int`): informal definition

Integer: sequence of numbers with no periods nor commas.

For instance:

In [10]:
```
x = 10
y = -20
print(x)
print(y)
```

```
10
-20
```

Integers (`int`): operators

Operator	Semantics	Example	Example Result	Result Type
`-` (unary)	Negation	`-5`	`-5`	`int`
`+`	Addition	`5 + -2`	`3`	`int`
`-` (binary)	Subtraction	`5 - -2`	`7`	`int`
`*`	Multiplication	`5 * -2`	`-10`	`int`
`/`	Division	`5 / -2`	`-2.5`	`float`
`//`	Floor Division	`5 / -2`	`-2.5`	`int`
`%`	Remainder (modulo)	`5 % 2`	`3`	`int`
`**`	Exponentiation	`5**2`	`25`	`int`

Integers (`int`): try!

In [11]:

```
x = 5
y = -2
print(-x)
print(x + y)
print(x - y)
print(x * y)
print(x / y)
print(5 // y)
print(x % y)
print(x ** -y)
```

```
-5
3
7
-10
-2.5
-3
-1
25
```

Integers (`int`): operator order

Operators have a similar priority rules as in mathematics.
Use parentheses `(` `)` to force the order.

In [12]:

```
x = 5
y = 2
z = 3
print(x + 2 * z) # same as the next one due to priority
print(x + (y * z))
print((x + y) * z) # force a specific operator order
```

```
11
11
21
```

Floating point (`float`)

Floating point (`float`): informal definition

Floating point: sequence of numbers containing one `.`.

For instance:

In [13]:
```
pi = 3.14159
x = -5.0
print(pi)
print(x)
```

```
3.14159
-5.0
```

Floating point (`float`): operators

Operator	Semantics	Example	Example Result	Result Type
`-` (unary)	Negation	`-5.0`	`-5.0`	`float`
`+`	Addition	`5.0 + -2.0`	`3.0`	`float`
`-` (binary)	Subtraction	`5.0 - -2.0`	`7`	`float`
`*`	Multiplication	`5.0 * -2.0`	`-10.0`	`float`
`/`	Division	`5.0 / -2.0`	`-2.5`	`float`
`//`	Floor Division	`5.0 / -2.0`	`-2.5`	`float`
`%`	Remainder (modulo)	`5.0 % 2.0`	`3.0`	`float`
`**`	Exponentiation	`5.0**2.0`	`25.0`	`float`

Floating point (`float`): try!

In [14]:

```
print(-5.0)
print(5.0 + -2.0)
print(5.0 - -2.0)
print(5.0 * -2.0)
print(5.0 / -2.0)
print(5.0 // 2.0)
print(5.0 % -2.0)
print(5.0 ** 2.0)
print(5.0 + 2.0 * 3.0) # same as the next one due to priority
print(5.0 + (2.0 * 3.0))
print((5.0 + 2.0) * 3.0) # force a specific operator order
```

```
-5.0
3.0
7.0
-10.0
-2.5
2.0
-1.0
25.0
11.0
11.0
21.0
```

`int` and `float` aspects

What if we mix `int`s and `float`s?

If one of the operands is a `float`, then the result will be a `float`

In [15]:
```
print(5 + 2.0)
print(5.0 - 2)
```

```
7.0
3.0
```

How to convert from `int` to `float` (or viceversa)?

Use `int(<data>)` and `float(<data>)`:

In [16]:
```
print(int(3.6))
print(float(5))
```

```
3
5.0
```

Notice that:

- converting a `float` to an `int` may lead to a loss of information
- `int(<data>)` truncates the number to its decimal part

If want to round a `float` to the nearest integer, then we can use `round(<data>)`:

In [17]:
```
print(round(3.6))
```

```
4
```

Python still obliges to math rules!

Invalid math operations

In [18]:
```
5 / 0 # this cannot be done... it will raise an exception
```

```
---------------------------------------------------------------------------
ZeroDivisionError                         Traceback (most recent call last)
/tmp/ipykernel_2884802/3267015569.py in <module>
----> 1 5 / 0 # this cannot be done... it will raise an exception

ZeroDivisionError: division by zero
```

In general, an invalid operation in Python raises an `Exception`.
We will learn how to deal with `Exception`s later on.

Python has a fixed amount of resources!

Fixed precision

In [ ]:

```
print(1 / 3)  # A computer keep tracks of an approximation
              # of the number. Hence, there are no periodic
              # numbers in Python.

print((1 / 3) * 3)  # still, in Python, in "easy" cases, we get back
                    # what we expect.

print(3.14 + 1) # however, in other cases, we only get an apx
                # Here, we get something slightly bigger than 4.14!
                # This is due to the way computers store numbers.
```

```
0.3333333333333333
1.0
4.140000000000001
```

Mixing assignment and arithmetic operators

Often, we write:

In [ ]:
```
x = 2
y = 4
x = x + y
x = x * y
x = x / y
```

These arithmetic+assgniment operations can be written as:

In [ ]:
```
x += y
x *= y
x /= y
x
```

Booleans (`bool`)

Booleans (`bool`): informal definition

Boolean: either `True` or `False`.

For instance:

In [ ]:

```
is_raining = False
is_too_hot = True
print(is_raining)
print(is_too_hot)
```

```
False
True
```

Booleans (`bool`): operator `not`

`not` performs the negation of the operand:

- the result is `True` when the operand is `False`
- the result is `False` when the operand is `True`

A	**Expression: `not` A**	**Result**
`False`	`not False`	`True`
`True`	`not True`	`False`

Booleans (`bool`): operator `or`

`or` performs the disjunction between two boolean operands:
the result is `True` when at least one of the operands is `True`.

A	**B**	**Expression: A `or` B**	**Result**
`True`	`True`	`True or True`	`True`
`True`	`False`	`True or False`	`True`
`False`	`True`	`False or True`	`True`
`False`	`False`	`False or False`	`True`

Booleans (`bool`): operator `and`

`and` performs the conjunction between two boolean operands:
the result is `True` when both operands are `True`.

A	B	Expression: A `or` B	Result
`True`	`True`	`True or True`	`True`
`True`	`False`	`True or False`	`False`
`False`	`True`	`False or True`	`False`
`False`	`False`	`False or False`	`False`

Booleans (`bool`): operator `xor`

`^` performs the exclusive or between two boolean operands:
the result is `True` when exactly one of the two operands is `True`.

A	B	Expression: A `^` B	Result
`True`	`True`	`True ^ True`	`False`
`True`	`False`	`True ^ False`	`True`
`False`	`True`	`False ^ True`	`True`
`False`	`False`	`False ^ False`	`False`

Booleans (`bool`): recap binary operators

A	**B**	**A `or` B**	**A `and` B**	**A `^` B**
`False`	`False`	`False`	`False`	`False`
`True`	`False`	`True`	`False`	`True`
`False`	`True`	`True`	`False`	`True`
`True`	`True`	`True`	`True`	`False`

Booleans (`bool`): try!

In [ ]:

```
print(not True)
print(True or False)
print(True and False)
print(True ^ False) # this is the XOR operator!
```

```
False
True
False
True
```

Why booleans are useful?

1. A `bool` will be generated when, e.g., comparing other types:
    - Is `5` smaller than `2`? `False`
2. We often want to perform a task:
    - when a condition is not true: `not`
    - when one of the conditions is true: `or`
    - when all conditions must be true: `and`
3. We need to enable or disable a feature

Data comparison

Comparison operators

Both `int`s and `float`s can be compared using a comparison operator and the result will be a `bool`:

Operator	Semantics	Example	Example Result
`<`	Less than	`1 < 3`	`True`
`<=`	Less or equal than	`5 <= 6`	`False`
`>`	Greater than	`1 > 6`	`False`
`>=`	Greater or equal than	`1 <= 6`	`True`
`==`	Equal to	`5 == 6`	`False`
`!=`	Not equal to	`5 != 6`	`True`

Strings (`string`)

Strings: informal definition

String: sequence of any *kind* of characters enclosed in single (`'`) or double (`"`) quotes. For instance:

In [ ]:
```
university_short_name = "LUISS"
university_long_name = 'Libera Università Int. degli Studi Sociali'
print(university_short_name)
print(university_long_name)
```

```
LUISS
Libera Università Int. degli Studi Sociali
```

In [ ]:
```
university_short_name = "LUISS' # we need to be consistent
                                # with the use of quotes!
```

```
  File "/tmp/ipykernel_794386/1682044638.py", line 1
    university_short_name = "LUISS' # we need to be consistent
                            ^
SyntaxError: unterminated string literal (detected at line 1)
```

How to have a string containing a quote?

If we want to have a quote ***within*** a string, we have several strategies:

In [ ]:
```
s1 = 'Hello "world"'          # we can use double quotes
                              # inside single quotes
s2 = "Hello 'world'"          # we can use single quotes
                              # inside double quotes
s3 = "Hello \"world\""        # we can use the escape \ to
                              # make the double quotes
                              # part of the string
s4 = '''Hello 'world' '''     # we can use the triple quotes
```

String: escape characters

Some characters, when escaped, will be treated in a specific way by `print`:

In [ ]:
```
s1 = "Hello\nWorld!" # \n is the newline
print(s1)
```

```
Hello
World!
```

In [ ]:
```
s2 = "Hello\tWorld!" # \t is the tabular
print(s2)
```

```
Hello	World!
```

In [ ]:
```
s3 = "Hello\\World!" # \\ prints \
print(s3)
```

```
Hello\World!
```

String: operators

Operator	Semantics	Example	Example Result
`+`	Concatenation	`"a1" + "b2"`	`"a1b2"`
`*`	Repetition	`"a1" * 3`	`"a1a1a1"`
`in`	Membership	`"LU" in "LUISS"`	`True`
`not in`	Membership	`"LU" not in "LUISS"`	`False`
`==`	Equality	`"LUISS" == "luiss"`	`False`
`!=`	Inequality	`"LUISS" != "luiss"`	`True`

NOTE: strings are case sensitive in Python!

String: indexing

Using indexing, we can access a specific character of a string:

In [ ]:
```
s1 = "Hello\nWorld!"
print(s1[0]) # we access the first character
print(s1[4]) # we access the fifth character

i = 2
print(s1[i]) # we access the (i+1)-th character
```

```
H
o
l
```

NOTE: indexes start their count from zero (not from one)!

String: negative indexing?

Quite strangely, Python supports negative indexes:

In [ ]:
```
s1 = "Hello\nWorld!"
print(s1[-1]) # we access the last character
print(s1[-2]) # we access the second last character
```

```
!
d
```

Strings are immutable

Even if a `string` is a non-scalar data type, it is immutable, i.e., we cannot change its internal data. Hence, we cannot change an existing string:

In [ ]:
```
s1 = "Hello\nWorld!"
s1[5] = ", " # this will raise an exception
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
/tmp/ipykernel_1885124/1214696963.py in <module>
      1 s1 = "Hello\nWorld!"
----> 2 s1[5] = ", " # this will raise an exception

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

Notheless, we can always create a new string:

In [ ]:
```
s1 = "Hello\nWorld!"
s2 = s1[:5] + ", " + s1[6:] # concatenation gives a new string
print(s2)
```

```
Hello, World!
```

String: slicing

We can get a slice, i.e., substring, by specifying the starting and ending index:

In [ ]:
```
s1 = "Hello\nWorld!"
print(s1[0:5])  # we access the first five characters
                # the last index is not included
```

```
Hello
```

When the starting or ending index is the first and last position, respectively, then we can omit them:

In [ ]:
```
print(s1[:5]) # starting index is 0
print(s1[6:]) # ending index is the last character
```

```
Hello
World!
```

We can even use negative indexes:

In [ ]:
```
print(s1[-6:])  # we access the last three characters
```

```
World!
```

Strings: interpolation

We can build string by embedding the values of other variables:

- Interpolation with `f`-strings:

In [ ]:
```python
pi = 3.14159
msg = f"An apx of pi is {pi}" # notice the f before the string
print(msg)
msg = f"An apx of pi is {int(pi)}"
print(msg)
```

```
An apx of pi is 3.14159
An apx of pi is 3
```

Strings: interpolation (cont'd)

- Interpolation with modulo operator:

In [ ]:
```
msg = "An apx of pi is %f" % (pi,) # %f means print as a float
print(msg)
msg = "An apx of pi is %d" % (pi,) # %d means print as an int
print(msg)
msg = "An apx of pi is %s" % (pi,) # %s means print as a string
print(msg)
msg = "An apx of pi is %f, or after truncation, %d" % (pi, pi)
print(msg)
```

```
An apx of pi is 3.141590
An apx of pi is 3
An apx of pi is 3.14159
An apx of pi is 3.141590, or after truncation, 3
```

In the next weeks, we will see more advanced aspects of interpolation.

Multiple arguments in `print`

`print` can take more than one argument:

In [ ]:
```python
s1 = "Hello"
s2 = "World"
print(s1, s2) # the resulting output will have
              # a space between the two strings
```

```
Hello World
```

String operations

Given a string `s = "ciaO"` and `s2 = "ia"`:

Operations	Semantics	Result
`len(s)`	length, i.e., number of chars	`4`
`s.lower()`	lowercased `s`	`ciao`
`s.upper()`	uppercased `s`	`CIAO`
`s.capitalize()`	titlecased `s`	`Ciao`
`s.count(s2)`	count occurrences of `s2` in `s1`	`1`
`s.find(s2)`	finds index of `s2` in `s`, or `-1`	`2`
`s.index(s2)`	finds index of `s2` in `s`, or raise exception	`2`

We will see more examples later on. This just to give a hint about what Python can give you for free.

String operations (cont'd)

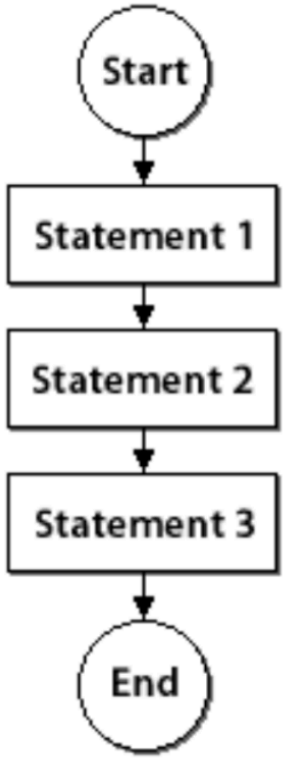
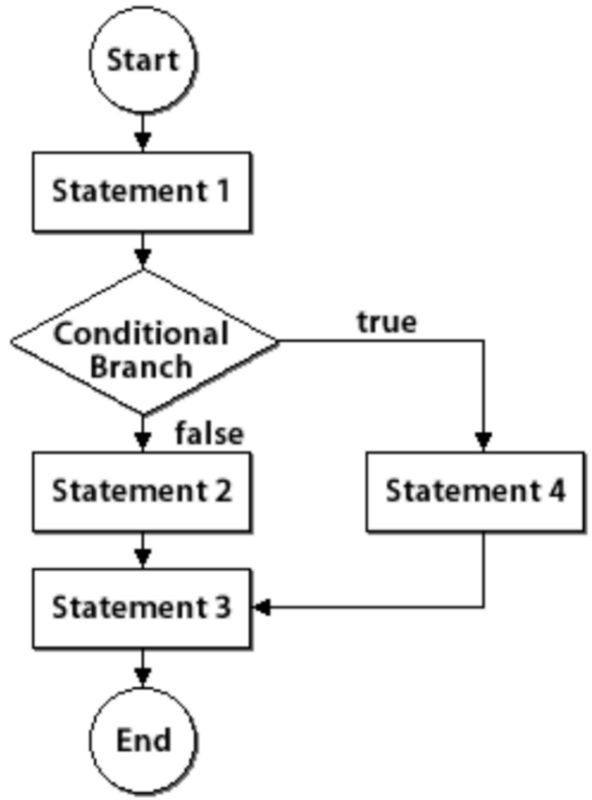
Given a string `s = "ciaO"` and `s2 = "ia"`:

Operations	**Semantics**	**Result**
`s.startswith(s2)`	check if `s` starts `s2`	`False`
`s.endswith(s2)`	check if `s` ends `s2`	`False`
`s.istitle()`	check if `s` is titlecased	`False`
`s.islower()`	check if `s` is lowercase	`False`
`s.isupper()`	check if `s` is uppercase	`False`
`s.isalpha()`	check if `s` contains only letters	`True`
`s.isdigits()`	check if `s` contains only digits	`False`
`s.isalnum()`	check if `s` contains only letters or digits	`True`

We will see more examples later on. This just to give a hint about what Python can give you for free.

Conditional execution

Conditionally execute something?

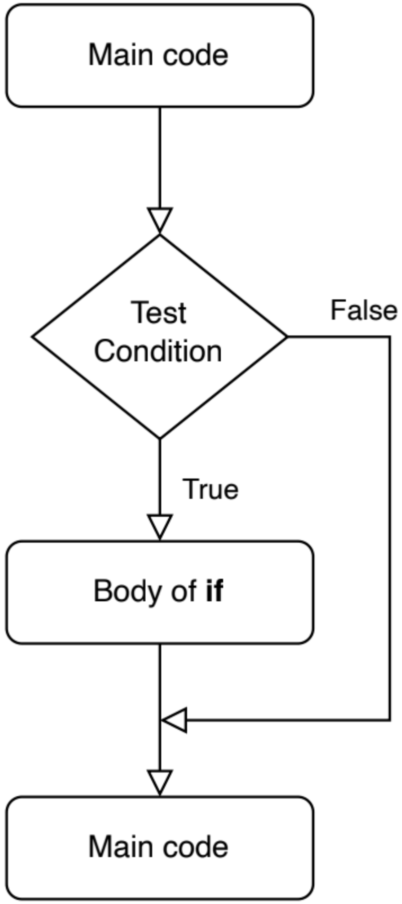
No branching	Branching
	
Stataments 1, 2, and 3 are always executed	First, statement 1 is executed. If the condition is true, then statement 4 is executed, otherwise statement 2 is executed. Finally, statement 3 is executed.

Why to conditionally execute?

Most programs perform some tasks only when some conditions are met. E.g.:

- **IF** *the temperature is greater than 30* **THEN** *start the AC*
- **IF** *it is raining* **THEN** *take the umbrella* **ELSE** *leave the umbrella*

Conditional: `if` (flow diagram)



Conditional: `if`

The `if` statement allows us to conditionally execute a group of instructions (*body of the if*) based on a condition:

```
if <COND> :
    <instruction #1>
    <instruction #2>
    [...]
    <instruction #N>
```

Important remarks:

- ***<COND>*** must be a boolean. This could be yielded by the evaluation of different boolean condition through `not`, `and`, and `or` operator. Also, the condition may be generated by using a comparison operator.
- after ***<COND>*** we must have `:`
- **the body of the `if` must be indented.** Indentation is, by convention, four spaces or a tabular (tab key on your keyboard!).

In [ ]:
```
current_temp = 50 # suppose we take it from a sensor
```

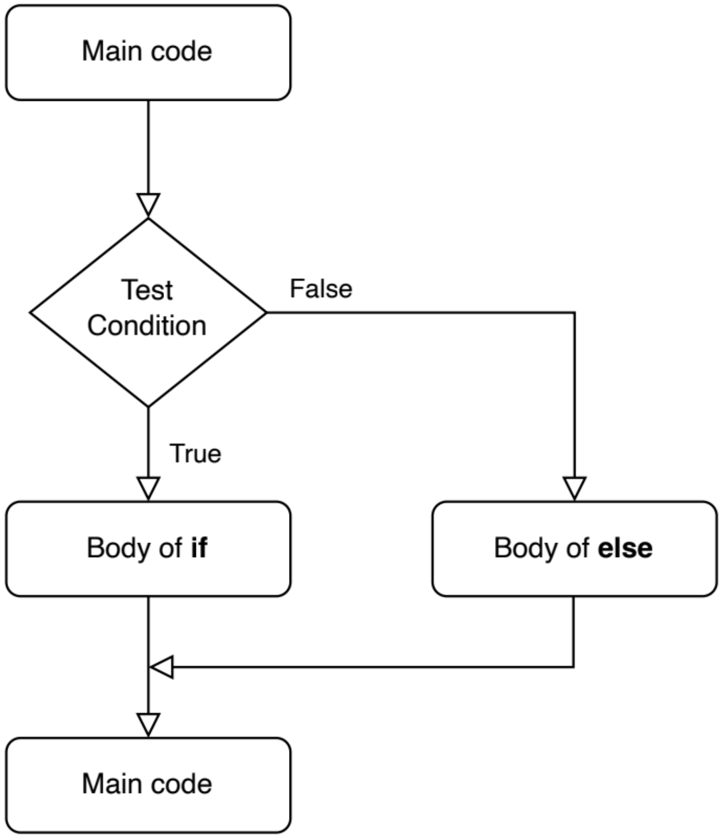
In [ ]:
```
if current_temp > 30:
    print("Need to start the AC!")  # the body is one instr.
print("---") # this is not part of the if body
```

```
Need to start the AC!
---
```

In [ ]:
```
if current_temp > 45:
    print("Need to start the AC...") # body first instr.
    print("or go to vacation")       # body second instr.
print("---") # this is not part of the if body
```

```
Need to start the AC...
or go to vacation
---
```

Conditional: `if`-`else` (flow diagram)



Conditional: `if`-`else`

The `if` and `else` statements allows us to alternatively execute two groups of instructions (*body of the if* and *body of the else*, respectively) based on a condition:

`if` ***<COND>*** `:`
    <instruction #A1>
    <instruction #A2>
    [...]
    <instruction #AN>
`else:`
    <instruction #B1>
    <instruction #B2>
    [...]
    <instruction #BN>

Important remarks:

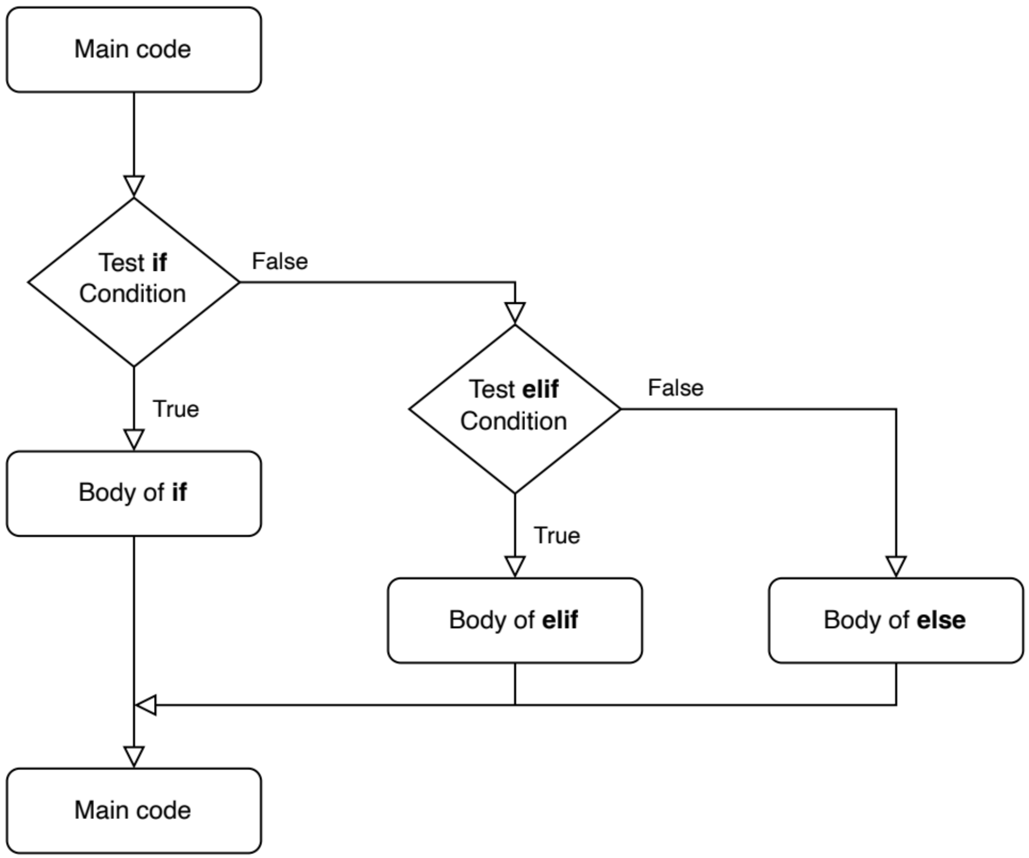
- after `else` we must have `:`
- **the body of the `else` must be indented.** Indentation is, by convention, four spaces or a tabular (tab key on your keyboard!). It must be consistent with the indentation of body of the if.

In [ ]:
```
current_temp = 50 # suppose we take it from a sensor
```

In [ ]:
```
if current_temp >= 20:
    print("Warm") # the body of the if is one instr.
else:
    print("Cold") # the body of the else is one instr.
print("weather") # this is not part of the if body
```

```
Warm
weather
```

Conditional: `if`-`elif`-`else` (flow diagram)



Conditional: `if`-`elif`-`else`

The `if`, `elif`, and `else` statements allows us to alternatively execute different groups of instructions:

```
if <COND-A> :
  <instructions #A1-N>
elif <COND-B> :
  <instructions #B1-N>
elif <COND-C> :
  <instructions #C1-N>
else:
  <instructions #D1-N>
```

Important remarks:

- we can have an arbitrary number of `elif` statements
- each group of instructions must be indented
- the conditions are checked in order and the first one matching will lead to the related group of instructions (while other groups will be skipped)
- if no condition yields `True` then the body of the `else` is executed

In [ ]:
```
current_temp = 50 # suppose we take it from a sensor
```

In [ ]:
```
if current_temp >= 40:
    print("Hell")    # the body of the if is one instr.
elif current_temp >= 30:
    print("Hot") # the body of the elif is one instr.
elif current_temp >= 20:
    print("Warm") # the body of the elif is one instr.
else:
    print("Cold") # the body of the else is one instr.
print("weather") # this is not part of the if body
```

```
Hell
weather
```

Nested conditionals

We can nest one conditional within another conditional:

In [ ]:
```
current_temp = 50 # suppose we take it from a sensor
is_raining = True # suppose we take it from a sensor
```

In [ ]:
```
if current_temp >= 0:
    if is_raining:
        print("Wet hot") # notice the double indentation
    else:
        print("Dry hot") # notice the double indentation
else:
    if is_raining:
        print("Wet cold") # notice the double indentation
    else:
        print("Dry cold") # notice the double indentation
```

```
Wet hot
```

Nested conditionals (cont. d)

The prevsious code, it could be rewritten as:

In [ ]:
```
if current_temp >= 0 and is_raining:
    print("Wet hot")
elif current_temp >= 0 and not is_raining:
    print("Dry hot")
elif current_temp < 0 and is_raining:
    print("Wet cold")
else:
    print("Dry cold")
```

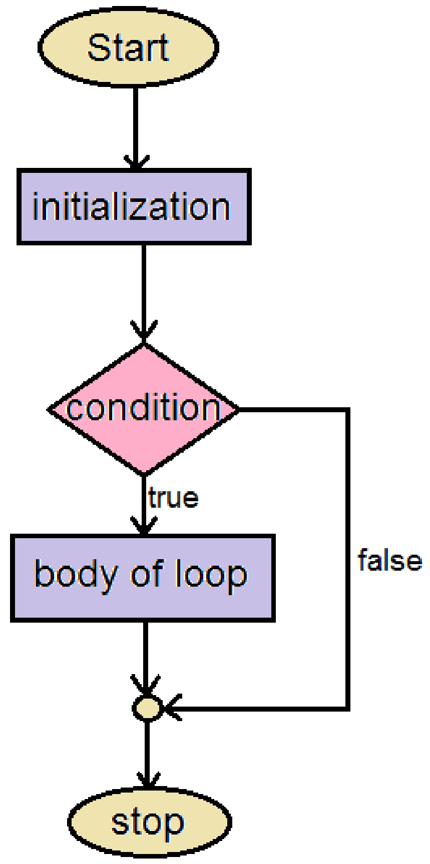
```
Wet hot
```

However, it would be slightly:

- less readable: less clear which are the common preconditions
- more error-prone: mistakes when rewriting the same condition more than once

Iteration

Iterate: repeated execution of something



Why we need to repeat the execution of something?

There are several cases where we need to repeatedly execute a group of instructions until a condition is met. For instance:

- read for the N times the current temperature and for each time sum it to an accumulator variable; finally compute the average.
- sum the first N positive numbers

Loop: `while`

The `while` statement allows us to repeat the execution of a group of instructions (body of the for) until a condition is met:

```
while <COND> :
    <instruction #1>
    <instruction #2>
    [...]
    <instruction #N>
```

Important remarks:

- ***<COND>*** must be a boolean
- after ***<COND>*** we must have `:`
- **the body of the `while` must be indented.**
- if ***<COND>*** is `True`, then the body of the `while` is executed once
- after the execution of the body, ***<COND>*** is evaluated again, deciding whether to execute again the body
- repat until ***<COND>*** is `False`

In [ ]:

```python
n = 10 # change as you wish
k = 0
sum_temps = 0
while k < n:
    current_temp = 35   # suppose we take it from a sensor
                        # making something that changes
    sum_temps += current_temp
    k += 1
avg_temp = sum_temps / n
print("Average temperature is", avg_temp, "after", n, "measurements")
```

```
Average temperature is 35.0 after 10 measurements
```

In [ ]:

```python
n = 100 # change as you wish
k = n
sum_n = 0
while k > 0:
    sum_n += k
    k -= 1
print("Sum of the first", n, "numbers is", sum_n)
```

```
Sum of the first 100 numbers is 5050
```

Iteration N times?

Iterating for N times is quite common in most programs. For this reason, Python provides:

- `for` statement
- `range(<number>)`

Let us see how they play together.

Loop: `for`

The statement `for` performs an iteration (i.e., execution of its body) *for* each ***<data item>*** available in the ***<dataset>*** specified after `in`.

`for` ***<data item>*** `in` ***<dataset>*** `:`
    <instruction #1>
    <instruction #2>
    [...]
    <instruction #3>

Remarks:

- ***<data item>*** will be a new variable that we define to represent the current item. Making it a variable, allow us to access it within the body of the `for`.
- ***<dataset>*** can be any piece of data that can be *iterated*. As we will see later, non-scalar data types are iterable. For now, we consider the iterable dataset generated by `range(<number>)`.

Loop: `for` + `range(<n>)`

`range(<n>)` generates an iterable dataset containing integers from `0` to `n - 1`, where `n` is a positive integer. We will embed into our `for` loop in this way:

`for` ***<data item>*** `in` ***range(<n>)***`:`
    <instruction #1>
    <instruction #2>
    [...]
    <instruction #3>

The body of the `for` will be executed exactly `n` times.

In [ ]:
```python
n = 100 # change as you wish
sum_n = 0
for k in range(n + 1): # remember that the last number is not included!
    sum_n += k
print("Sum of the first", n, "numbers is", sum_n)
```

```
Sum of the first 100 numbers is 5050
```

`range` is a bit more powerful

`range(<start>, <stop>, <step>)` returns a sequence of intergers:

- starting from `<start>`
- incremented by `<step>`
- ending at `<stop>-1`

Caveats:

- `<stop>` is mandatory
- `<step>` is optional: if not provided, it defaults to 1
- `<start>` is optional: if not provided, it defaults to 0

In [ ]:
```python
sum_n = 0
start = 10 # we assume it is an even number
end = 101
for k in range(start, end, 2):
    sum_n += k
print(f"Sum of the even numbers in interval [{start},{end-1}) is {sum_r
```

```
Sum of the even numbers [10,100) is 2530
```

Loops: `for` + `string`

A `string` is an iterable sequence. We can thus use it within a `for`:

`for` ***<data item>*** `in` ***<string>***`:`
    <instruction #1>
    <instruction #2>
    [...]
    <instruction #3>

The body of the `for` will be executed for each character of the `<string>`.

In [ ]:
```python
s1 = "Hello"
for c in s1:
    print(c)
```

```
H
e
l
l
o
```

`break` statement

Within a `for` or `while` body, we can force the termination of the entire loop using `break`. This is often used to break out from a loop when a specific condition is met.

In [ ]:
```
sum_n = 0
pivot = 0
limit = 50
for x in range(100):
    sum_n += x
    if sum_n > limit:
        pivot = x
        break           # break the loop
print(f"After summing the first {pivot} numbers, the sum is greater tha
```

```
After summing the first 10 numbers, the sum is greater than 50
```

In [ ]:
```
x = 0
sum_n = 0
pivot = 0
limit = 50
while x < 100:
    sum_n += x
    if sum_n > limit:
        pivot = x
        break       # break the loop
    x += 1
print(f"After summing the first {pivot} numbers, the sum is greater tha
```

```
After summing the first 10 numbers, the sum is greater than 50
```

`continue` statement

Within a `for` or `while` body, we can arbitrarily move to the next iteration using `continue`. As for `break`, this is often used when a specific condition is met.

In [ ]:
```python
sum_n = 0
for x in range(20):
    sum_n += x
    if sum_n % 13 != 0:
        continue    # skip the rest of the body
    print("Current sum is multiple of 13: ", sum_n)
```

```
Current sum is multiple of 13:  0
Current sum is multiple of 13:  78
Current sum is multiple of 13:  91
```

We can refactor our loop body, making it conditional, avoiding to use `continue`. However, `continue` may improve the readability of our code.

In [ ]:
```
sum_n = 0
x = 0
while x < 20:
    sum_n += x
    x += 1
    if sum_n % 13 != 0:
        continue    # skip the rest of the body
    print("Current sum is multiple of 13: ", sum_n)
```

```
Current sum is multiple of 13:  0
Current sum is multiple of 13:  78
Current sum is multiple of 13:  91
```

Nesting

We can nest conditionals and loops:

- loops within conditionals
- conditionals within loops
- loops within loops
- conditionals within conditionals

For instance:

In [ ]:

```
for x in range(3):
    for y in range(3):      # nested loop
        if x == y:          # nested if
            print(f"({x},{y})")
```

```
(0,0)
(1,1)
(2,2)
```

Lists

Lists: informal definition

A list:

- is an *ordered* sequence of data elements
- can contain data elements of *heterogeneous data types*
- is *mutable*, i.e., we can update its content (e.g., add/remove/replace elements)
- is denoted by squared brackets (`[` at the begin and `]` at the end), with elements seperated by a comma `,`

For instance:

In [ ]:
```
l = [1, 2, 3]
print(l)
```

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

Lists: construction

In [ ]:

```
l0 = []           # empty list
l0 = list()       # alternative way to create an empty list
print(l0)

l1 = [1, 2, 3]   # list with three
                  # homogeneous elements
print(l1)

l2 = [1, "two", 3.0] # list with three
                     # heterogeneous elements
print(l2)

l3 = [1, [2, 3], 4] # list with three
                    # elements, one of which is a list
print(l3)
```

```
[]
[1, 2, 3]
[1, 'two', 3.0]
[1, [2, 3], 4]
```

Lists: indexing

Similarly to a string, we can perform *indexing*:

In [ ]:
```
l = [1, 'two', 3.0]

print(l[0]) # access the first element
print(l[1]) # access the second element
print(l[-1]) # access the last element
print(l[-2]) # access the second last element

i = 2
print(l[i]) # access the element at index i
```

```
1
two
3.0
two
3.0
```

Lists: slicing

Similarly to a string, we can perform *slicing*:

In [ ]:
```
l = [1, 'two', 3.0]

print(l[0:2])   # access the first two elements
print(l[:2])    # starting index is 0
print(l[1:])    # ending index is the last element
print(l[-2:])   # access the last two elements
```

```
[1, 'two']
[1, 'two']
['two', 3.0]
['two', 3.0]
```

Slicing generates new and independent lists.

Lists: mutability

We **can** mutate a list:

In [ ]:
```
l = [1, 'two', 3.0]
print("Original list:", l)

l[0] = "one" # the original list is modified
print("Updated list:", l)
```

```
Original list: [1, 'two', 3.0]
Updated list: ['one', 'two', 3.0]
```

If we want a *copy* of a list:

In [ ]:
```
l2 = l.copy()    # we create a new list with the same elements
l2[0] = 1        # we modify the new list
print("Original list:", l)
print("Copied and updated list:", l2)

l3 = l[:] # we create a new list with the same elements
print("Another copy of the original list:", l3)
```

```
Original list: ['one', 'two', 3.0]
Copied and updated list: [1, 'two', 3.0]
Another copy of the original list: ['one', 'two', 3.0]
```

Lists: operators and operations

Given a list `l = [1, 2, 3]` and `l2 = [4]`:

Operation	Semantics	Result	In-place?
`len(l)`	length, i.e., number of items	`3`	N/A
`l + l2`	concatenation	`[1, 2, 3, 4]`	New list
`l * 2`	replication	`[1, 2, 3, 1, 2, 3]`	New list
`l.extend(l2)`	concatenation	`[1, 2, 3, 4]`	Original list
`l.append(4)`	append element	`[1, 2, 3, 4]`	Original list
`del(l[0])`	remove element at a given index	`[2, 3]`	Original list
`l.pop()`	remove the last element	`[1, 2]`	Original list
`l.remove(2)`	remove the first occurrence of an element	`[1, 3]`	Original list

Lists: try!

In [ ]:

```
l = [1, 2, 1, 1]
l.append(4) # we add an element at the end
print(l)
l.pop()      # we remove the last element
print(l)
del(l[0])    # we remove the first element
print(l)
l.remove(1) # we remove the first occurrence of 1
print(l)
l.remove(1) # we remove the second occurrence of 1
print(l)
l.extend([5, 6]) # we add two elements at the end
l2 = l + [7, 8] # this does not mutate list l
print(l)
print(l2)
```

```
[1, 2, 1, 1, 4]
[1, 2, 1, 1]
[2, 1, 1]
[2, 1]
[2]
[2, 5, 6]
[2, 5, 6, 7, 8]
```

Lists are iterable

Using the `for` statement and the `in` operator we can iterate over a list:

In [ ]:
```
l = [1, 2, 3]
for x in l:
    print(x)
```

```
1
2
3
```

Or, if you want to get the index:

In [ ]:
```
for i in range(len(l)):
    print(f"Value at index {i}: {l[i]}")
```

```
Value at index 0: 1
Value at index 1: 2
Value at index 2: 3
```

Lists: use of `enumerate`

A more compact version of the last example is done by using `enumerate(<dataset>)`:

In [ ]:

```python
l = [1, 2, 3]
for i, x in enumerate(l):
    print(f"Value at index {i}: {x}")
```

```
Value at index 0: 1
Value at index 1: 2
Value at index 2: 3
```

`enumerate` returns at each iteration the current index and the current element from the iterable dataset.

Lists: iteration vs mutability

Be aware that you should not mutate a list while iterating over it:

In [ ]:
```
l = [1, 2, 3]
for x in l:
    print(x)
    l.pop()
```

```
1
2
```

This code does not print the elements of the original list! Indeed, `pop()` is removing elements from the list, making hard to understand the iteration workflow.

Lists and strings

Common *conversions* between lists and strings:

In [ ]:
```
s = "Hello"
l = list(s) # we convert the string into a list
print(l)

s = "Do you want a coffee?"
l2 = s.split(" ")   # we split the string into a list
                    # using the space character
                    # as separator
s2 = " ".join(l2)   # we join the list into a string
                    # using the space character
                    # as separator
print(l2)
print(s2)
```

```
['H', 'e', 'l', 'l', 'o']
['Do', 'you', 'want', 'a', 'coffee?']
Do you want a coffee?
```

List: sorting

Two ways to sort a list:

In [ ]:
```
l = [2, 3, 1, 4]
l2 = sorted(l)  # we create a new list with the elements sorted
print(l2)
l.sort()        # or... we sort the original list
print(l)
```

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

To mutate or not to mutate, that is the question

Lists: aliasing

Since copying groups of data could be expensive (e.g., think about a list with 100k elements), by default, Python does not make a copy of a list when we use the assignment operator (`=`). It makes an alias:

In [ ]:
```
l = [1, 2, 3]
l2 = l              # we create an alias to the original list
l2.append(4)        # we modify the alias
print(l)            # the original list is modified!
```

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

We can check whether two variables are aliases to the same data using the `is` operator:

In [ ]:
```
print(l2 is l)
print(l is l2)
```

```
True
True
```

Lists: cloning

We you want to get a copy of a list:

```
In [ ]: l = [1, 2, 3]
l2 = l.copy()   # we create a new list with the same elements
l2.append(4)    # we modify the new list
l3 = l[:]       # alternative way to create a new list with the same el
l3.append(5)    # we modify the new list
l4 = list(l)    # alternative way to create a new list with the same el
l4.append(6)    # we modify the new list
print(l)
print(l2)
print(l3)
print(l4)
```

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

Tuples

Tuples: informal definition

A tuple is:

- an **immutable** list
- is denoted by squared parantheses (`(` at the begin and `)` at the end), with elements seperated by a comma `,`

For instance:

In [ ]:
```
t1 = (1, 2, 3)              # tuple with three homogeneous elements
t2 = (1, 'two', 3.0)        # tuple with three heterogeneous elements
print(t1)
print(t2)
```

```
(1, 2, 3)
(1, 'two', 3.0)
```

Tuples: construction

We can build a tuple in different ways:

In [ ]:

```
t1 = ()           # empty tuple
t2 = tuple()      # alternative way to create an empty tuple
print(t1)
print(t2)

t3 = (1,)         # tuple with one element... notice the comma!
i4 = (1)          # this is not a tuple, it is an int!
t4 = tuple([1]) # tuple created from a iterable data structure
print(t3)
print("i4 is", i4, "of data type", type(i4))
print(t4)

t5 = (1, 'two', 3.0)
t6 = tuple([1, 'two', 3.0]) # tuple created from a list
print(t5)                   # same for t6
```

```
()
()
(1,)
i4 is 1 of data type <class 'int'>
(1,)
(1, 'two', 3.0)
```

Tuples are similar to lists

These two data structure have a lot in common:

In [ ]:
```python
t = (1, 'two', 3.0)

# indexing
print(t[0])     # access the first element

# slicing
print(t[:2])    # access the first two elements

# non in-place operations and operators
print(len(t))         # length of the tuple
print(t * 3)          # repeat the tuple three times
print(t + (5,))       # concatenate another tuple to the tuple
print("two" in t)     # check if "two" is in the tuple
print(2 in t)         # check if "two" is in the tuple
```

```
1
(1, 'two')
3
(1, 'two', 3.0, 1, 'two', 3.0, 1, 'two', 3.0)
(1, 'two', 3.0, 5)
True
False
```

Tuples are different from lists

Differently from lists, tuples are **immutable**:

In [ ]:

```
t = (1, 'two', 3.0)
t[0] = 2    # this will raise an exception
```

```
---------------------------------------------------------------
------------
TypeError                                 Traceback (most recen
t call last)
/tmp/ipykernel_794386/3993153899.py in <module>
      1 t = (1, 'two', 3.0)
----> 2 t[0] = 2    # this will raise an exception

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

What if you *really* need to mutate a tuple?

The trick is to convert it to a list, mutate the list, and convert the list to a tuple:

In [ ]:
```
t = (1, 'two', 3.0)
l = list(t)      # we convert the tuple into a list
l.append(4)      # we add an element at the end
t2 = tuple(l)    # we convert the list into a tuple
print(t2)
```

```
(1, 'two', 3.0, 4)
```

Tuples may contain mutable data!

The immutability property covers only the *container* and not its *content*:

In [ ]:
```
t = (1, 2, [0, 0])  # the third element is a list
                    # which is mutable data structure
print(t)
t[2][0] += 1        # this is allowed
                    # because we are modifying the list
print(t)
```

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

Tuples are iterable

As lists, tuples are iterable

In [ ]:
```
t = (1, 'two', 3.0)
for x in t:
    print(x)
```

```
1
two
3.0
```

Sets

Sets: informal definition

A set:

- is an **unordered** sequence of data elements with **no repetition**
- can contain data elements of *heterogeneous data types*
- is *mutable*, i.e., we can update its content (e.g., add/remove elements)
- is denoted by curly brackets (`{` at the begin and `}` at the end), with elements seperated by a comma `,`

For instance:

In [ ]:
```
s = {4, 5.0, "six"}
print(s)    # the output does not respect the order
            # in which the elements were inserted
            # this is because a set is unordered
```

```
{'six', 4, 5.0}
```

Sets: construction

Different ways:

In [ ]:
```
s1 = set()  # empty set
s2 = {}     # strangely, this is not a set!
print(s1)
print(s2)
print(type(s2))

s3 = {1, 2, 3}                # set with three elements
s4 = set({1, 'two', 3.0})     # set created from a list
print(s3)
print(s4)
```

```
set()
{}
<class 'dict'>
{1, 2, 3}
{1, 'two', 3.0}
```

Sets do not contain repetitions

In [ ]:

```
sss = "Hello"
```

In [ ]:

```
s = {1, 1, 1}
print(s)    # the output is {1} because a set
            # does not allow duplicates
```

```
{1}
```

In [ ]:

```
s = set(["ciao", 2.0, "ciao", 2.0])
print(s)    # the output is {'ciao', 2.0} because a set
            # does not allow duplicates
```

```
{2.0, 'ciao'}
```

How does Python check for repetitions?

Python exploits data *hashing* to efficiently check the repetitions in a set. We do not talk in detail about *hashing* at this point of the course. What you need to know is that only **immutable** data is *hashable*. Hence, mutable data cannot be inserted into a set:

In [ ]:
```
s1 = {1, 2.0, tuple([1, 2])}    # this is fine
print(s1)                       # because a tuple is immutable

s2 = {1, 2.0, [1, 2]}    # this is not allowed
                         # because a list is mutable
```

```
{1, 2.0, (1, 2)}
```

```
---------------------------------------------------------------
------------
TypeError                                 Traceback (most recen
t call last)
/tmp/ipykernel_794386/1262637465.py in <module>
      2 print(s1)
      3
----> 4 s2 = {1, 2.0, [1, 2]}    # this is not allowed
      5                          # because a list is mutable

TypeError: unhashable type: 'list'
```

Sets: operators and operations

Given `s1 = {1, 2, 3}` and `s2 = {3, 4}`:

Operation	Semantics	Result	In-place?
`len(s1)`	number of items	`3`	N/A
`1 in s1`	membership	`True`	N/A
`5 not in s1`	membership	`True`	N/A
`s1.add(4)`	add an element	`{1, 2, 3, 4}`	Original set
`s1.update([3, 4])`	union with any iterable data structures	`{1, 2, 3, 4}`	Original set
`s1.remove(3)`	remove an element (exception if missing)	`{1, 2}`	Original set
`s1.discard(3)`	remove an element (no exception if missing)	`{1, 2}`	Original set
`s1.pop()`	remove one (arbitrary) element and returns it	`{1}`	Original set
`s1.clear()`	remove all elements	`{}`	Original set

Sets: operators and operations

Given `s1 = {1, 2, 3}` and `s2 = {3, 4}`:

Operation	Semantics	Result	In-place?
`s1.union(s2)`	union	`{1, 2, 3, 4}`	New set
`s1 | s2`	union	`{1, 2, 3, 4}`	New set
`s1.intersection(s2)`	intersection	`{3}`	New set
`s1 & s2`	intersection	`{3}`	New set
`s1.difference(s2)`	difference	`{1, 2}`	New set
`s1 - s2`	difference	`{1, 2}`	New set

Sets: try!

In [152]:

```
s1 = {1, 2, 3}
s2 = {3, 4, 5}
print(s1)
s1.add(4)
print(s1)
print(s1.union(s2))          # union of two sets
print(s1.intersection(s2))   # intersection of two sets
print(s1.difference(s2))     # difference of two sets
```

```
{1, 2, 3}
{1, 2, 3, 4}
{1, 2, 3, 4, 5}
{3, 4}
{1, 2}
```

Why do we need sets?

Since they are efficient at checking repetitions thanks to *hashing*, we use sets when we want to check whether we have already met a specific piece of data.

In [ ]:
```
s = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}
is_in_the_set = 5 in s
print(is_in_the_set)

l = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
is_in_the_list = 5 in l # this is way slower than the previous one
print(is_in_the_list)
```

```
True
True
```

Dictionaries

Dictionary: informal definition

Features of a dictionary:

- it maps a given `<key>` to a given `<value>`
- `<key>` can be any immutable value (actually, it must be a *hashable* value)
- `<value>` can be anything
- the (`<key`, `<value`) pairs are sorted without a specific ordering (it was implementation specific, while in the last releases it is ordered but you should not rely on it)
- it is *mutable*, i.e., we can update its content (e.g., add/remove elements)
- it is denoted by curly brackets (`{` at the begin and `}` at the end), with pairs seperated by a comma `,` where each pair has `:` to seperate the key from the value

For instance:

In [ ]:
```
d = {1: 'one', 2: 'two', 3: 'three'} # dictionary with three key-value
print(d)
```

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

Dictionaries: construction

Different ways:

In [ ]:
```
d1 = {}          # empty dictionary
d2 = dict()      # alternative way to create an empty dictionary
print(d1)
print(d2)
```

```
{}
{}
```

In [ ]:
```
d3 = {1: 'one', 'two': 2, 3.0: 'three'} # dictionary with:
                                        # - different data types for the keys
                                        # - different data types for the values
print(d3)
```

```
{1: 'one', 'two': 2, 3.0: 'three'}
```

Dictionaries: add, update, or delete a pair

The assignment operator `=` adds/update a pair in the dictionary, while `del` remove an existing pair from it:

In [ ]:

```
d = {1: 'one', 'two': 2}
print(d)
d[3.0] = "tree" # we add a new key-value pair
print(d)
d[1] = "uno"    # we update the value of an existing key
print(d)
del(d[1])       # we remove a key-value pair
print(d)
```

```
{1: 'one', 'two': 2}
{1: 'one', 'two': 2, 3.0: 'tree'}
{1: 'uno', 'two': 2, 3.0: 'tree'}
{'two': 2, 3.0: 'tree'}
```

Dictionary: a **single** value for each key

Given a key, a dictionary only keeps track of a **single** value for it:

In [ ]:
```
d = dict()
d['a'] = 1
d['a'] = 2  # we update the value of an existing key
            # the previous value is lost!
print(d)
```

```
{'a': 2}
```

Dictionary: retrieve value associated to a key

Quite easy:

In [ ]:
```
d = {1: 'one', 'two': 2}
print(d[1])      # access the value associated with the key 1
print(d['two']) # access the value associated
                # with the key 'two'

print(d[2])    # this will raise an exception
```

```
one
2
```

```
---------------------------------------------------------------
------------
KeyError                                  Traceback (most recen
t call last)
/tmp/ipykernel_1885124/3592842802.py in <module>
      4                 # with the key 'two'
      5
----> 6 print(d[2])    # this will raise an exception

KeyError: 2
```

Dictionaries: operators and operations

Given `d = {1: 'one', 'two': 2}`:

Operation	Semantics	Result
`len(d)`	number of key-value pairs	`2`
`1 in d`	membership: whether there is pair with a specific **key**	`True`
`2 not in d`	membership: whether there is **not** a pair with a specific **key**	`True`
`d.keys()`	(unsorted) list of keys	`[1, 'two']`
`d.values()`	(unsorted) list of values	`[2, 'one']`
`d.items()`	(unsorted) list of pairs	`[(1, 'one'), ('two', 2)]`

NOTE: `d.values()`, `d.values()`, and `d.items()` do not actually returns *standard* lists (due to optimization reasons) but you can treat their result as list.

Dictionaries: operators and operations (cont'd)

Given `d = {1: 'one', 'two': 2}`:

Operation	Semantics	Result	In-place?
`d.get(3)`	return the value associated with a key (if it exists) or `None` (without raising an exception)	`None`	N/A
`d.pop(1)`	remove the pair with the given key and return its value; if the key is not present, then exception	`'one'`	Yes
`d.clear()`	remove all pairs	`{}`	Yes
`d.update({'3': 3.0})`	add pairs from another dictionary	`{1: 'one', 'two': 2, '3': 3.0}`	Yes

Dictionaries are iterable

By default, iterating over a dictionary with a `for` gives us its keys:

In [ ]:
```
d = {1: 'one', 2: 'two', 3: 'three'}
for k in d:
    print(f"Key: {k}, Value: {d[k]}")
```

```
Key: 1, Value: one
Key: 2, Value: two
Key: 3, Value: three
```

Which is equivalent to:

In [ ]:
```
for k in d.keys():
    print(f"Key: {k}, Value: {d[k]}")
```

```
Key: 1, Value: one
Key: 2, Value: two
Key: 3, Value: three
```

Dictionaries are iterable (cont'd)

If want to get both the key and value while iterating:

In [ ]:
```python
d = {1: 'one', 2: 'two', 3: 'three'}
for k, v in enumerate(d):
    print(f"Key: {k}, Value: {v}")
```

```
Key: 0, Value: 1
Key: 1, Value: 2
Key: 2, Value: 3
```

Which is equivalent to:

In [ ]:
```python
for k, v in d.items():
    print(f"Key: {k}, Value: {v}")
```

```
Key: 1, Value: one
Key: 2, Value: two
Key: 3, Value: three
```

Dictionaries are iterable (cont'd)

If want only wants to iterate only over its values:

In [ ]:
```python
for v in d.values():
    print(f"Value: {v}")
```

```
Value: one
Value: two
Value: three
```

Functions

Make the code reusable

It is not convenient in programming to copy&paste code around. Most of the time we want to perform similar tasks but in slightly different order.

In other words, we need to introduce the concept of a **function**!

Notice that unctions can come from three sources:

1. Our code: we write them!
2. Python: they are **built-in** from the language
3. External packages: we can use functions implemented by the Python community after installing the related **external package**(s).

Function: informal definition

A function:

- takes zero or more data inputs: ***arguments*** (or ***parameters***)
- returns zero or more data outputs: ***return values***
- performs a task, processing the *arguments* (if any), possibly producing side effects (e.g., writing a file) or/and returning some *values*
- has a ***name***
- has a function ***body***, i.e., the **nested** group of instructions defining its behavior
- is not executed unless we explicitly call it using its *name* (passing its *arguments* if required)

Function: definition

To define a new function, we use the `def` statement:

`def` ***<NAME>*** `(` ***<PARAM1>*** `,` ***<PARAM2>*** `,` [...] `):`
    <instruction #1>
    <instruction #2>
    [...]
    <instruction #N>
    return ***<RET_VALUES>***

Remarks:

- the ***<NAME>*** follows the same rules as for variable naming (and its conventions)
- the parameters are optional (e.g., ***<PARAM1>***)
- when writing the function, we do not know the values of the parameters
- the body of the functions is indented to mark is begin and end
- if the function wants to return one or more values (***<RET_VALUES>***), the function can use the `return` statement

Function: invocation

To execute a function, we call or *invocate* it:

<NAME> (***<ARG1>*** , ***<ARG2>*** , [...])

At this time, we will decide the values of the function parameters (e.g., ***<PARAM1>***) by passing some arguments (e.g., ***<ARG1>***).

Remarks:

- *local scope*: if a function defines a new variable, it generates a **local** variable which is not observable outsite of the function.
- *global scope*: any variable defined outside functions are **global** variables

Function: examples

Let us consider a function with:

- no parameters
- no return values
- no side effects

In [ ]:
```
def do_nothing_valuable():  # function definition
    a = 1                   # local variable a
    a = a + 1               # new local variable a

do_nothing_valuable() # first invocation
do_nothing_valuable() # second invocation
# print(a)            # this will raise an exception:
                      # we cannot access a local variable
                      # because we are in the global scope
```

This function is **NOT** useful since its effects are not observable.

Function: examples (cont'd)

- no parameters
- no return value
- some side effects (i.e., print something on the screen)

In [ ]:
```
def say_hello():    # function definition
    s = "World"     # local variable s
    print("Hello,") # side effect
    print(f"{s}!")  # side effect

say_hello() # first invocation
say_hello() # second invocation
# print(s)  # this will raise an exception:
            # we cannot access a local variable
            # because we are in the global scope
```

```
Hello,
World!
Hello,
World!
```

Since we called it twice, we get twice its side effects.

Function: examples (cont'd)

Function with:

- one parameter
- no return value
- no side effects

In [ ]:

```
def increment(x):  # function definition
    x = x + 1      # the assignement is creating a new variable x
                   # this new variable is local to the function
                   # and does not affect the variable x outside the fur

x = 1          # global variable x
increment(x) # first invocation
increment(x) # second invocation
print(f"global x: {x}")
```

```
global x: 1
```

Remarks:

- This function is **NOT** useful since its effects are not observable.
- Any defined variable within the function is local to it.

Function: examples (cont'd)

- one parameter
- one return value
- no side effects

In [ ]:
```
def increment(x):  # function definition
    x = x + 1      # local variable x
    return x       # we return the value of the local x

x = 1       # global variable x
y = 0       # global variable y
y += increment(x) + increment(x) # two invocations
print(f"global x: {x}")
print(f"global y: {y}")
```

```
global x: 1
global x: 4
```

Remarks:

- This function is valuable **only** if we use its return value!
- Outside of a function, we can access the *value* of a local variable only if the local variable is returned by the function.

Function: examples (cont'd)

Function with:

- one parameter
- one return value
- side effects

In [ ]:
```
def increment_and_print(x):  # function definition
    x = x + 1          # the assignement is creating a new variable x
                       # this new variable is local to the function
                       # and does not affect the variable x outside the fur
    print(f"local x: {x}") # we print the new value of x
    return x           # we return the new value of x

x = 1
y = 0
y += increment_and_print(x) + increment_and_print(x) # two invocations
print(f"global x: {x}")
print(f"global x: {y}")
```

```
local x: 2
local x: 2
global x: 1
global x: 4
```

Function parameters: required by default

Each parameter:

- is **required** by default:
    - the caller must pass it...
    - ...otherwise we get an exception

In [ ]:
```
def add(a, b, c): # three required parameters
    return a + b + c

print(add(1, 2, 3)) # we must pass three arguments
```

```
6
```

In [ ]:
```
print(add(1, 2)) # this will raise an exception
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
/tmp/ipykernel_2327557/3570833341.py in <module>
----> 1 print(add(1, 2)) # this will raise an exception

TypeError: add() missing 1 required positional argument: 'c'
```

Function parameters: optional by choice

- can be made **optional**:
  - the functions defines a default value
  - the caller may omit to pass it
  - if the caller pass it, the caller's value is used in place of the default one

In [ ]:

```
def add(a, b=2, c=3): # three required parameters
    return a + b + c

print(add(1))           # we must pass the first argument
                        # while the other two have default values
print(add(1, 4))        # we can pass the second argument
print(add(1, 4, 5))     # we can pass all the arguments
```

```
6
8
10
```

Function parameters: optional by choice (cont'd)

However, optional parameters must come after required parameters:

In [ ]:
```
def add(a=0, b=2, c): # incorrect because required argument
    return a + b + c  # is after optional ones
```

```
  File "/tmp/ipykernel_2327557/2774706269.py", line 1
    def add(a=0, b=2, c): # incorrect because required argument
                      ^
SyntaxError: non-default argument follows default argument
```

Function arguments ordering: positional by default

When invoking a function, we must pass the arguments consistently with the parameters ordering:

In [ ]:
```
def say_hello(name, age): # first parameter is name, second is age
    print(f"{name} is {age} years old")

say_hello(45, "Francesco")  # this does not work as expected!
                            # because we swapped the arguments!
```

```
45 is Francesco years old
```

We can use parameters names to get the correct mapping even when ignoring the expected ordering:

In [ ]:
```
say_hello(age=45, name="Francesco")  # this works as expected!
```

```
Francesco is 45 years old
```

Built-in functions

Python provides several built-in functions:

- type conversion: e.g., `int(x)`, `float(x)`, `str(x)`, `tuple(it)`, `list(it)`
- input and output: e.g., `print(s)`
- utils: e.g., `range(n)`, `emumerate(l)`, `sorted(l)`
- mathematical: see next slide(s)
- ...and many aditional ones!

We will cover the most common ones over the weeks.

Built-in mathematical functions

Function	Semantics	Example	Example Result
`abs(x)`	Absolute integer value	`abs(-5)`	`5`
`round(x, ndigits=None)`	Return number rounded to `ndigits` precision after the decimal point. If `ndigits` is omitted, it returns the nearest integer to its input	`round(5.256, 1)`	`5.3`
`min(a, b)`	Min value between `a` and `b`	`min(1, 2)`	`1`
`min(L)`	Min value within an iterable	`min([1, 2, 3])`	`1`
`max(a, b)`	Max value between `a` and `b`	`min(1, 2)`	`2`
`max(L)`	Max value within an iterable	`min([1, 2, 3])`	`3`
`sum(L)`	Sum over an iterable	`min([1, 2, 3])`	`6`
`pow(a, b)`	Exponentiation. Same as `a**b` but more efficient	`pow(5, 2)`	`25`

Modules and Packages

Each Python file is a module

In Python, each `.py` file is called a ***module*** and we can we can `import` its functions from other modules. For instance, let suppose we have `my_math.py` containing:

```
def custom_add(a, b):
    return a + b

def custom_sub(a, b):
    return a - b
```

Then, in other file, e.g., `test.py`, we can reuse the functions from `my_math.py`:

```
import my_math # import the entire module

# we can call a function from an imported module using the dot notation:
# <module_name>.<function_name>
print(my_math.custom_add(10, 20))
```

Or:

```
from my_math import custom_add, custom_sub # import specific functions
from my_math import *                      # import all functions

# we can call the function(s) directly!
print(custom_add(10, 20))
```

Notice that `import` will look for the imported module in the current directory (of the module importing it) or a few fixed locations on our filesystem (e.g., a few

Package: collection of modules

Often, we want to organize our functions in different modules but group them together into the same logical *container*. This brings the idea of a ***package***.

For instance, let suppose we have in the `mypackage`:

- `my_math.py`: functions `custom_add` and `custom_sub`
- `my_utils.py`: functions `say_hello`

To make it a package, we need to add within the same directory a file called `__init__.py`:

```
from . import my_math
from . import my_utils
```

Then, any other module can import the package:

```
import mypackage # entire package
print(mypackage.my_math.custom_add(10, 20))
# or...
from mypackage import my_math # import module from package
print(my_math.custom_add(10, 20))
# or...
from mypackage import * # all modules from the package
print(my_math.custom_add(10, 20))
```

Again, `import` will look for our package in the current directory and specific system directories.

Python pre-installed packages

Python ships with many pre-installed packages:

- `string`: additional string functions
- `math`: additional mathematical functions
- `io`: utils to read and write files
- `random`: pseudo-random number generator
- `sys`: check execution environment aspects

We will cover their interesting bits when needed. For instance:

In [ ]:
```
import math
print(f"Square root of 9 is {math.sqrt(9)}, while pi is {math.pi}")
```

```
Square root of 9 is 3.0, while pi is 3.141592653589793
```

However, there is way more in `math`: `acos`, `acosh`, `asin`, `asinh`, `atan`, `atan2`, `atanh`, `ceil`, `comb`, `copysign`, `cos`, `cosh`, `degrees`, `dist`, `e`, `erf`, `erfc`, `exp`, `expm1`, `fabs`, `factorial`, `floor`, `fmod`, `frexp`, `fsum`, `gamma`, `gcd`, `hypot`, `inf`, `isclose`, `isfinite`, `isinf`, `isnan`, `isqrt`, `lcm`, `ldexp`, `lgamma`, `log`, `log10`, `log1p`, `log2`, `modf`, `nan`, `nextafter`, `perm`, `pi`, `pow`, `prod`, `radians`, `remainder`, `sin`, `sinh`, `sqrt`, `tan`, `tanh`, `tau`, `trunc`, `ulp`.

Install third-party packages

We can easily install third-party packages from the community using `pip` from the terminal:

```
pip install <package>
```