

Introduction to Python

Verjina Metodieva and Daniel Parthier

2025-01-21

Why would you code?

Motivation

- Saving time
- Reproducible workflow
- Flexibility
- Unlimited creativity

Goal of today

```
# This script exports metadata information to a JSON file.
# The metadata includes the author, date, and the average resting
# membrane potential, units and the sweep count.
# The output is saved to 'data/data_info.json'.
import json
import numpy as np
path = 'data/'
resting_membrane = [-70.1, -73.3, -69.8, -68.5, -71.2]
resting_membrane_avg = np.mean(resting_membrane)
sweeps = [1, 2, 3, 4, 5]
voltage_unit = 'mV'
sweep_count = len(resting_membrane)
output_file = path + 'data_info.json'
output_data = {
    'author': 'Doe, John',
    'date': '2025-01-10',
    'resting_membrane_avg': resting_membrane_avg,
    'unit': voltage_unit,
```

```
    'sweep_count': sweep_count
}
with open(output_file, 'w') as f:
    json.dump(output_data, f)
```

This is an example to showcase what we will achieve today.

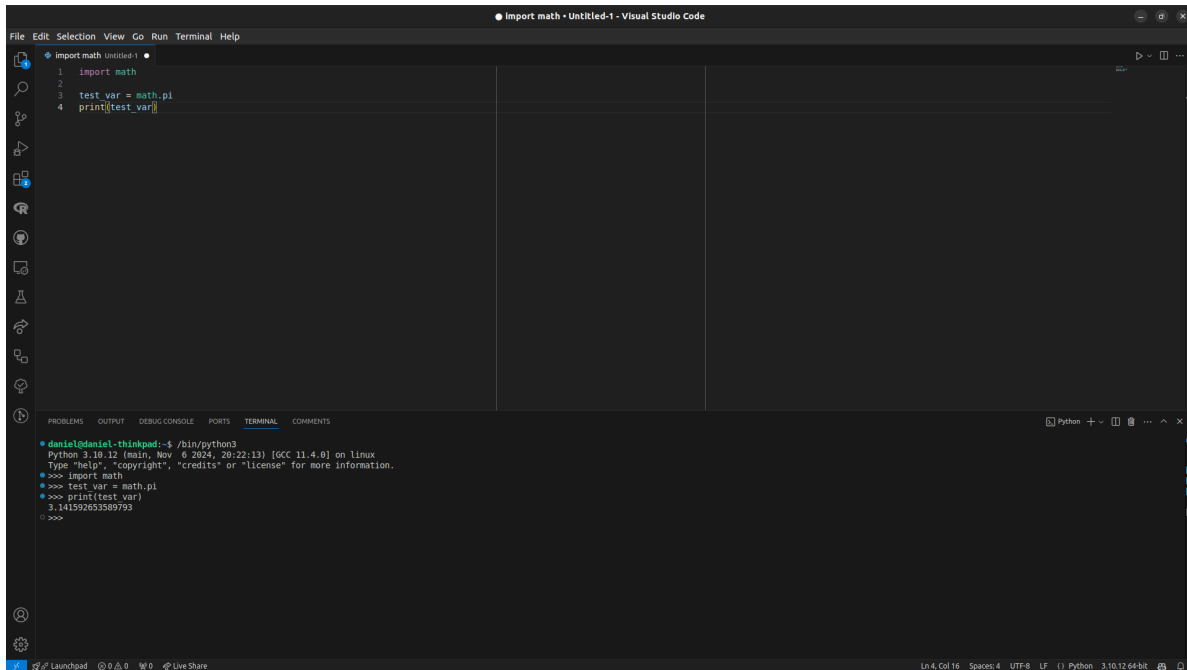
Basic usage

- Can be run from the terminal/console as well
 - Start python by typing `python/python3` into the console
 - You can quit by typing `quit()` into the console
 - Most of the time with a GUI (graphical user interface)
 - Sometimes code is run in document style (*Jupyter Notebook*)
 - Run scripts
-

The console is mainly used for quick testing of commands you will use once and won't need to track. If you want to save your workflow or keep track of what you did, a script is required. In principle, a script is nothing else than a text file with a language-specific extension (`.py`). The code is saved in such a file and can be used by activating the script as a whole or running single code lines.

Visual Studio Code

- 1 of multiple options ([PyCharm](#), [Spyder](#))
- VS Code offers multifunctionality and integration of useful extensions (Git, Remote Explorer, Jupyter, GitHub Copilot)



A graphical user interface, like VS Code, provides code highlighting, formatting, and completion. At the same time, it gives a structured overview of a project. In the case of VS Code, you can use multiple languages by just adding the appropriate extension.

Visual Studio Code (Features)

- Multi-language support (*Python, R, Matlab, Julia, C++*, etc.)
- Set up your project (make environment, create files and folders)
- Provide visual notation (code highlighting)
- Auto-complete code snippets
- Show documentation of functions
- Find and fix errors in code (debugging)
- Synchronise code with GitHub
- And much more...

Environments



- Only bring the tools you need
 - Less bloated
 - Fewer conflicts
- Only project-specific packages

Make environment

- Setting up an empty environment (get a drawer)



- Can be done via terminal

```
python -m venv .venv
```

- Make one in VS Code
 - CTRL + SHIFT + P → type: *env*
 - Select: *Create Environment*

The `python` command determines the version of python used to setup the virtual environment. You could also specify a different version of python by explicitly writing it out (i.e. `python3.13`).

Start environment

Windows

```
.venv\Scripts\activate
```

Unix/macOS

```
source .venv/bin/activate
```

- VS Code will start the environment for you

TO DO

On your own laptop:

1. Create an environment
 2. activate it
- Then try the second way using VS Code directly.

Removing a virtual environment requires to remove the folder where it is saved.

Quit environment

```
deactivate
```

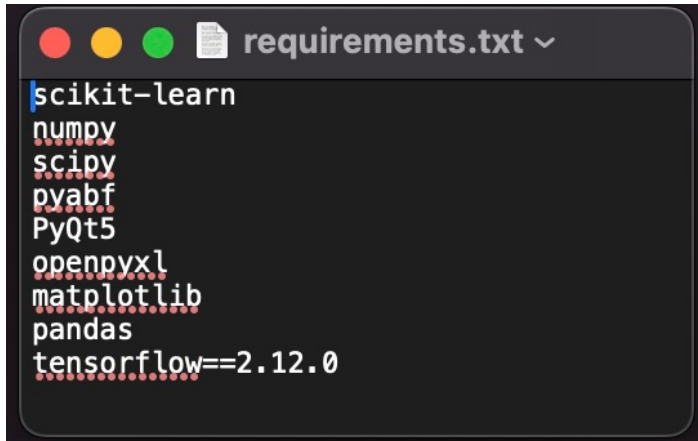

Install packages



Package managers

- *What are they?*
- pip (recommended)
conda-forge (if you really have to)

Usage



```
pip install --upgrade pip
pip install -r requirements.txt
```

```
# installing packages from
requirements.txt file
```

```
pip uninstall tensorflow
pip install tensorflow==2.12
```

```
# uninstalling a package
# package with specified version
```

-
- a package is a collection of functions
 - package manager = a collection of tools that automates the process of installing, upgrading, configuring, and removing computer programs
 - helps the user to easily and consistently work with packages - installing, updating, etc.
 - provides some security, in the sense that packages that are provided by package managers are already checked for malfunctions

TO DO

- in the terminal

```
pip install --upgrade pip
pip install notebook
python -c "import notebook; print(notebook.__version__)"
```

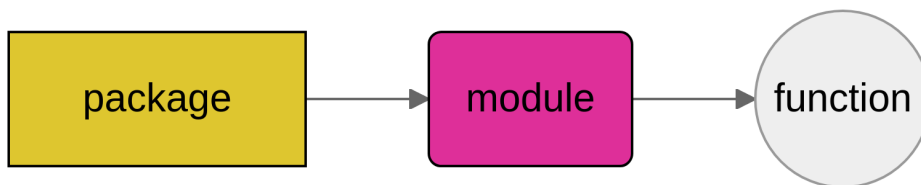
7.3.2

```
pip install numpy
python -c "import numpy; print(numpy.__version__)"
```

Import

When do you have to import?

- Only some functions are available by default
- Other functions are available through external packages
- A package can have smaller 'packages' inside called modules



Import packages

Let's open the 'numpy' drawer!

```
import numpy
```

This will open our numumpy *toolbox* drawer

- Pull out a tool to use it with the dot notation: toolbox.tool

```
numpy.pi
```

3.141592653589793

```
numpy.sin(1)
```

```
np.float64(0.8414709848078965)
```

Importing a package only has to happen once. By using `import package` everything from the package will be made available.

Import (abbreviated)

- Some packages can have long names or you want an abbreviation (ie. `numpy` to `np`)
- Assign a new name during the import (`as`)

```
import numpy as np
```

Generally abbreviating longer packages will make writing, but also reading code easier. At the same time you should check whether your abbreviation makes sense and is understandable for others. There are also common ways to abbreviate well known packages. Some other examples would be `numpy` as `np`, `pandas` as `pd`.

Import single functions

Load only parts of the package

- This could mean single functions or multiple functions/objects
- Avoid clutter and only import what you need

```
from numpy import sin, cos
```

```
sin(1)
```

```
cos(1)
```

- Now everything after `import` is available
-

This way of import comes in handy if you just need a function or part of a large package. However, be careful with conflicting names which can arise from loading the function directly.

Word of advice

- Some packages use the same function names
- Avoid conflicts: reference package or use alias

```
import math
import numpy as np
```

```
math.sin(1)
np.sin(1)
```

Import modules

- Also a module as part of a package can be loaded using `.` or with `from`

```
from numpy import random
import matplotlib.pyplot as plt

random_number = random.normal(size=2)
plt.plot(random_number)
```

Programming building blocks



Photo by JAQUES London

Building blocks are small objects which can be changed, combined and used in many different ways to build something more complex. We always start with small blocks first. Such building blocks exist in all the programming languages. They might differ slightly but in principle will be very similar. We can also think in the same way about tasks we want to solve. Most of the time we can make a big task into smaller tasks and a small task into even smaller blocks.

Variables

- Variables are objects we want to keep
- We assign them and can use them in the future

```
cell_count = 1  
print(cell_count)
```

1

- Now `cell_count` will be 1 until changed or deleted
- We can assign anything we want

In this example `print()` will print the content of `cell_count` to the terminal.

Assign multiple variables

- Multiple variables can be assigned at the same time

```
cell_count, cell_density, cell_size = 1, 0.3, 4.1
```

- Consider when this is useful (readability)
- It is equivalent to writing 3 lines of code

Operators



Kind of like functions¹ but different

- Have elements on both sides: `a operator b`

¹more on functions later

Basic operators

1. + add two elements together
 2. - subtract
 3. * multiply
 4. ** power
 5. / division, // integer² division
 6. % modulus
-

Comparison operators

Let's compare things!

- Comparison operators will tell you if something is:

- True or False³

1. == equal
 2. != not equal
 3. < smaller and > larger
 4. <= smaller or equal and >= larger or equal
-

Logical operators

Logical operators check for conditions and returns True or False

1. and checks if both side are True

`1==1 and 2==2`

`1==1 and 2>3`

True

²whole numbers

³True and False are referred to as boolean/bool

False

2. or checks if at least one of the sides is True

```
1==1 or 2!=2
```

```
1==1 or 2==2
```

```
1<0 or 1>4
```

True

True

False

(data-) types

There are many...

- But you only need to know a few
 - They can do very different things and might have different properties
-

Strings

- Strings are simply text
- Very important for loading files
 - Directory is a string
- Typically made with ' or " as in 'text' or "text"

```
path = 'data/'
```

What to do with strings

Combine:

```
path = 'data/'  
path + 'data_info.json'
```

```
'data/data_info.json'
```

Split string into multiple strings:

```
output_file = path + 'data_info.json'  
output_file.split('/')
```

```
['data', 'data_info.json']
```

You are curious about other things?

- Type the name of your string into the python console with a `.` and press `tab` twice
 - `output_file.`
-

Other things to do with strings

- They have a length
 - Number of characters including spaces etc.

```
test_string = 'four'  
len(test_string)
```

```
4
```

- You can access parts of a string (indexing)

```
test_string[1]
```

```
'o'
```

What did you expect?

- In python we start counting positions from 0
 - 0: 'f', 1: 'o', 2: 'u', 3: 'r'

What is your intuition for:

```
test_string[-1]
```

```
'r'
```

Strings, as you can see, are characters strung together to form a long chain of single elements. At the same time, you can still access and use single elements from your chain of characters. Should you want to access elements from the end of the chain, you can use negative indices and count backward.

How to break things⁴ 101

Be careful how you write text or name folders

```
folder = 'path/sub_path\'
```

```
File "<stdin>", line 1
  folder = 'path/sub_path'
            ^
```

```
SyntaxError: unterminated string literal (detected at line 1)
```

- Avoid [escape characters](#)
- Some functions cannot handle special characters

Having complicated folder structures or names with special characters can break you code or functions which want to access this directory. Keep in mind to avoid such characters which could lead to errors (*, \, /). For example when using a folder `data/subpath/` with a file inside called `strange/file/name.txt` python will assume that `strange` and `file` are directories where a file called `name.txt` exists.

⁴strings

There are numbers and there are numbers

- Whole numbers: Integers `int`

```
type(1)
```

```
int
```

- Real numbers: Floats `float`

```
type(1.0)
```

```
float
```

- Most of the time it might not matter⁵

```
1 == 1.0
```

```
True
```

- Sometimes there is a difference and we will see later why

Most of the time python handles the integer vs. float automatically. You will not have to worry about assigning.

None

- A variable which exists but has no content can be `None`

```
var_a = None
```

```
type(var_a)
```

```
NoneType
```

- Your program then knows that `var_a` exists
- You can change it later to another value

```
var_a = 1
```

```
type(var_a)
```

```
int
```

⁵In python

Tuple

You can combine single elements into one

- Can be different types (`strings`, `int`, `float`, or other objects)
- Chain elements and combine them with (and)
- Tuples cannot be changed after creation ('immutable')

```
resting_membrane = (-70.1, -73.3, -69.8, -68.5, -71.2)
```

- Single elements can be accessed by their location

```
resting_membrane[1]
```

```
-73.3
```

- Indexing start in python at 0⁶

Tuples cannot be changed

- You cannot modify elements inside the tuple or add any after creation

```
resting_membrane[1] = -72.2
```

```
Traceback (most recent call last):
```

```
File "<stdin>", line 1, in <module>
```

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

⁶more on indexing later

Lists



- Multiple items in a list
- Similar to `tuple` but more powerful
- Lists can be changed after creation ('mutable')

Let's list things!

Make lists

- Lists are made by using `[and]`
- Elements are inside

```
author_list = ['Verjina', 'Daniel']  
author_list
```

```
['Verjina', 'Daniel']
```

- Access elements inside a list⁷

```
author_list[1]  
author_list.index('Daniel')
```

```
'Daniel'
```

```
1
```

The crucial difference between `lists` and `tuples` is that a `list` allows you to modify the results. Depending on how your code generates the output you might have to decide to take the `list`. If you want that the chain cannot be modified by your code (intended or by accident) a `tuple` is a safe option.

⁷remember we start counting at 0

Features of lists

- Lists can do special things

```
author_list.sort()
author_list
```

```
['Daniel', 'Verjinia']
```

```
author_list.append('Dietmar')
author_list
```

```
['Daniel', 'Verjinia', 'Dietmar']
```

```
author_list.remove('Daniel')
author_list
```

```
['Verjinia', 'Dietmar']
```

```
author_list[1] = 'Daniel'
author_list
```

```
['Verjinia', 'Daniel']
```

You can try to sort different lists with numbers and strings or even mixed lists. You will see that there is an order. Also try to use capitalised letters vs. small letters.

Slicing

Sometimes you want to access multiple elements in a chain

- You can use `:` to access a slice between two indices

```
resting_membrane = [-70.1, -73.3, -69.8, -68.5, -71.2]
resting_membrane[1:3]
```

```
[-73.3, -69.8]
```

- Specify 'slice' properties `slice(start, stop, step)`


```
resting_membrane[slice(1,5,2)]
```

```
[-73.3, -68.5]
```

- Alternative using `:stop:step` or `start::step`

```
resting_membrane[:5:2]
```

```
resting_membrane[1::2]
```

```
[-70.1, -69.8, -71.2]
```

```
[-73.3, -68.5]
```

Slicing is an important part of accessing data. This allows you to select a subset of the whole data set without going through all the elements separately and without copying the data. When using `:` or `::` without having an integer in front, Python will start at the 0 index. If you use a negative integer as a step, also referred to as stride, you will access items backwards.

Dictionary

You want to have different things in different things and maybe add some things?

Hello dictionary!

- Very flexible
- Still very structured
- Easily accessible

Make dictionary

- Made using { and }
- Contains key and values

```
new_dict = {  
    "project": 'course',  
    "date": '2025-01-21',  
    "authors": author_list  
}  
new_dict
```

```
{'project': 'course', 'date': '2025-01-21', 'authors': ['Verjina', 'Daniel']}
```

```
new_dict["authors"]  
new_dict["authors"].append('Dietmar')  
new_dict
```

```
['Verjina', 'Daniel']
```

```
{'project': 'course',  
 'date': '2025-01-21',  
 'authors': ['Verjina', 'Daniel', 'Dietmar']}
```

Properties of dictionary

- List all the keys

```
new_dict.keys()
```

```
dict_keys(['project', 'date', 'authors'])
```

- Get all values

```
new_dict.values()
```

```
dict_values(['course', '2025-01-21', ['Verjina', 'Daniel', 'Dietmar']])
```

- Get all values from specific key

```
new_dict['authors']
new_dict.get('authors')
```

```
['Verjina', 'Daniel', 'Dietmar']
```

```
['Verjina', 'Daniel', 'Dietmar']
```

- In case you need an output even if key does not exist use `.get`

```
new_dict.get('experimenter', 'unknown')
```

```
'unknown'
```

Simple functions

```
print('This function is boring')
```

```
This function is boring
```

```
# combine variable types
```

```
var_a = 'a variable'
```

```
value_a = 42
```

```
print('more interesting when we include \n', var_a, 'with value', value_a)
```

```
print('the variable type of var_a is', type(var_a))
```

```
print('the variable type of value_a is', type(value_a))
```

```
more interesting when we include
```

```
  a variable with value 42
```

```
the variable type of var_a is <class 'str'>
```

```
the variable type of value_a is <class 'int'>
```

```
# sort a list
```

```
animal_list = ['SNA 0254581', 'DSC 035576', 'SNA 0954581', 'SNA 0856662', 'DSC 024504']
```

```
sorted_animal_list = sorted(animal_list)
```

```
print(sorted_animal_list)
```

```
['DSC 024504', 'DSC 035576', 'SNA 0254581', 'SNA 0856662', 'SNA 0954581']
```

- call a function
- function
 - A named group of instructions that is executed when the function's name is used in the code.
 - may process input arguments and return a result back
 - logically grouping together pieces of code
- print() - display information on the screen
- type() - outputs the variable type
- can look up functions while typing code

Methods

```
# sort a list with a method
animal_list = ['SNA 0254581', 'DSC 035576', 'SNA 0954581', 'SNA 0856662', 'DSC 024504']

# using the function sorted()
sorted_animal_list = sorted(animal_list)

# same thing but using a method .sort()
animal_list.sort() # sorting in ascending order
print(animal_list)

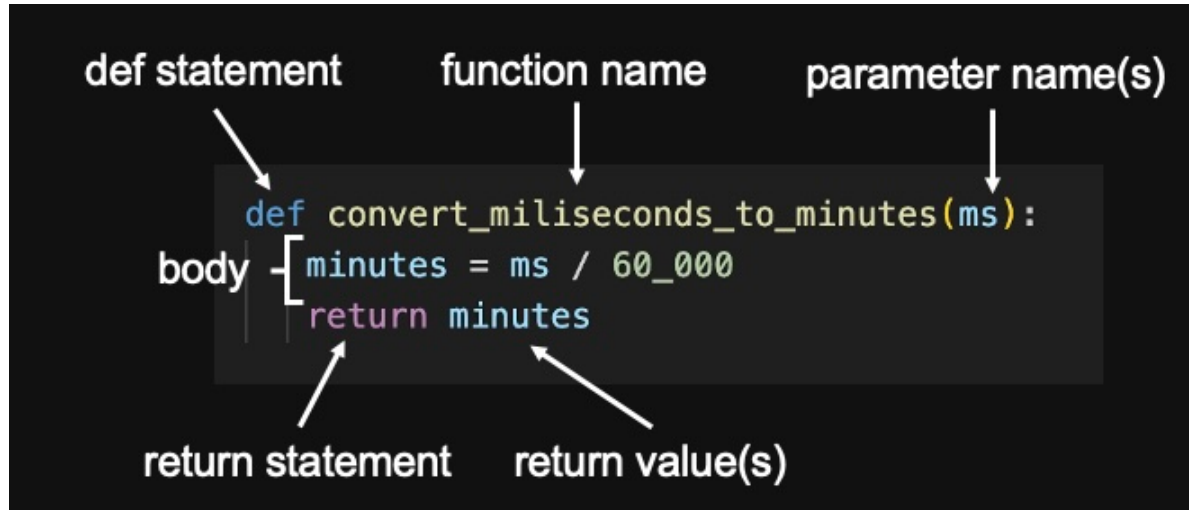
animal_list.sort(reverse = True) # sorting in descending order
print(animal_list)

num_animals = len(animal_list)
print("I've analyzed the data of", num_animals, "animals.")

['DSC 024504', 'DSC 035576', 'SNA 0254581', 'SNA 0856662', 'SNA 0954581']
['SNA 0954581', 'SNA 0856662', 'SNA 0254581', 'DSC 035576', 'DSC 024504']
I've analyzed the data of 5 animals.
```

-
- methods
 - .sort()
 - Function — a set of instructions that perform a task
 - Method — a set of instructions that are associated with an object.
 - method is called with an object and has the possibility to modify data of an object.
 - can define your own functions -> live coding example

Define your own functions



```
import json  
import numpy as np  
  
path = 'data/'  
resting_membrane = [-70.1, -73.3, -69.8, -68.5, -71.2]  
  
resting_membrane_avg = np.mean(resting_membrane)  
sweeps = [1, 2, 3, 4, 5]  
voltage_unit = 'mV'  
sweep_count = len(resting_membrane)  
  
output_file = path + 'data_info.json'  
  
output_data = {  
    'author': 'Doe, John',  
    'date': '2025-01-10',  
    'resting_membrane_avg': resting_membrane_avg,  
    'unit': voltage_unit,  
    'sweep_count': sweep_count  
}  
  
with open(output_file, 'w') as f:  
    json.dump(output_data, f)  
  
import json
```

```

import numpy as np

def create_meta_data_json(patcher, date_of_rec, RMPs, save_path, save_filename):
    avg_RMP = np.mean(RMPs)
    num_sweeps = len(RMPs)

    output_data = {
        'author': patcher,
        'date': date_of_rec,
        'resting_membrane_avg': avg_RMP,
        'unit': 'mV',
        'sweep_count': num_sweeps
    }

    print('saving the file ', save_filename, 'in', save_path)
    with open(save_path + save_filename, 'w') as f:
        json.dump(output_data, f)

    return output_data

patcher = 'Verji'
date_of_rec = '2025-01-15'
save_path = 'data/'
save_fn = 'verji_s_first_recording.json'
resting_membrane = [-70.1, -73.3, -69.8, -68.5, -71.2]

# ways to call the function
create_meta_data_json(patcher = 'Verji', date_of_rec = date_of_rec , RMPs = resting_membrane
                      save_path = save_path, save_filename = save_fn)

out_data = create_meta_data_json(patcher, date_of_rec, resting_membrane, save_path, save_fn)

out_data = create_meta_data_json('Verji', '2025-01-15', [-70.1, -73.3, -69.8, -68.5, -71.2],
                                'verji_s_first_recording.json')

```

-
- The function definition opens with the keyword *def* followed by the name of the function (*convert_milliseconds_to_minutes*) and a parenthesized list of parameter names (*ms*). The body of the function — the statements that are executed when it runs — is indented below the definition line. The body concludes with a **return** keyword followed by the return value.

- can set default parameters in a function. this means that a function will work with those parameters, if one doesn't pass other ones
- when passing parameters to a function, it's important that one passes them in the correct order
- local variables
 - variables that live only inside of functions, minutes in our example
 - they no longer exist once the function is done executing show it by running minutes
 - If we try to access their values outside of the function, we will encounter an error
- global variables
 - variables defined outside any function

Documentation

comments describe the code

- audience - you or other developers
- functionality
- 'why?'

'''docstrings give explanations'''

- how to use?
- for single functions, modules, scripts
- accessed through *help()*

README.md

- project documentation

-
- commenting
 - use #
 - when something is not intuitive or has to be paid attention to
 - docstrings
 - ''' '''
 - from single functions, to modules, to whole scripts

- different formal formats. see resources.docx for complete overview documenting projects
- appear (if existing) when you wiggle the mouse above a function either in VSC or in jupyter notebook
- readme files
 - purpose of the project, use case example

Documentation example

```
import json
import numpy as np

def create_meta_data_json(patcher, date_of_rec, RMPs, save_path, save_filename):
    """
    Returns and saves a dictionary with metadata.

    Args:
        patcher (str): name of experimenter
        date_of_rec (str): date of experiment
        RMPs (list): list of recorded resting membrane potentials
        save_path (str): destination folder
        save_filename (str): name of the file

    Returns:
        output_data (dictionary): containing the metadata
    """
    avg_RMP = np.mean(RMPs)
    num_sweeps = len(RMPs) # have as many sweeps as values

    # define metadata dictionary
    output_data = {
        'author': patcher,
        'date': date_of_rec,
        'resting_membrane_avg': avg_RMP,
        'unit': 'mV', # always mV for RMP
        'sweep_count': num_sweeps
    }

    # confirmation to user
    print('saving the file ', save_filename, 'in', save_path)

    with open(save_path + save_filename, 'w') as f:
        json.dump(output_data, f)
```



```
    return output_data

resting_membrane = [-70.1, -73.3, -69.8, -68.5, -71.2]
# create a out_dict containing the metadata
out_dict = create_meta_data_json('Verji', '2025-01-15', resting_membrane, 'data/', 'verji_s_')
```

Homework

- explaining how to use jupyter notebooks for the homework
- important to mention that the correct environment (kernel) needs to appear in the top right