



pythonTM

Introduction to Python

BIO334

Maria Heimlicher & Dean Sumner

Christian von Mering's group

courtesy of Lyon, Tackmann, Dmitrijeva & Gable

maria.heimlicher@mls.uzh.ch

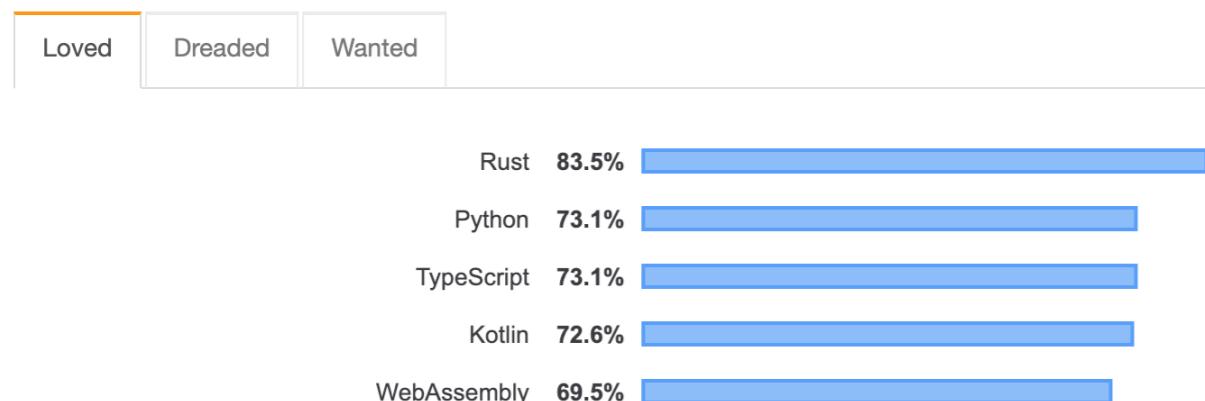
dean.sumner@uzh.ch

<https://github.com/meringlab/Bio334.git>

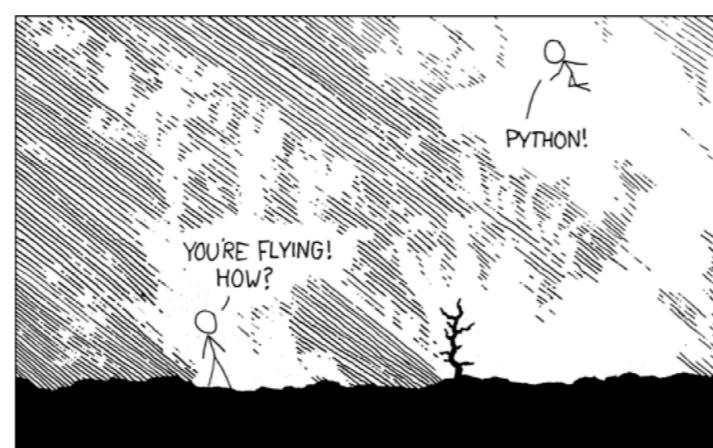
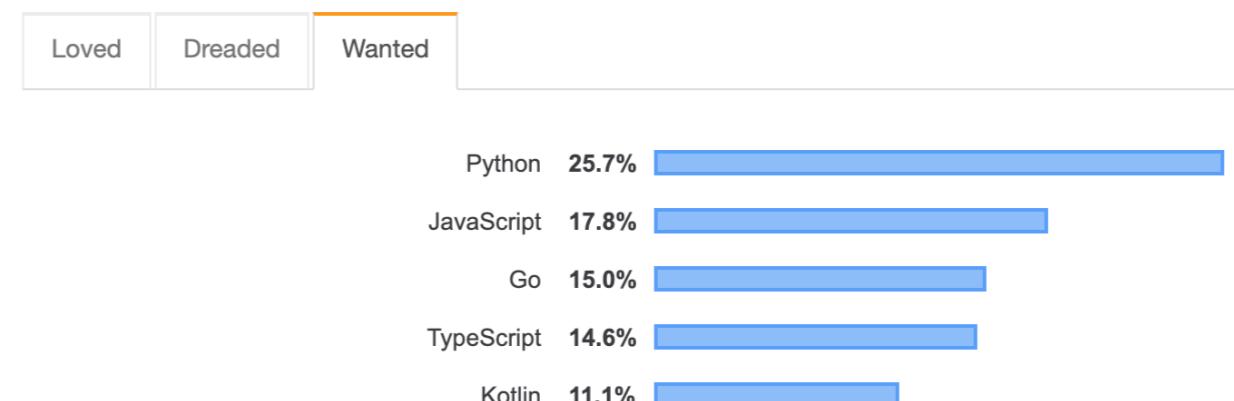
What is Python?

1. Dynamic, interpreted **programming language**
2. **Simple syntax** with fast learning curve

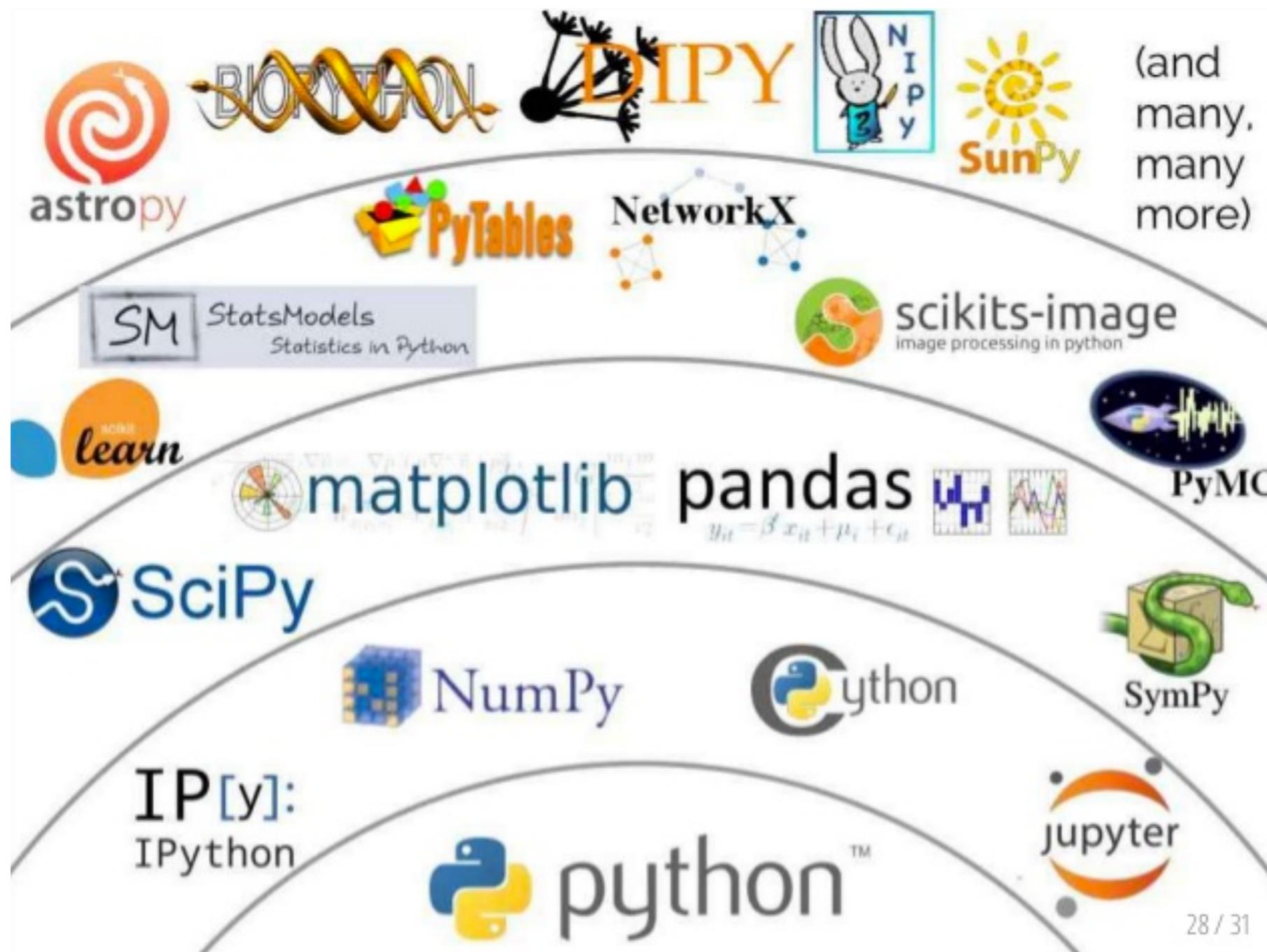
Most Loved, Dreaded, and Wanted Languages



Most Loved, Dreaded, and Wanted Languages



Scientific Python stack



Today's program

1. Introduction to programming
basic concepts with small hands-on sessions
in JupyterLab using iPython
2. Break
3. Writing Python code to solve Exercises 1
and 2 (and optional Exercises 3 and 4)
4. Go through solutions of exercise 1 and 2
at 4.15pm

Part I:

Programming basics

Variables

- Store a piece of data and give it a specific name with the “=” (equal) operator

```
a = 4
```

```
pi = 3.14159
```

```
my_string = "hello"
```

```
# single and double ticks are equal
```

```
# (just stick to one) 'hello' or "hello"
```

```
my_protein_sequence = 'MRHIAHTQRCLSRLLTSLVALLLIVLP'
```

- Basic rules for variable names:

- use descriptive names, NO spaces, don't start with numbers

Operators

I. Arithmetic operations

- addition + , subtraction -
- division /, multiplication *
- exponent **
- parenthesis ()

```
>>> 2 + 3  
5  
>>> 23 - 3  
20  
>>> 22.0 / 12  
1.833333333333333  
>>> (1 + 2) * 3
```

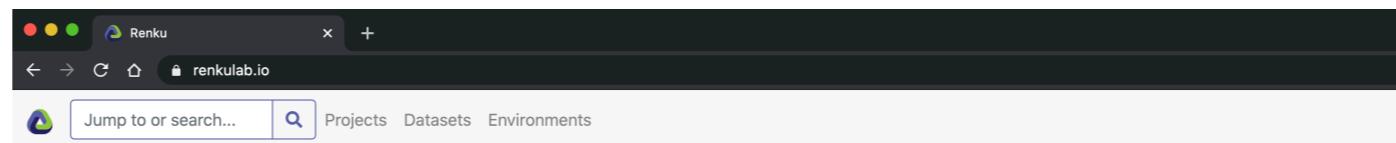
2. Boolean operations

- return **True** or **False**
- == , > , < ,
- & (AND) , | (OR)

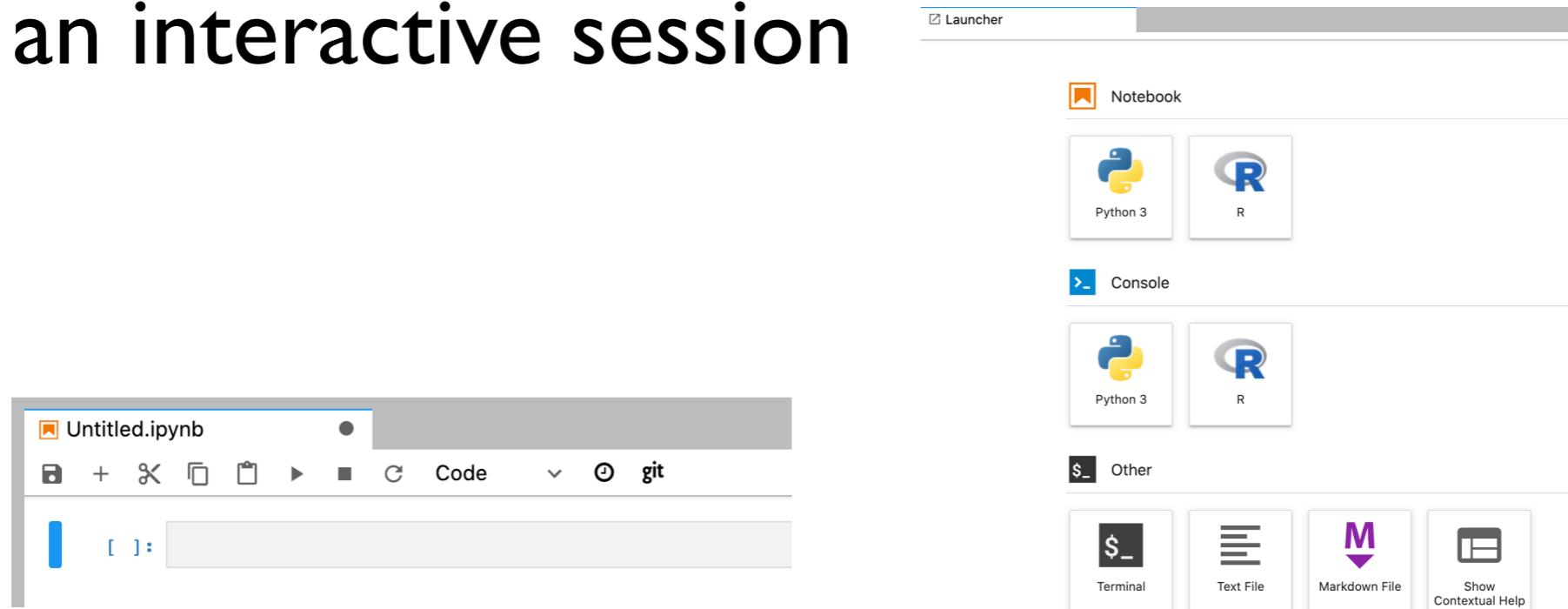
```
>>> 1 < 2  
True  
>>> 3 > 34  
False  
>>> 23 == 45  
False  
>>> 34 != 323  
True
```

First live session

- Start by opening <https://renkulab.io/> in your browser



- Launch Jupyter Notebook “Python 3” for an interactive session



Show how to use JupyterLab and checkout **Cheat Sheets**

To access the files you need, enter the following command in a terminal window

```
git clone https://github.com/meringlab/Bio334.git
```

Session I:

Type a command and hit shift + enter

```
welcome_message = 'hello world!' # hit [shift + enter] after every line
welcome_message

# Use python as your advanced calculator
a = 4
b = a + 3
(a + b) * 4

a / 8

a**2

# Let's try with strings
welcome_message + welcome_message

a = '4'
a + 3 # anything strange?

# whats the difference?
a + str(3)
int(a) + 3
```

Arithmetics

```
>>> welcome_message = 'hello world!' # hit [shift + enter]
>>> welcome_message
'hello world!'

# Use python as your advanced calculator
>>> a = 4
>>> b = a + 3
>>> (a + b) * 4
44

# float division (caveat: Python 2 would return 0!)
>>> a / 8
0.5

>>> a**2
16
```

Concatenation

```
# Let's try with strings

# use + to add two strings
>>> welcome_message + welcome_message
'hello world!hello world!'

>>> a = '4'

# We need to have the same type to add elements
>>> a + 3      # anything strange?
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: cannot concatenate 'str' and 'int' objects

# whats the difference?
>>> a + str(3)
'43'
>>> int(a) + 3
```

Functions

- function: stores instructions (not values)
- basic use:
 - `function_name(arguments)`
- functions loaded by default in python, e.g.
 - `str()` - convert an object into a string
 - `int()` - convert an object into an integer
 - `float()` - convert a object into a floating point number
 - `type()` - tells you the type of an object
- see many other in the cheat-sheet and find them on
 - <https://docs.python.org/3/library/functions.html>

Functions

Let's create a function using "def" (for define)

```
[ ]: 1 def add_things(a, b):  
      2     result = a + b  
      3     return result
```

We need to have the same type to add elements

```
1 add_things(3, 5)
```

8

```
1 add_things("Hello ", "there")
```

'Hello there'

```
1 add_things("3", 5)
```

TypeError

Traceback (most recent call last)

```
<ipython-input-14-df373cddff49> in <module>
```

```
----> 1 add_things("3", 5)
```

```
<ipython-input-12-eb66cd937434> in add_things(a, b)
```

```
    1 def add_things(a, b):
```

```
----> 2     result = a + b
```

```
    3     return result
```

TypeError: can only concatenate str (not "int") to str

List data structure

- I. like a shopping list we have an object that can store multiple objects at once.

```
my_list = ['butter', 'milk', 'oranges']
```

3. it can hold different objects as well

```
my_list = ['butter', 1, 1.5, 'milk']
```

5. Every element has an index, starting from 0 which you can access with the square brackets []

I. e.g. >>> my_list[0]
 'butter'

List data structure

I. get subsets of a list (“slicing”)

```
>>> my_list[0:2]  
['butter', 'milk']
```

3. assign new values to list elements

```
my_list[0] = 'bananas'
```

5. powerful list operations

I. e.g. sort, reverse, insert, search

Session II: Work with lists

```
# create your first list and try accessing it with indices
```

```
my_list = [1,2,3,4,5]
my_list[1]
my_list[5]
my_list[0:3]
my_list[-1]

len(my_list)
```

```
# mixed lists, put different variable types in your list
```

```
my_mixed_list = ['UZH','founded in',1834]
my_mixed_list[2] = 1834
del my_mixed_list[1]
my_mixed_list.append('A.D.')
```

```
my_mixed_list
```

```
# apply the arithmetic operators on lists
```

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

```
['Hello'] * 4
```

Accessing list elements

```
# create your first list and try accessing it with indices
>>> my_list = [1,2,3,4,5]
>>> my_list[1]
2
>>> my_list[5]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: list index out of range
```

```
# slice your list with index ranges
>>> my_list[0:3]
[1, 2, 3]
>>> my_list[-1]
5

# Check how many elements your list contains
>>> len(my_list)
5
```

List modifications

```
# mixed lists, put different variable types in your list
>>> my_mixed_list = ['UZH', 'founded in', 1834]
>>> my_mixed_list[2] = 1834

>>> my_mixed_list
['UZH', 'founded in', 1834]

# delete an element at a specified index
>>> del my_mixed_list[1]

>>> my_mixed_list
['UZH', 1834]

# add another element to the list with the append command
>>> my_mixed_list.append('A.D.')

>>> my_mixed_list
['UZH', 1834, 'A.D.']
```

List concatenation

```
# apply the arithmetic operators on lists

# use + to make a longer list out of two small ones

>>> [1,2,3] + [3,4,6]
[1, 2, 3, 3, 4, 6]

# Use * to form a new list by repeating the content of a list

>>> ['Hello'] * 4
['Hello', 'Hello', 'Hello', 'Hello']
```

Strings & Lists

- Strings can also be considered lists of characters and can be accessed by index
- To convert them to an actual list (and make them mutable) use `list`

```
>>> my_sequence = 'MRHIAHTQRCLSRL'  
>>> list(my_sequence)  
['M', 'R', 'H', 'I', 'A', 'H', 'T', 'Q', 'R', 'C', 'L', 'S', 'R', 'L']
```

- While this opens many possibilities, check the cheat-sheet for convenient built-in string operations
 - e.g. `split`, `join`, `replace`

Dictionaries

- Similar to lists but elements are accessed through a user defined ‘key’

```
my_proteins_seqs = {}  
my_proteins_seqs = dict() # same as above  
my_proteins_seqs[ 'DROME_HH_Q02936' ] = 'MRHIAHTQRCLSRSLTSLVA'  
my_proteins_seqs[ 'DROME_PATC_P18502' ] = 'MDRDSLPRVPDTHGDVVD'
```

- retrieve their **value** by using the **key**

```
>>> my_proteins_seqs[ 'DROME_HH_Q02936' ]  
'MRHIAHTQRCLSRSLTSLVA'
```

Dictionary definition

```
# create your first dictionary

>>> dna_to_rna = {}
>>> dna_to_rna[ 'A' ] = 'A'
>>> dna_to_rna[ 'T' ] = 'U'
>>> dna_to_rna[ 'C' ] = 'C'
>>> dna_to_rna[ 'G' ] = 'G'

>>> dna_to_rna
{'A': 'A', 'C': 'C', 'T': 'U', 'G': 'G'}

#or in one line

>>> dna_to_rna = {'A':'A', 'T':'U', 'C':'C', 'G':'G'}
>>> dna_to_rna
{'A': 'A', 'C': 'C', 'T': 'U', 'G': 'G'}
```

Dictionary usage

```
#access an element with its key
>>> dna_to_rna['U']
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'U'

# Test if a key is in the dictionary
>>> 'U' in dna_to_rna
False

# See all keys in the dictionary
>>> list(dna_to_rna.keys())
['A', 'C', 'T', 'G']

# Dictionaries don't support concatenation
>>> dna_to_rna + dna_to_rna
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unsupported operand type(s) for +: 'dict' and 'dict'
```

Session III: Strings and dictionaries

```
# Try accessing a string like a list
```

```
my_string = 'hello world!'
```

```
my_string[6]  
my_string[-1] = '?'
```

```
my_list = list(my_string)  
my_list[-1] = '?'  
my_modified_string = ''.join(my_list)
```

```
# create your first dictionary
```

```
dna_to_rna = {}  
dna_to_rna['A'] = 'A'  
dna_to_rna['T'] = 'U'  
dna_to_rna['C'] = 'C'  
dna_to_rna['G'] = 'G'
```

```
#or in one line
```

```
dna_to_rna = {'A': 'A', 'T': 'U', 'C': 'C', 'G': 'G'}
```

```
#dictionary operations
```

```
dna_to_rna['U']  
'U' in dna_to_rna  
dna_to_rna.keys()  
dna_to_rna + dna_to_rna
```

String lists

accessing a character by index

```
>>> my_string = 'hello world!'
>>> my_string[6]
'w'
```

Changes are not allowed

```
>>> my_string[-1] = '?'
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'str' object does not support item assignment
```

Convert your string to a list to do that

```
>>> my_list = list(my_string)
>>> my_list[-1] = '?'
```

Combine your list into a string with the join method

```
>>> my_modified_string = ''.join(my_list)
>>> my_modified_string
'hello world?'
```

Methods

- functions of a specific object class
- access by `<variable_name>.<method>(arguments)`

```
>>> s = 'The quick brown fox jumps over the lazy dog'  
>>> s.split()  
['The', 'quick', 'brown', 'fox', 'jumps', 'over', 'the', 'lazy', 'dog']  
>>> s.split('fox')  
['The quick brown ', ' jumps over the lazy dog']
```

- in ipython: write `.` after a variable name and press `<tab>` to get an overview about available methods
- alternatively: `dir(object)`
- use `? / ??` (in ipython) or `help()` to get information about a method and its arguments e.g. `?str.split` or `help(str.split)`
- Alternatively: google!

Break

Part 2: Writing Python code

Why write a script?

1. Organize your commands in a text file and build more complicated workflows that can be executed at once.
2. save typing, make your work reproducible
3. Use comments (#) to describe your code
4. Run it at any point by executing your script

Scripting ingredients

I. Use the **print** function to print the output

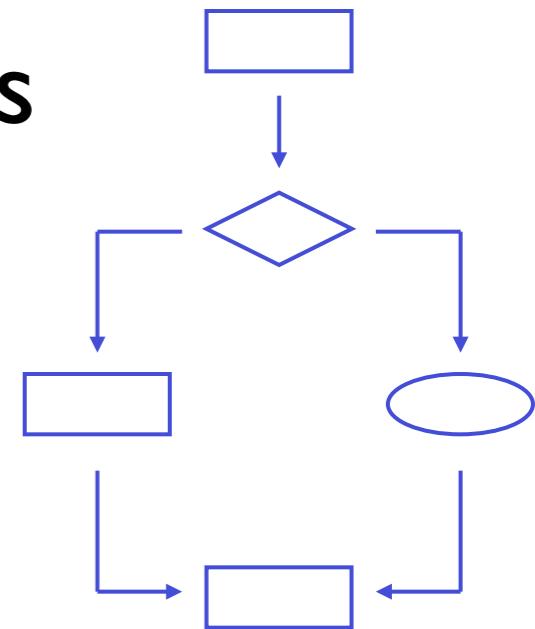
```
>>> print("Hello", "Python!")  
Hello Python!
```

```
print("Hello", "Python!") # use this (for Python 3)  
print 'hello world!' # not this (for Python 2)
```

Conditional statements

I. Use if/else clauses to make decisions

```
if boolean_expression:  
    print("The statement is True")  
else:  
    print("The statement is False")
```



4. Remember the indentation!

- I. While other programming languages use brackets or end statements, Python uses whitespace to structure code. Simply use tabulator to indent.



Loops

1. Loops are essential for repeating an action several times
2. The **for** loop executes the nested statements as many times as there are elements in the input list.

```
>>> input_list = [1,2,3,4,5]
>>> for my_number in input_list:
...     print(my_number)
...
1 2 3 4 5
```

- Note: Don't forget the colon (:) at the end.

for loop for reading

```
[1]: 1 for line in open("my_file.txt", "r"):  
2     print(line)
```

1st line

2nd line

3rd line

File:
my_file.txt

1st line

2nd line

3rd line

EOF

Conditional loop

- I. Use the **while** loop to continue an action until a condition is not satisfied anymore

```
>>> number_apples = 3
>>> while number_apples > 0:
...     number_apples -= 1
...     print("Ate an apple,",number_apples,'left')
...
Ate an apple, 2 left
Ate an apple, 1 left
Ate an apple, 0 left
```

Session IV: Loops and friends

1. try out this for loop

```
for my_number in range(6):  
    print(my_number)
```

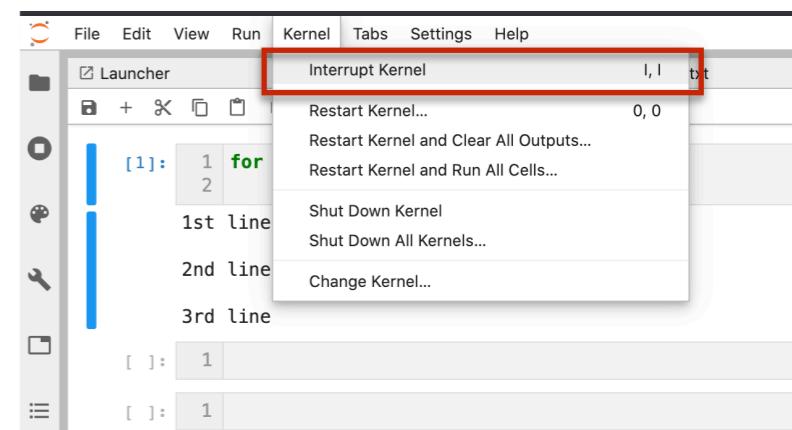
2. A new loop key-word: **continue**

```
for my_number in range(6):  
    if my_number == 5:  
        continue  
    print(my_number)
```

3. try using **break** instead of continue

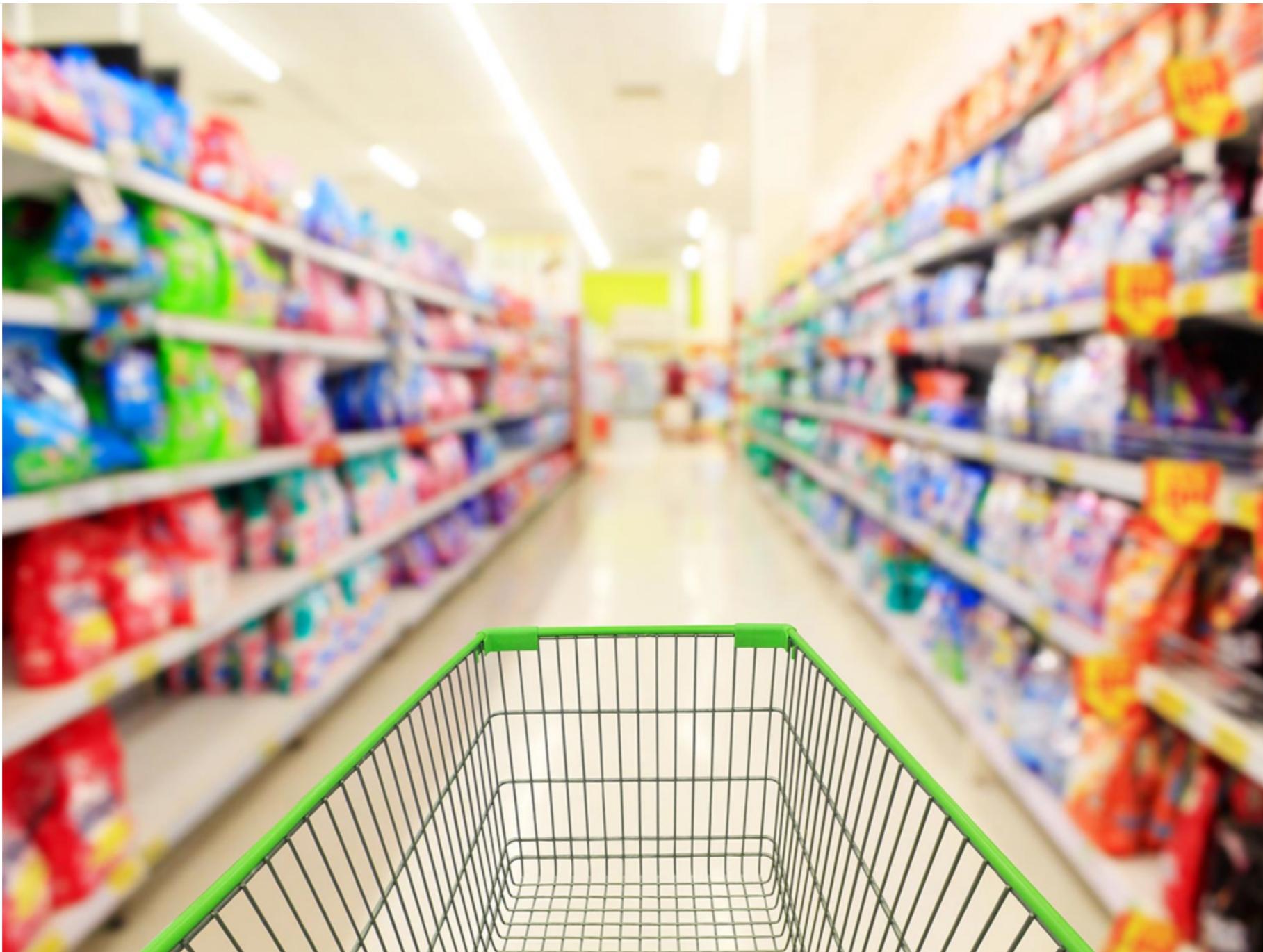
4. when will this while loop finish?

```
my_number = 1  
from time import sleep  
while my_number < 5:  
    print("hurray! my number is increasing:",  
    my_number)  
    sleep(1)
```

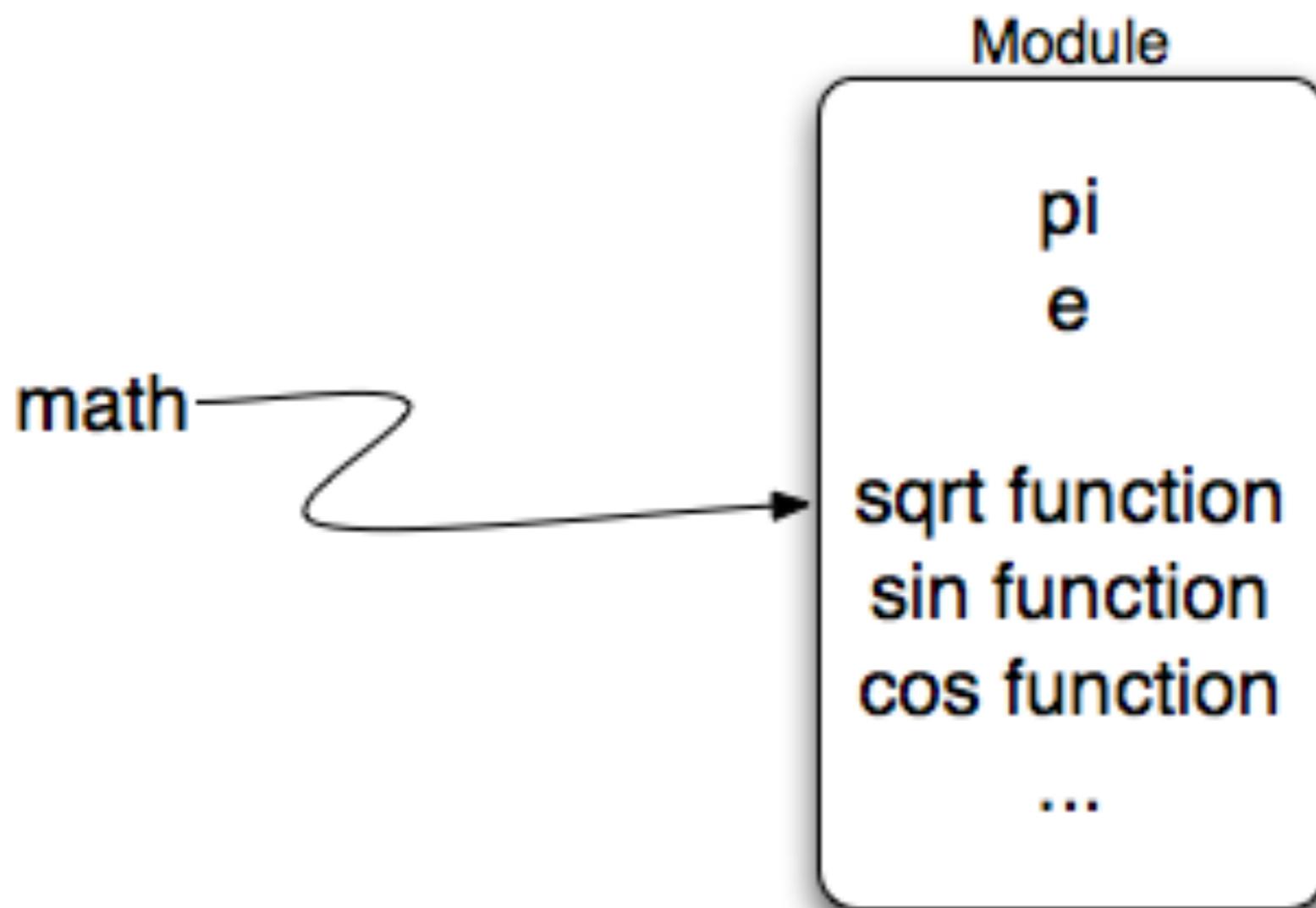


HINT: use Kernel —> Interrupt Kernel to stop the running program

python modules



math module



Import statement

1. Use **import** to load additional modules for more functionalities
2. For example the **math** module:

Script: print_pi.py

```
import math
print('Pi is equal to', math.pi)
print('or in degrees', math.degrees(math.pi))
```

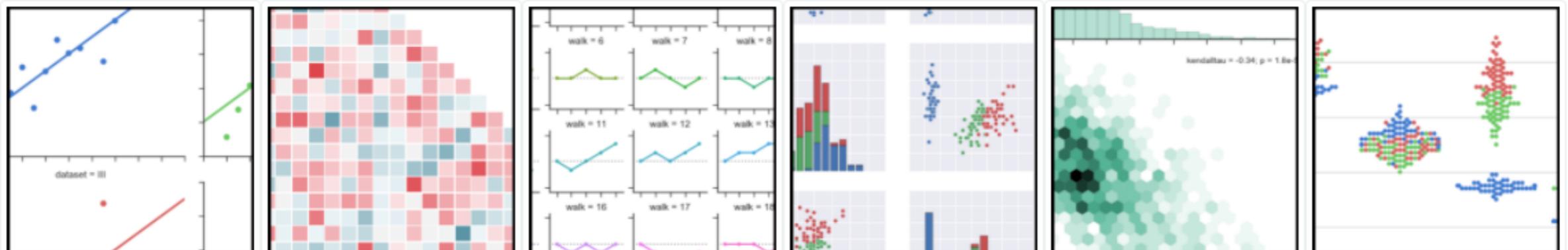
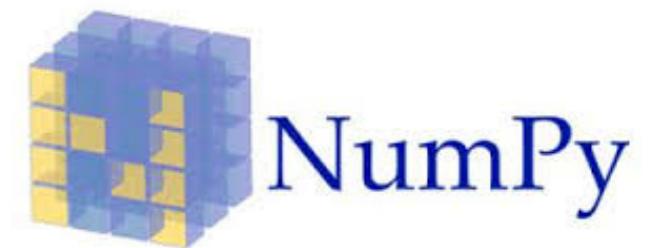
```
davide$ python print_pi.py
Pi is equal to 3.141592653589793 or in degrees 180.0
```

more details at: <https://docs.python.org/3/library/math.html>

Much more to discover

- I. ipython magics make your life a lot easier
 - I. time your code, debug it, call other languages
2. make python lightning fast using numpy, scipy, and cython/pypy/numba
3. visualize your data with seaborn, bokeh and matplotlib

IP[y]:
IPython



Further reading

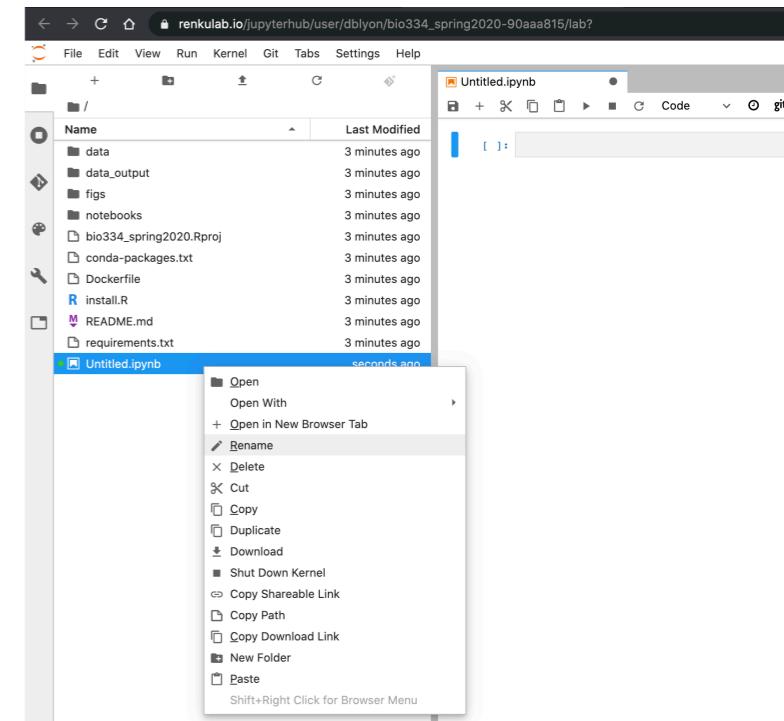
1. <https://snakify.org/> (interactive tutorial)
2. <http://www.diveintopython.net/> (comprehensive, general purpose)
3. <http://swcarpentry.github.io/python-novice-inflammation/> (scientific python by example)
4. <http://www.scipy-lectures.org/intro/intro.html> (intro by the scientific python consortium)
5. <https://github.com/dblyon/pandasintro> (extensive introduction to pandas)
6. <https://cs50.harvard.edu/college/2021/spring/weeks/0/>



Exercise session



- I. Within <https://renkulab.io/projects/mark.robinson/bio334-spring2021> create a new Python3 Jupyter Notebook and start exploring
2. Change the name of your newly created file by right clicking on Untitled.ipynb
3. To execute a cell press Shift + Enter
4. To access the files you need enter the following command in a terminal window



```
git clone https://github.com/meringlab/Bio334.git
```

DON'T FORGET TO DOWNLOAD YOUR OWN .IPYNB SCRIPTS AT THE END OF THE DAY

**optional exercise slides
follow**

Optional Exercise #3

Learn the basics of **Pandas**, a powerful python module for data analysis, including reading, writing, filtering, merging, arithmetic operations on and sorting of tabular data

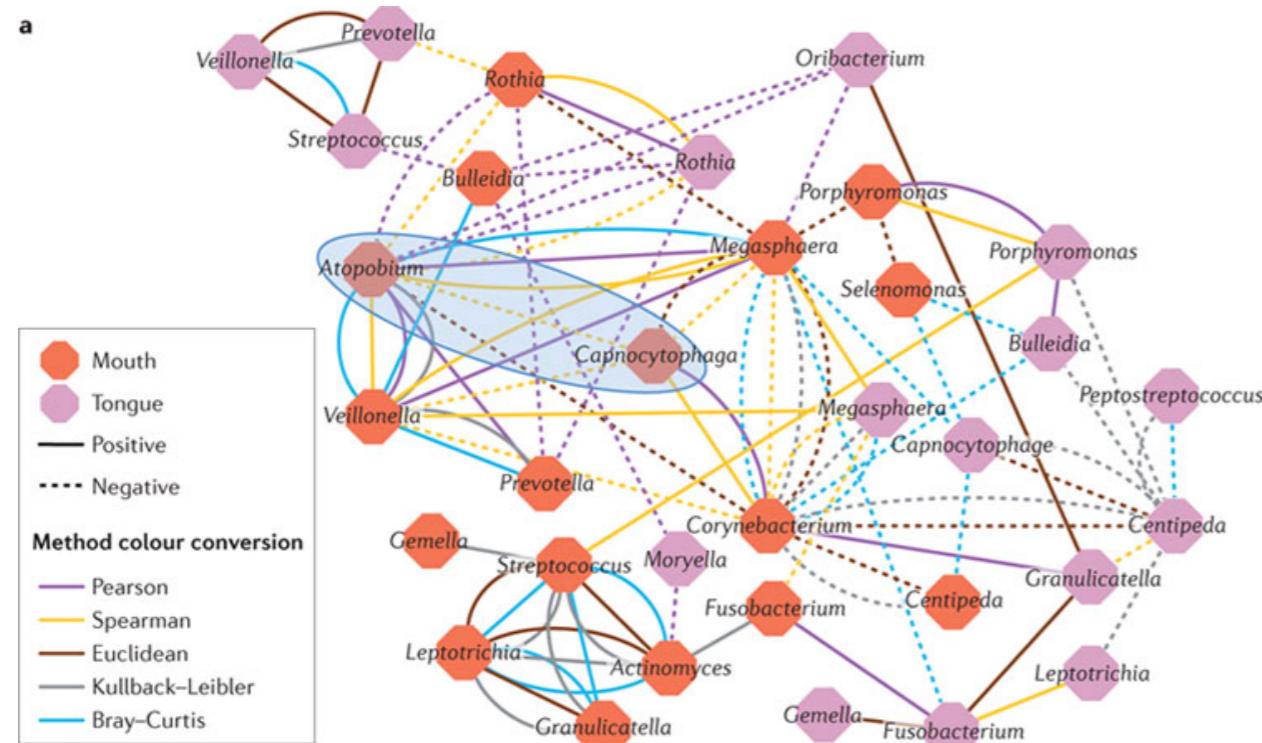
```
age animal priority visits
b   3.0  cat yes 3
d   NaN  dog yes 3
f   2.0  cat no  3
```



	age	animal	priority	visits
b	3.0	cat	yes	3
d	NaN	dog	yes	3
f	2.0	cat	no	3

Optional Exercise #4

create a pipeline to infer simple ecological relationships in the Human Microbiome



Optional exercise session

1. Create a new text document and rename it, giving it a “.py” ending
2. To execute, launch a terminal tab within Renku and enter

```
ipython <script_name>.py
```
3. Files can be found within Renku (if you’ve git cloned them)
`/Bio334`
5. Good luck!

sys module

1. A built-in module that contains system-specific parameters and functions
2. For example we can use it to read arguments from the command line:

Script: say_hello.py

```
import sys
print('Hello there', sys.argv[1])
# Command line arguments are in sys.argv[1], sys.argv[2]...
# sys.argv[0] is the script name itself
```

```
davide$ python say_hello.py bio334_Students
Hello there bio334_Students
```

os module

1. Another built-in module that contains miscellaneous operating system interfaces
2. For example we can use it to obtain the name of the user currently logged in:

Script: check_directory.py

```
1 import os
2
3 dir_ = "Bio334"
4 if not os.path.exists(dir_):
5     print("It seems you haven't cloned the git repository yet. \
6           Please enter the following command in a terminal window.")
7     print("git clone https://github.com/meringlab/Bio334.git")
8 else:
9     print("Great! The 'Bio334' directory exists. You are good to go.")
```

Run the script in a terminal window

```
base > work > bio334_spring2020_dbl > master > 3? > $ > python check_directory.py
Great! The 'Bio334' directory exists. You are good to go._
```