Foundations of Programming in Python

Philipp Gloor[1]

[1]University of Zurich

About me

Education

- 2012 – Bachelor of Science UZH in Physics
- 2016 – Master of Science UZH in Computational Science

Work

- 2014 – 2016 Software engineer CERN (remote)
- 2016 – now PDF Tools AG

Programming experience

C++, C#, Java, JavaScript, Python

Email

philipp.gloor@gmail.com

Round of introduction

- Name
- Occupation
- Programming experience? What language?
- Expectations

Learning targets

After this course...

- ... you will know what programming is
- ... you will know how to write a basic computer program
- ... you will know the fundamental components of programming
- ... you are able to run Python code
- ... you are able to write a Python program based on a written out problem statement
- ... you know where you can find more information to improve your programming skills

Introduction to Programming

- Introduction to Programming
- Fundamental Concepts
  - Values, Variables, Expressions, Operators, Comments
  - Functions
  - Naming Conventions & Debugging
  - Conditionals
  - Functions with Return Values
  - Lists
  - Iteration
  - Dictionaries
- Persistence

What is a Computer Program

Modular System

- **Input**: Data input from keyboard, files, internet, etc...
- **Output**: Processed data is displayed or saved to a file
- **Assignment**: Values are assigned to variables
- **Conditional execution**: Statements are executed only if certain conditions are fulfilled
- **Loops**: Repeating statement or group of statements
- **Libraries**: Using existing implementations

Examples: Hello World I

Java

```java
public class HelloWorld {
    public static void main(String args[]) {
        System.out.println("Hello World");
    }
}
```

C++

```cpp
#include <iostream>
int main() {
    std::cout << "Hello World" << std::endl;
    return 0;
}
```

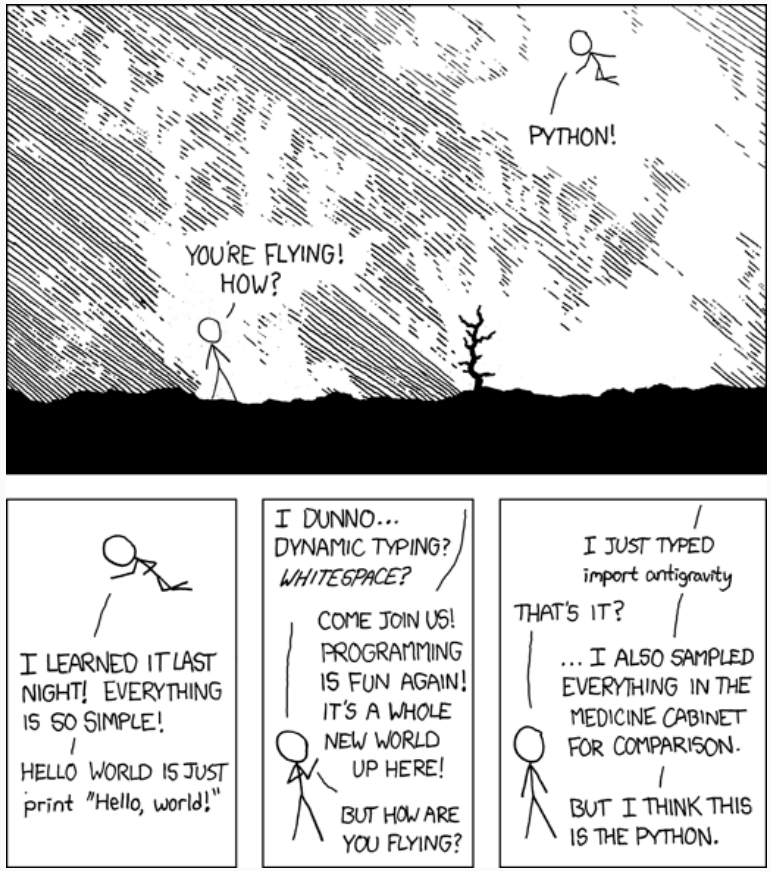
Examples: Hello World II

Python

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

Why Python?

- ”Simple” syntax
- High-level programming language
- Cross-platform
- Interpreted
- Object-oriented
- Many libraries available



Source: https://xkcd.com/353/

Development Environment

- Integrated Development Environment (IDE)
- Collection of tools that are commonly used for software development
- Popular IDEs
  - Eclipse with pydev - `http://pydev.org`
  - JetBrains PyCharm - Community Edition available for free `http://jetbrains.com/pycharm/download`

Demo: Hello World

Options to run Python code:

- Directly in the Python prompt
- Write the code into a file and run python with the file
- Use IDE to run Python code

Fundamental Concepts

- Introduction to Programming
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  - Iteration
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- Persistence

Values, Variables, Expressions, Operators, Comments

Values, Variables, Expressions, Operators, Comments

Values

- Numbers
  - 2
  - 1000000
  - -2
  - 3.2
  - 1.3333333
- Strings (Text)
  - 'Hello World'
  - "Hello World"

Data Types

Strings

- 'Single quotes' or "double quotes" can be used to declare them
  - 'Hello World'
  - "Hello World"
  - "5"

Boolean

Binary data type

- True
- False

Variables I

- Variables hold values
- Similar to mathematics
  - x = 2
  - y = x + 2
- Values assigned using the = operator

Variables II

Examples

Use meaningful names

- Declaration

```
salutation = "Hello"
name = "Dennis Reynolds"
pi = 3.13159
```

- Usage

```
print(name)
```

Variables III

Keywords - reserved words

```
and, assert, break, class, continue, def, del, elif, else, except, exec,
finally, for, from, global, if, import, in, is, lambda, not, or, pass,
print, raise, return, try, while, yield
```

Variables IV

Variables and values can be combined

```
print(2+2)
a = 2
print(a+2)

salutation = "Hello"
name = "Dennis Reynolds"
print(salutation + " " + name)
```

Operators

Order of precedence

- ()
- **
- unary +,-
- *,/,%
- binary +,-
- <, >, <=, >=, !=, ==
- **not**
- **and**
- **or**

Comments

- Comments have no impact on the program
- Should explain the code
- A comment starts with a # character

Examples

```
# Declaring the name
name = "Philipp"
print(name) # Prints Philipp
```

Functions

Functions I

- `print()` is a function that you have already used
- A function can take arguments which can be used inside the function

```
name = "Some name"
print(name) # Some name is used inside the print function
```

- Functions can also return a result
  - `return` statement

Examples

```
text = "Python programming language"
print(text) # Prints: Python programming language
text_length = len(text)
print(text_length) # Prints length of the string
```

Functions II

Type conversions

- `int('32')`: Converts a string that holds a number to an integer
- `int('Hello')`: This doesn't work and it will throw a ValueError exception
- `float('313.333')`: Converts a string that hold a number to a float
- `str(32)`: Converts a number to a string

Examples

```
a = 20
b = 10
res = a + b
print("The sum of " + str(a) + " and " + str(b) + " is " + str(res))
```

Functions III

Rounding

```
a = 1.888
int(a) # = 1
int(round(a)) # = 2
int(a+5) # = 2
```

Math functions

```
import math
log_res = math.log(17.0)
sin_res = math.sin(45)
angle = 20
x = math.cos(20*math.pi/180))  # cos/sin etc take radians as arguments ->
    conversion from degree to radians necessary
```

- http://docs.python.org/library/math.html

Functions IV

User-defined functions

- A function encapsulates some functionality
- Reduces complexity

```
def my_function(param1, param2):
    print(param1)
    print(param2)
```

- Syntax is important
  - Indentation
  - The colon

Functions V

Examples

```
def line_separator():
    print('')

print("First Line")
line_separator()
print("Second Line")
line_separator()
print("Third Line")
line_separator()
print("Fourth Line")
```

- If we want to change the line separator to a dashed line we only need to change a single line of code

```
def line_separator():
print('————————————————————————————————————')
```

Functions VI

Examples

- If the line seperator should output two lines we can define a new function that calls the `line_separator()` function twice

```
def two_lines():
    line_separator()
    line_separator()

print ("First Line")
two_lines()
print("Second Line")
```

Functions VII

Parameters and arguments

- Arguments are passed when calling a function
- Value of arguments is assigned to parameters

```
def print_sum(number_1, number_2):
    result = number_1 + number_2
    print(result)

print_sum(1,3)
print_sum(10,5)
```

Functions VIII

Parameters and arguments

- Variables are valid within a scope
- Variables that are defined in a function can only be seen inside that function
- Scope can be identified by indentation

```
def concatenation(param1, param2):
    concat = part1 + part2
    print(concat)

concatenation("Hello", "World")
print(concat) # NameError: name 'concat' is not defined
```

Functions IX

Conclusion

- A function can be called multiple times
- If some code can be reused, put it in a function so you need to write less
  - Higher factorization
  - Less redundancy
  - Better maintenance
- Functions can also call other functions

Naming Conventions & Debugging

Naming Conventions I

How to name your functions and variables (PEP8)

- Naming convention is a set of rules for choosing names of functions and variables
- Every programming language has different naming conventions
- Python
  - No spaces in variable and function names
  - Variable and function names are in lowercase and _ is used to separate words

```
length_in_cm = 15

def say_hello():
    print("Hello")
```

Debugging I

Finding and resolving ”bugs”

- Programming is a complex activity
- Mistakes happen all the time
- A mistake made in programming is called a bug
- The process of finding and resolving bugs is called debugging

Debugging II

Errors

- Syntax error
  - Incorrect syntax of a statement: `print(Hello World)` instead of `print("Hello World")`
- Runtime error
  - Error that occurs during the execution of a program
  - e.g. division by 0
- Semantic errors
  - Program does not deliver correct results
  - No error messages (code is syntactically correct)
  - Fixing semantic errors can be extremely complicated (good software design is important)

Debugging III

Techniques

- Reading code
- Print variables with `print()` to examine values (a poor man's debugger)
- Go through the program step by step -> **Debugger**!

Conditionals

Conditionals I

- Boolean algebra is a part of mathematics
- Often used in programming
- A boolean expression is either true or false

```
5 == 5 # ---> True
5 == 6 # ---> False
6 > 4 # ---> True
5 >= 8 # ---> False
```

Conditionals II

Examples

if

- The expression if defines a condition
- If the condition is true, subsequent statements will be executed
- If the condition is false, subsequent statements will not be executed
- There has to be at least one statement after the condition

```
x = 10
if x > 0:
    print(str(x) + ' is positive')
if True:
    # This statement will always be executed
    print('Yes')
if False:
    # This statement will never be executed
    print('No')
```

Conditionals III

else

- Expression else is executed if the if condition is false
- Can only be used in combination with an if expression

```
if x == 0:
    print(str(x) + ' is zero')
else:
    print(str(x) + ' is not zero')
```

Conditionals IV

Examples

%-operator (remainder after division)

```
def print_parity(x):
if x % 2 == 0:
    print(str(x) + ' is even')
else:
    print(str(x) + ' is odd')

print_parity(2)
print_parity(3)
```

Conditionals V

Chained conditionals

- lbelif is used to combine multiple conditions
- The lbelse expression is executed when neither lbif nor any of the lbelifs is true.
- Any number of lbelif expressions can be used but only one lbif and one lbelse

Conditionals VI

Examples

```
if x < y:
    print(str(x) + ' is less than ' + str(y))
elif x > y:
    print(str(x) + ' is greater than ' + str(y))
else:
    print(str(x) + ' and ' + str(y) + ' are equal')
```

```
# Python 3
answer = input('Do you like Python?')
# Python 2.7
# answer = raw_input('Do you like Python?')
if answer == 'yes':
    print('That is great!')
else:
    print('That is disappointing!')
```

Exercise 1 I

- Write a function `compare(x,y)` that
  - prints 1 if $x > y$
  - prints 0 if $x == y$
  - prints -1 if $x < y$
- Use `input()` to receive user input

Exercise 1 II

- Attention: `input()` stores the input as a string (not as a number)
- If the input is supposed to be a number (int, float) you need to convert it

```
first_number = input('Please enter a first number ')
first_number = int(first_number)
second_number = input('Please enter a first number ')
second_number = int(second_number)
result = first_number + second_number
print(str(result))
```

Conditionals I

Nested conditionals

- Conditionals can be nested

```
if x > 0:
    if x < 10:
        print('x is a positive single digit')
```

and

- Deep nesting can be difficult to read
- Use and to combine conditionals

Conditionals II

```
if x > 0:
    if x < 10:
        print('x is a positive single digit')
# is the same as
if x > 0 and x < 10:
    print('x is a positive single digit')
```

or

- At least one statement must be true for the condition to be true

```
if x > 0 or x < 0:
    print("x is not zero")
```

Conditionals III

not

- Negation, inverts the boolean.
- not True -> becomes False
- not False -> becomes True

```
if not (y == 0):
    print(x/y)
else:
    print("Cannot divide by zero")
```

X	Y	X and Y	X or Y
False	False	False	False
False	True	False	True
True	False	False	True
True	True	True	True

Functions with Return Values

Functions with return value I

- Some functions will return a value

```
# Python 3
answer = input('Do you like Python?')

# Python 2.7
# answer = raw_input('Do you like Python?')
```

- Our previously defined functions have never returned anything, but only printed something out

Functions with return value II

return

- Functions that return a value use the return keyword

```
import math
def area(radius):
    result = math.pi * radius ** 2
    return result

print(area(10))
my_circle_area = area(8)
```

- Functions can return any valid data type

Functions with return value III

Boolean return values

- The functions can return a boolean vlaue (True, False)
- The function name should be formulated as a yes/no question

```
def is_divisible(x, y):
    if x % y == 0:
        return True
    else:
        return False
```

Functions with return value IV

Boolean return values

- The return value can be used in a condition

```
if is_divisible(x, y):
    print(str(x) + ' is divisible by ' + str(y))
else:
    print(str(x) + ' is not divisible by ' + str(y))
```

Exercise 2

- Write a function called `distance(x1, y1, x2, y2)` which computes the distance between point 1 $(x1, y1)$ and point 2 $(x2, y2)$
- Note:
  - distance $= \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$
  - x^2 is represented by `x**2` in Python
  - The root of x is computed with math.sqrt(x)
  - Use the import math statement at the beginning of the file

Exercise 3

- Write a function `volume_from_radius(radius)`, which calculates the volume of a sphere
- Note:
  - volume $= \frac{4\pi}{3} \cdot r^3$
  - Pi is math.pi

Exercise 4

- Write a function `volume_from_points(x1, y1, x2, y2)`
- This function calculates the volume of a sphere whose radius is the distance between the points $(x1, y1)$ and $(x2, y2)$
- Tip: Use the implemented methods from the previous exercises

Exercise 5

- Write a function `is_between(x, y, z)` which returns True if x <= y <= z and False otherwise

Lists

Lists I

- Lists are a data type
- Lists are used in most programming languages (arrays)
- Lists are a set of values

```
list_a = [1, 2, 4]
list_b = ['Monty', 'Python']
```

Lists II

Creating lists

- The easiest way to create a list is using []

```
numbers = [10, 12, 14, 19]
words = ['spam', 'bungee', 'swallow']
```

- Data types can be mixed

```
my_list = ['music', 2000, 3.5, True]
```

Lists III

Creating lists

- Since numbers are often stored in a list, there is a special method for doing so
- With only one argument, range returns a number series starting at 0

```
list(range(4))
# returns [0, 1, 2, 3]
```

- When using two arguments it is possible to define the start and end of the range [start, end) (end is not included in the list)

```
list(range(1,5))
# returns [1, 2, 3, 4]
```

Lists IV

Creating lists

- The step size can be defined with a third argument

```
list(range(1, 10, 2))
# return [1, 3, 5, 7, 9]
```

- An empty list can also be created

```
empty_list = []
```

- This is often done when the values to be inserted in the list are not yet known.

Lists V

Creating lists

- Accessing elements can be done with the [] operator

```
names = ['Anna', 'Tom', 'Ralph', 'Peter']
print(names[1])
# prints Tom
```

Important

Array indices start at 0!

0	1	2	3
Anna	Tom	Ralph	Peter

Lists VI

Accessing lists

- A negative index is used to access the list from the end

```
names = ['Anna', 'Tom', 'Ralph', 'Peter']
print(names[-1])
# prints Peter
```

Lists VII

Length

- The number of elementsi n a list can be obtained using the `len()` function

```
names = ['Anna', 'Tom', 'Ralph', ‘Peter']
print(len(names))
# prints 4
```

Out of range

- If there is no item in the list at the desired index, Python will print an error message

Lists VIII

```
names = ['Anna', 'Tom', 'Ralph', 'Peter']
nNames = len(names)
print(names[nNames])
# IndexError: list index out of range
```

Lists IX

Changing elements in a list

- An element can be changed using [INDEX]

```
names = ['Anna', 'Tom', 'Ralph', 'Peter']
names[0] = 'Alice'
# ['Alice', 'Tom', 'Ralph', 'Peter']
```

Lists X

Adding elements

- The `append()` method can be used t o add an element at the end of the list

```
numbers = range(5)
# [0, 1, 2, 3, 4]
numbers.append(5)
# [0, 1, 2, 3, 4, 5]
```

Lists XI

Concatenate lists

- The + operator can be used to join lists

```
a = [1, 2, 3]
b = [4, 5, 6]
c = a + b
# [1, 2, 3, 4, 5, 6]
```

Lists XII

Slices

- Lists can be cut into slices
- The operator [n:m] returns a list of the elements that start at index n and stop before m

```
my_list = ['a', 'b', 'c', 'd', 'e', 'f']
my_list[1:3]
# ['b', 'c']
```

Lists XIII

Slices

- If the first index is empty, the slice starts at the beginning

```
my_list = ['a', 'b', 'c', 'd', 'e', 'f']
my_list[:4]
# ['a', 'b', 'c', 'd']
```

- If the second index is empty, the slice will include elements until the end of the list

```
my_list = ['a', 'b', 'c', 'd', 'e', 'f']
my_list[3:]
# ['d', 'e', 'f']
```

Lists XIV

Deleting elements

- The `del()` method deletes items from the list

```
list_a = ['one', 'two', 'three']
del(list_a[1])
# ['one', 'three']
list_b = ['a', 'b', 'c', 'd', 'e', 'f']
del(list_b[1:5])
# ['a', 'f']
```

Tuples I

Tuples is an immutable sequence data type

- It is not possible to assign to the individual items of a tuple, however it is possible to create tuples which contain mutable objects, such as lists.
- Tuples are declared using () instead of []

```
tuple = ('a', 'b', 'c', 'd', 'e')
```

- Tuples containing only one element must have a comma at the end of the definition

```
tuple = ('a', )
```

Strings I

Strings are immutable

- Unlike lists, strings cannot be changed
- Operations on strings always return a modified copy of the string
- The original string remains unchanged

```
greeting = 'Hello, world!'
greeting[0] = 'J'
# TypeError: 'str' object does not support item assignment
```

Iteration

Iterations I

- Iterations are used to repeat statements
- There are two expressions for iterations
  - while
  - for

while

- As long as the condition of the while loop is True, the body of the loop gets executed

Iterations II

Example

```
def countdown(n):
    while n > 0:
        print(n)
        n = n - 1
    print('Lift off!')

countdown(10)
```

Iterations III

while

- If the condition is False at the beginning, the body of the loop is never executed
- If the variable that is used to check the condition of the while loop does not change, the loop will never terminate -> ininite loop
- Whether a while loop terminates can be hard to determine

```
def sequence(n):
    while n != 1:
        print(n)
    if n % 2 == 0:
        n = n / 2
    else:
        n = n * 3 + 1
```

Iterations IV

while

- A while loop can be used to iterate through a list

```
names = ['Tom', 'Anna', 'Christopher']
index = 0
while index < len(names):
    name = names[index]
    print(name)
    index = index + 1
```

Exercise 6

- Write a function `calc_sum(numbers)` which expects a list of numbers as input and returns their sum
- The method should be called as follows `calc_sum([4,6,7])`

Iterations

for

- Since it is often necessary to operate through lists and other data types, there is a special expression for this

```
for element in element_list:
    print(element)
```

Exercise 7

- Write a function `print_reverse(text)` which expects a string as an argument and prints every character of the string in reverse order
- Use a while loop to do this

Exercise 8

- Write a function `count_words(words, min_word_length)` that counts the number of words in a list that are at least as long as the specified word length
- Use a for loop to do this
- Example:

```
words = ['Emanuel', 'John', 'Ale']
count_words(words, 4)
# 2
```

Dictionaries

Dictionaries I

Key-Value pair

- Dictionaries are very similar to lists but have a key and value for each entry
- The entries of a dictionary are not sorted

Dictionaries II

Creating dictionaries

- Dictionaries are created using {}

```
eng2sp = {}
eng2sp['one'] = 'uno'
eng2sp['two'] = 'dos'
```

- Values can be added directly

```
inventory = {
'apples': 430,
'bananas': 312,
}
```

Dictionaries III

Accessing entries

- Values can be accessed directly using dictionary['key']

```
inventory = {
'apples': 430,
'bananas': 312,
}
print(inventory['apples'])
# 430
```

Dictionaries IV

Assigning and modifying values

- The key is assigned a value
- If the key already exists the existing value is overwritten

```
inventory = {
'apples': 430,
'bananas': 312,
}
inventory['oranges'] = 530
inventory['bananas'] = 250
print(inventory['bananas'])
# 250
```

Dictionaries V

Deleting entries

- Key-Value pairs can be delted using the `del()` function

```
inventory = {
'apples': 430,
'bananas': 312,
}
del(inventory['bananas'])
```

Dictionaries VI

Number of entries

- The `len()` function returns the number of entries

```
inventory = {
    'apples': 430,
    'bananas': 312,
}
len(inventory)
# 2
```

Dictionaries VII

Checking if an entry exists

- The in keyword can be used to check if a key exists in a dictionary

```
inventory = {
    'apples': 430,
    'bananas': 312,
}
if 'apples' in inventory:
    inventory['apples'] += 100
else:
    inventory['apples'] = 100
```

Dictionaries VIII

Iterating over entries

- The `items()` function combined with the for statement can be used to iterate through every key-value pair

```
for (my_key, my_value) in my_dict.items():
    print(my_key + ' : ' + my_value)
```

Exercise 9 I

- Write a function `calculate_mark(points, max_points)` which returns a grade in the Swiss grading scale

$$\text{mark} = \frac{\text{points} \cdot 5}{\text{max points}} + 1$$

- The function rounds the grade to the nearest 0.5
  - 5.66666 -> 5.5
  - 5.75 -> 6
- The function should accept strings as arguments
- Arguments should be therefore converted to floats

Exercise 9 II

- Write a function that asks for points and max_points as long as the user does not enter ”exit”
- The grade should be printed after each run

```
while True:
    # input points (use input)
    if points == 'exit':
        break
    # input max_points
    # call calculate_mark function
    # print result
```

Exercise 9 III

- Change your code that it additionally asks for a name
- A dictionary should now store the grade of each name
  - The name is a key, the grade the value
- As soon as the user enters ”exit” the program should print the grades of all names before it exits

Exercise 9 IV

- Change your code in such a way that for each name it additionally outputs if the user has passed or failed
- Mark >= 4 -> passed
- Mark < 5 -> failed

Exercise 9 V

- Change your in such a way that the application outputs the average grade before it exits

Exercise 10

- Write an application that generates a random number between 1 and 100
- import random
- random.randrange(min, max)
- The user makes a guess and enters a number. If the number is incorrect, the program outputs whether the entered number was too small or too large and allows the user to guess again.
- The application quits when the correct number is guessed
- The application should output how many user attempts have been made before it quits

Exercise 11

- Implement the opposite of Task 10 so that the user thinks of a number and makes the computer guess
- The user provides feedback on whether the number is too high, too small, or correct
- $<$ (too low)
- $>$ (too high)
- = (correct)
- How many steps does the computer need?

Persistence

- Introduction to Programming
- Fundamental Concepts
  - Values, Variables, Expressions, Operators, Comments
  - Functions
  - Naming Conventions & Debugging
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- Persistence

Persistence

- So far no data has been saved in any of our examples
- All data was deleted from the memory as soon as our examples quit
- There are several ways to permanently store data on the hard disk
  - Database
  - Simple text files

Files I

Common procedure

- Open file
- Do something with the file
- Close the file

```
file = open('my_file.txt', 'modus')
# do some stuff
file.close()
```

Files II

Different modes

- The mode defines how the content of the file should be treated
- Modes
- 'r': read only
- 'w': write only
- 'r+': read and write
- 'a': append

```
# open a file in read/write mode
file = open('my_file.txt', 'r')
```

Files III

Write

- The write() function is used to write something into a file
- '\n' is used to insert a line break

```
file = open('my_file.txt', 'a')
file.write('Das ist eine Linie\n')
file.write('Das ist eine neue Linie\n')
file.close()
```

Files IV

Read

- A for loop can be used to read a file line by line
- `line.strip()` removes the trailing '\n'

```
file = open('my_file.txt', 'r')
for line in file:
    line = line.strip()
    print line
file.close()
```

Dictionaries/list in JSON

- file.write() only accepts strings as arguments
- If complex structures such as dictionaries or lists should be stored in a file, it's necessary the convert these structures into strings first
- An example of a standard used for this purpose is JSON (Javascript Object Notation)

```
import json
my_dict = {'one': 'uno', 'two': 'dos'}
my_dict_as_string = json.dumps(my_dict)
print(my_dict_as_string)
```

JSON II

Convert JSON to dictionaries/lists

- Example of a string in JSON that is converted into a dictionary

```
import json
my_dict_as_string = '{"two": "dos", "one": "uno"}'
my_dict = json.loads(my_dict_as_string)
print(my_dict)
```

Exercise 12 I

- Write an application which repeatedly asks for a name and phone number until the user enters “exit”
- Each name/telephone number pair should be stored as an entry in a dictionary
  - The names are the keys of the dictionary
  - The telephone numbers are the values of the dictionary
- As soon as the user enters “exit”, create a JSON string of the dictionary using the json.dumps() function and store the string in a file called address_book.txt

Exercise 12 II

- Extend your application so that it reads the address_book.txt file when it starts
- Convert the JSON text into a dictionary again

```
import json
address_book_file = open('address_book.txt', 'r')
address_book_dict = json.load(address_book_file)
```

- Ask the user if he wants to add more names or not
- Let the user search for names in the dictionary and print out the according phone number

Additional Resources

- How to Think Like a Computer Scientist from Allen Downey, Jeffrey Elkner, and Chris Meyers
- Learning with Python: Interactive Edition 2.0
  - http://interactivepython.org/courselib/static/thinkcspy/index.html
- Official Python Documentation
  - http://www.python.org/doc/
- Project Euler: Mathematical problems that can be solved programmatically
  - http://projecteuler.net/
- Platforms to prepare for coding interviews
  - https://leetcode.com/
  - https://www.interviewbit.com/