1. Expressions and Variables

Python evaluates expressions. The results can be stored in variables, which can be reused. Spaces around operators are optional!

Simple mathematical expressions

```
1+1          # evaluates to: 2
# Text after '#' is a comment (ignored by Python)
1+2*3        # 7
(1+2)*3      # 9
5**2         # 25 (power)
```

Division

```
5/2          # 2.5
5//2         # 2 (integer division)
5%2          # 1 (modulo, remainder)
```

Variables

```
x = 2        # Assignment: x is now 2
hans = 1+x   # hans is now 3
z = x+hans   # z is now 5
```

2. Strings and Printing

Strings are sequences of characters; a representation of text. Printing refers to the output of text from the program.

Hello world

```
print('Hello world!') # prints: Hello world!
print("Hello world!") # prints: Hello world!
# Note: Only straight single (') or double (")
quotes can be used (not mixed)! Backticks and
accents ( ´ or ` ) will not work!
```

Hello world with variables

```
variable = 'Hello world!'
print(variable) # prints: Hello world!
```

f-strings

```
first = 'Albert'
last = 'Einstein'
sentence = f'I like {first} {last}.'
print(sentence) # I like Albert Einstein.
print(f'pi: {3.14159:.2f}') # format pi: 3.14
```

3. User Input

Programs can prompt (ask) the user to enter a value. The value is always stored as a string (i.e., text) and you may need to convert it.

Prompting for a value

```
name = input("What's your name? ")
# Note: Careful use of " and ' allows the
printing ' in a string!
print(f'Hello {name}')
```

Prompting for a numerical value

```
age = input("How old are you? ")
age = int(age) # convert to integer number
pi = input("What's the value of pi? ")
pi = float(pi) # convert to a decimal number
```

4. Conditional Tests (Comparisons)

Conditional tests evaluate to whether a statement is *True* or *False*.

Conditional tests

```
1 < 2        # True
1+1 >= 2     # True
1 < 2 < 3    # True (chaining)
1 == 1       # True (1 equals 1)
# Note: Double equal signs (==) have to be used
for equality testing!
1 != 2       # True: 1 is not equal 2
```

Boolean expressions

```
x = 7
x < 10 or x > 15         # True
x < 10 and x > 7         # False
x < 10 and not x > 7     # True
x = 2          # Assignment: x is now 2
hans = 1 + 1   # hans is now 2
z = x + hans   # z is now 4
```

5. Lists

Lists are a container for data. They contain multiple items in a particular order.

Creating a list

```
numbers = [1, 2, 3, 4, 5]
names = ['Alice', 'Bob', "Hans"]
empty_list = []
```

Get items from a list (indexing)

```
print(names[0])    # Alice
print(names[2])    # Hans
print(names[-1])   # Hans ([-1] -> last item)
names[0] = 'Al'    # ['Al', 'Bob', 'Hans']
```

Adding items to a list

```
numbers.append(42)    # [1,2,3,4,5,42]
more_names = ['Joe', 'Eve']
names.extend(more_names)
        # ['Al', 'Bob', 'Hans', 'Joe', 'Eve']
[1,2] + [3,4]         # [1,2,3,4]
```

Slicing a list (getting a range from a list)

```
names[0:2]      # ['Alice', 'Bob']
                # (exclusive index 2; no "hans"!)
numbers[:]      # [1,2,3,4,5,42]
numbers[:2]     # [1,2]
numbers[:-3]    # [1, 2, 3] (skip the last 3)
numbers[4:]     # [5,42]
numbers[0:5:2] # [1,3,5] (step: 2)
numbers[::-1]  # [42,5,4,3,2,1] (step: -1)
```

List comprehensions (to create lists)

```
even_numbers = [2*x for x in range(10)]
odd_numbers = [2*x+1 for x in range(10)]
div_by_3 = [x for x in range(100) if x%3==0]
```

Conditional tests with lists

```
2 in numbers                # True
17 in numbers               # False
'Charlie' not in names      # True
```

Removing items from lists

```
numbers = [1, 2, 3, 4, 5, 42]
numbers.remove(42)       # now: [1, 2, 3, 4, 5]
del numbers[3:5]         # now: [1, 2, 3]
```

Copying lists

```
x = [1,2,3]
y = x        # y refers to the same list as x
y[0] = 10    # modify y
print(x)     # [10,2,3] - x was modified, too!
z = x[:]     # z is a copy of x
z[0] = 5     # only z is modified, not x
```

Length of a list

```
x = [0,1,2,3,4]
len(x)       # 5
```

6. Modules

Python comes with an extensive standard library of useful functions grouped into modules. Refer to the online documentations!

Importing a module

```
import math # now we can use math functions
print(math.exp(1)) # 2.718281828459045
print(math.cos(0)) # 1.0
```

Importing functions from a module

```
from math import exp as e
from math import cos, pi
print(e(0))    # 1.0 (no math. needed)
print(cos(pi)) # -1.0
```

7. If-statements

If-statements allow conditional execution of your code

Simple tests

```
if age >= 18:
    print('You can vote!')
```

if-elif-else case distinctions

```
if age < 4:      # do not forget the colon (:)!
    ticket_price = 0
elif age < 18:  # you can chain multiple elif
    ticket_price = 10
else:
    ticket_price = 15
```

8. Loops

Loops allow repeating certain lines of your code a certain number of times or while a condition is fulfilled.

For-loop

```
my_list = []
for number in range(3):
    my_list.append(number)
print(my_list)     # [0,1,2]
```

For-loop: continue

```
my_list = []
for number in range(5):
    if number == 3:
        continue   # skips current for-iteration
    my_list.append(number)
print(my_list)     # [0,1,2,4]
```

Iterating over elements of a list

```
my_dogs = ['Rex', 'Snoopy', 'Rufus']
for dog in my_dogs:
    print(f'{dog} is the best dog ever!')

for number, dog in enumerate(my_dogs):
    print(f'{dog} is my dog no. {number}')
```

Progressbars

```
import time           # provides time.sleep()
from tqdm import tqdm # creates progressbar
for dog in tqdm(my_dogs):
    print(f'{dog} is the best dog ever!')
    time.sleep(1.5)   # pause for 1.5sec
#67%|▓▓▓▓▓▓▓▓    | 2/3 [00:03<00:01,  1.51s/it]
# shows remaining time & time/iteration
```

While-loop

```
my_list = []
x = 1
while x < 10:
    x *= 2    # same as: x = x * 2
    my_list.append(x)
print(f'my_list: {my_list} x: {x}')
    # my_list: [2, 4, 8, 16] x: 16
```

9. Functions

You can reuse code by defining functions (similar to print(…))

Defining and invoking (calling) functions

```
def say_hi():
    print('Hi!')
say_hi() # prints: Hi!
say_hi() # prints again: Hi!
```

Defining functions with parameters

```
def greet(name):
    print(f'Hi {name}!')
greet('Alice')        # prints: Hi Alice!
greet(name='Hans')    # prints: Hi Hans!
# naming parameters is optional, but recommended!
```

Multiple parameters

```
def print_sum(x,y):
    print(x+y)
print_sum(x=1, y=2)      # prints: 3
```

Default parameters

```
def print_big_sum(x,y,z=1):
    print(x+y+z)
print_big_sum(x=1, y=2)        # prints: 4
print_big_sum(x=1, y=2, z=0)   # prints: 3
```

Return values

```
def subtract(x, y=1):
    return(x - y)
a = subtract(x=3)          # returns 2
b = subtract(x=3, y=3)     # returns 0
print(f'a: {a}, b: {b}')  # a: 2, b: 0
```

10. Error Handling

Some conditions (e.g. user input) might bring your program into a state, where it cannot continue as normal (a crash).

Catching errors

```
age = input("What's your age? ")
try:      # Place below what could go wrong
    age = int(age)
except:
    print('You did not enter a number!')
else:
    print(f"You're {age} years young!")
```

11. Numpy

A module to perform numerical operations.

Basics

```
import numpy as np
x = np.arange(start=1, stop=2.5, step=0.5)
print(x)          # [1.,  1.5, 2. ]
print(np.exp(x))  # [2.71… 4.48… 7.38… ]
y = np.zeros_like(x) # same shape and dtype as x
z = np.zeros(shape=(10,10), dtype=np.uint8)
converted = z.astype(np.uint8) # convert to uint8
```

Comparisons & Masking

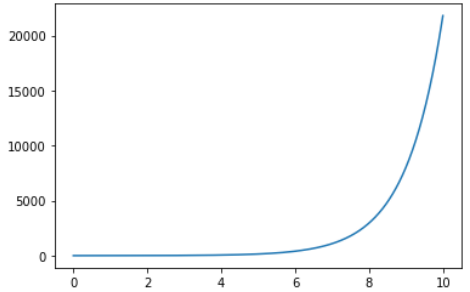
```
x = np.array([1, 2, 3, 4])
y = x > 2    # array([False, False,  True,  True])
x[y] = 0     # array([1, 2, 0, 0])
z = x[y]     # array([0, 0])
```

12. Matplotlib/pyplot

Visualizing (plotting) data graphically.

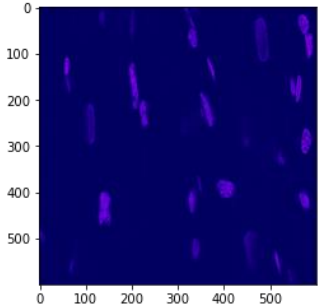
Lineplots

```
import matplotlib.pyplot as plt
x = np.arange(start=0, stop=10, step=0.1)
y = np.exp(x)

plt.figure()
plt.plot(x, y)
plt.show()
```



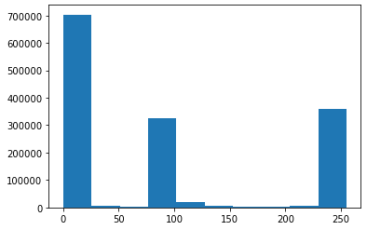
2D images

```
path_to_image_file = 'data/dapi.tif'
image = plt.imread(path_to_image_file)

print(f'image has the type: {type(image)}')
print(f'image has the shape: {image.shape} (rgb)')

plt.figure()
plt.imshow(image)
plt.show()
```



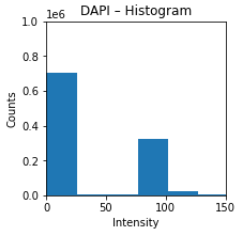
Histogram

```
plt.figure()
plt.hist(image.flatten()) # convert 2D -> 1D
plt.show()
```



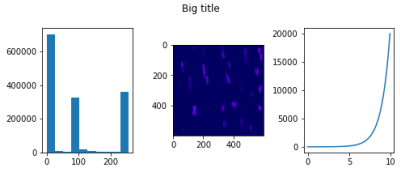
Customizing/labeling axes

```
plt.figure(figsize=(4,4)) # size in inches
plt.hist(image.flatten()) # convert 2D -> 1D
plt.xlabel('Intensity')   # label on x-axis
plt.ylabel('Counts')      # label on y-axis
plt.title('DAPI - Histogram') # title
plt.xlim([0, 150])        # x-axis range
plt.ylim([0, 1000000])    # y-axis range
plt.show()
```



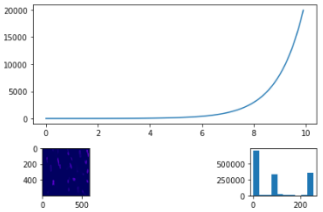
Grid subplot

```
number_rows = 1
number_cols = 3

plt.figure(figsize=(7,3))
plt.subplot(number_rows, number_cols, 1)
plt.hist(image.flatten()) # left plot

plt.subplot(number_rows, number_cols, 2)
plt.imshow(image)         # middle plot

plt.subplot(133) # omitting commas also works
plt.plot(x,y)    # right plot

plt.suptitle('Big Title') # title for all plots
plt.tight_layout() # adjust padding of subplots
plt.show()
```



Mosaic subplot

```
axes = plt.figure().subplot_mosaic(
    """
    aaa
    aaa
    b.c
    """
) # letters are axes, colons are empty spaces

plt.sca(axes['a']) # set current axis to 'a'
plt.plot(x,y)

plt.sca(axes['b']) # set current axis to 'b'
plt.imshow(image)

plt.sca(axes['c']) # set current axis to 'c'
plt.hist(image.flatten())

plt.tight_layout()
plt.show()
```



Saving/exporting figures

```
plt.savefig('data/fig.png') # saves latest figure
plt.savefig('data/fig.pdf') # vector graphic
```

Additional cheatsheets

```
https://matplotlib.org/cheatsheets/
```

13. Pandas

Data science/analysis platform for tabular data and time series.

Simple example

```
import pandas as pd
df = pd.DataFrame(
    {"area" : [1, 4],
     "intensity" : [5.2, 8.1]},
    index = ["cell_1", "cell_2"])
print(df)
# prints:  area  intensity
# cell_1     1        5.2
# cell_2     4        8.1
```

Accessing data

```
area = df['area']
```

Appending to DataFrame

```
df = df.append(
    pd.DataFrame({'area':5, 'intensity':4},
                 index=['cell_3'])
)
```

Writing DataFrame to disk

```
df.to_pickle('data/df.pkl') # recommended
df.to_csv('data/df.csv')
df.to_excel('data/df.xlsx') # needs 'openpyxl'
```

Reading DataFrame from disk

```
df2 = pd.read_pickle('data/df.pkl')
df2 = pd.read_csv('data/df.csv')
df2 = pd.read_excel('data/df.xlsx')
```

Additional cheatsheets

```
https://pandas.pydata.org/Pandas_Cheat_Sheet.pdf
```

14. scikit-image

Collection of algorithms and functions for image processing.

Reading images

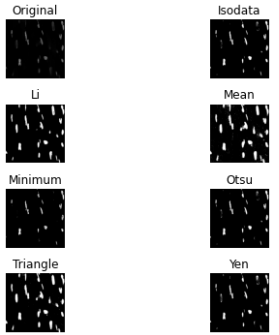
```
from skimage import io
path_to_image_file = 'data/dapi.tif'
image = io.imread(fname=path_to_image_file)
```

Writing images

```
filename_out = 'data/dapi_out.tif'
io.imsave(fname=filename_out, arr=image)
```

Filter Examples

```
from skimage.filters import median
filtered = median(image) # run median filter

from skimage.filters import  try_all_threshold
try_all_threshold(image)
```



Measurements with regionprops

```
from skimage.measure import regionprops_table
props = regionprops_table(labels_clear,# segments
                          image,       # intensities
                          properties=['label',
                                      'area'])
df = pd.DataFrame(props) # table with measurements
```

Further References

```
https://scikit-image.org/docs/stable/user_guide.html
https://scikit-image.org/docs/stable/index.html
```

15. Paths and Globbing

Paths and path-handling are common sources of breaking code. Use dedicated modules from os.path to avoid these.

Joining paths

```
import os
path_to_directory = 'data' # adding '/' optional
path_to_subdirectory = 'more_data'
path_to_file = 'dapi.tif'
joined_path = os.path.join(path_to_directory,
                           path_to_subdirectory,
                           path_to_file)
 # on windows: data\more_data\dapi.tif
 # on linux: data/more_data/dapi.tif
```

Checking if file exists

```
os.path.exists(path_to_file) # returns True/False
```

Extracting information from path

```
os.path.dirname(joined_path)   # data/more_data
os.path.basename(joined_path)  # dapi.tif
os.path.splitext(path_to_file) # ('dapi', '.tif')
```

Finding files with glob

```
from glob import glob
path_to_folder = os.path.join('data','glob')
glob(os.path.join(path_to_folder, '*'))
# finds all files in data/glob, here:
#['data\\glob\\1.tif',
# 'data\\glob\\2.png',
# 'data\\glob\\40x_1.tif',
# 'data\\glob\\1.png']

glob(os.path.join(path_to_folder, '*.tif'))
# finds all files that end with .tif
#['data\\glob\\1.tif',
# 'data\\glob\\40x_1.tif']

glob(os.path.join(path_to_folder, '1*'))
# finds all files which filename starts with 1
# ['data\\glob\\1.tif', 'data\\glob\\1.png']

glob(os.path.join(path_to_folder, '*1*.tif'))
# filename has to have a 1 end end with .tif
# ['data\\glob\\1.tif', 'data\\glob\\40x_1.tif']
```