



**University of  
Zurich** UZH

# Foundations of Programming in Python

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# Table of Contents

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: `def`
  - User Functions with Return Values: `return`
  - Naming Conventions & Debugging
  - Conditionals: `if/else/elif`
  - Lists: `[]`
  - Immutables: Tuples `()` and Strings
  - Iteration: `for/while`
  - Dictionaries: `{}`
- Persistence

# General Introduction

- General Introduction
  - Introduction to Programming
  - Fundamental Concepts
    - Types, Variables, Expressions, Operators, Comments
    - Functions: def
    - User Functions with Return Values: return
    - Naming Conventions & Debugging
    - Conditionals: if/else/elif
    - Lists: []
    - Immutables: Tuples () and Strings
    - Iteration: for/while
    - Dictionaries: {}
  - Persistence

# 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, TypeScript, JavaScript, Python

## Email

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# Round of introduction

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

# Learning targets

After this course...

- ... you will have an idea 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

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: def
  - User Functions with Return Values: return
  - Naming Conventions & Debugging
  - Conditionals: if/else/elif
  - Lists: []
  - Immutables: Tuples () and Strings
  - Iteration: for/while
  - Dictionaries: {}
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# What is a Computer Program

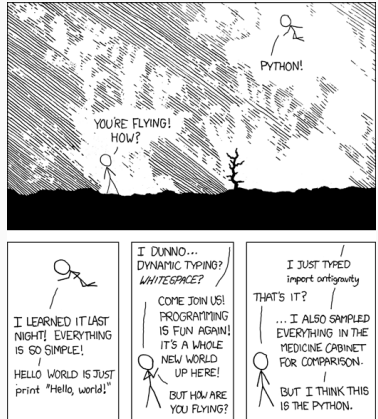
## Modular System

- **Input:** Data input from keyboard, files, internet, etc...
- **Output:** Processed data is displayed or saved to a file
- **Algorithms:**
  - **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 (can do anything of the above)



# Why Python?

- High-level programming language
- "Simple" syntax
- Cross-platform
- Interpreted (no compilation or linking needed)
- Many libraries available



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

# Examples: Hello World i

## Java

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

## C++

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

# Examples: Hello World ii

Or even worse:

## Machine Language

Example of a low level language

```
.LC0:
    .string "Hello world!"
main:
    push rbp
    mov rbp, rsp
    mov edi, OFFSET FLAT:.LC0
    mov eax, 0
    call printf
    mov eax, 0
    pop rbp
    ret
```

# Examples: Hello World iii

## Python

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

# How to Run Python Code

## Options to run Python code:

- Directly in the Python prompt (REPL - Read, Eval, Print, Loop)
- Write the code into a file and run python with the file
- Use IDE to run Python code

# Development Environment

- Integrated Development Environment (IDE)
- Collection of tools that are commonly used for software development (they make our life easier!)
- Popular IDEs
  - Visual Studio Code - <https://code.visualstudio.com>
  - JetBrains PyCharm - Community Edition available for free  
<http://jetbrains.com/pycharm/download>
  - Eclipse with pydev - <http://pydev.org>

# Fundamental Concepts

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: def
  - User Functions with Return Values: return
  - Naming Conventions & Debugging
  - Conditionals: if/else/elif
  - Lists: []
  - Immutables: Tuples () and Strings
  - Iteration: for/while
  - Dictionaries: {}
- Persistence

# Types, Variables, Expressions, Operators, Comments

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: `def`
  - User Functions with Return Values: `return`
  - Naming Conventions & Debugging
  - Conditionals: `if/else/elif`
  - Lists: `[]`
  - Immutables: Tuples `()` and Strings
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# Data Types, Variables, Expressions, Operators, Comments

## Types

- Numbers (Integers, Floats)
  - 2
  - 1000000
  - -2
  - 3.2
  - 1.3333333

# Data Types

## Strings

- Strings (Text)
  - 'Hello World'
  - "Hello World"
- '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

Assignment in R:  $x \leftarrow 3$

# Variables ii

## Examples

Use meaningful names

- Declaration

```
salutation = "Hello"  
name = "Monty Python"  
pi = 3.14159
```

- Usage

```
print(name)
```

## Keywords - reserved words

You cannot name a variable with these names as they are protected by the language.

```
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 and values can be combined

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

salutation = "Hello"
name = "Monty Python"
print(salutation + " " + name)
```

# Operators

## Order of precedence (kind of like PEMDAS)

- `()`
- `**` `x^2 --> x**2,    x^(1/2) --> x**(1/2)`
- unary `+` `-`
- `*` `/` `%` `//` `17 % 5 = 2,    3/2 -> 1.5 --> 3//2 = 1`
- 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
```



# How to Print to Console in Python

Printing is useful to provide feedback to the user or sometimes to debug your program. Printing different data types in the same print statement can be cumbersome.

- `print()` is the function to print something to console in python

```
print('This prints just a string')
print(42) # Just print a number
print('Combining a string and a number: ' + str(42))
print('Much cleaner way to print string and a number: {}'.format(42))
```

# Functions: def

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - **Functions: def**
  - User Functions with Return Values: return
  - Naming Conventions & Debugging
  - Conditionals: if/else/elif
  - Lists: []
  - Immutables: Tuples () and Strings
  - Iteration: for/while
  - Dictionaries: {}
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# 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 (and often do) also return a result
  - `return` statement
  - If a function has no explicit return statement it implicitly returns `None`

## Examples

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

Sometimes it is necessary to convert a variable from one data type to another (if possible). If you read data from a file into python, at first all the data is interpreted as strings even if your file only contains numbers.

In order to do mathematical analysis on these numbers, they need to be converted to the appropriate number type first.

## 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 {} and {} is {}".format(a, b, res))
```

# Functions iv

## Rounding

```
a = 1.888
int(a) # = 1
int(round(a)) # = 2
int(a+5) # = 6
```

## Math functions & First glance at a library

```
import math
log_res = math.log(17.0)
sin_res = math.sin(45) # does this return the correct result?

x = math.cos(math.radians(20)) # cos/sin etc take radians as arguments →
conversion from degree to radians necessary
```

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

## User-defined functions

- A function encapsulates some functionality
- Reduces complexity

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

- Syntax is important
  - Indentation
  - The colon

# Functions vi

## 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 vii

## Examples

- If the line separator 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")
```

## 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 ix

## 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 = param1 + param2  
    print(concat)  
  
concatenation("Hello", "World")  
print(concat) # NameError: name 'concat' is not defined
```

## 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 code
  - Higher factorization
  - Less redundancy
  - Better maintenance
- Functions can also call other functions

# User Functions with Return Values: return

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: def
  - User Functions with Return Values: return
  - Naming Conventions & Debugging
  - Conditionals: if/else/elif
  - Lists: []
  - Immutables: Tuples () and Strings
  - Iteration: for/while
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# 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 value (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('{} is divisible by {}'.format(x, y))  
else:  
    print('{} is not divisible by {}'.format(x, y))
```

# Naming Conventions & Debugging

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: `def`
  - User Functions with Return Values: `return`
  - Naming Conventions & Debugging
  - Conditionals: `if/else/elif`
  - Lists: `[]`
  - Immutables: Tuples `()` and Strings
  - Iteration: `for/while`
  - Dictionaries: `{}`
- Persistence

# Naming Conventions i

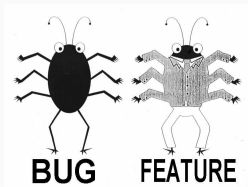
## How to name your functions and variables (PEP8)

- 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")
```

## 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

## 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)

## Techniques

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

# Conditionals: if/else/elif

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: def
  - User Functions with Return Values: return
  - Naming Conventions & Debugging
  - Conditionals: if/else/elif
  - Lists: []
  - Immutables: Tuples () and Strings
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# 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('{} is positive'.format(x))
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('x is zero')  
else:  
    print('x is not zero')
```

# Conditionals iv

## Examples

### %-operator (remainder after division)

```
def print_parity(x):  
    if x % 2 == 0:  
        print('The number is even')  
    else:  
        print('The number is odd')  
  
print_parity(2)  
print_parity(3)
```

## Chained conditionals

- `elif` is used to combine multiple conditions
- The `else` expression is executed when neither `if` nor any of the `elif`s is true.
- Any number of `elif` expressions can be used but only one `if` and one `else`

# Conditionals vi

## Examples

```
if x < y:
    print('{} is less than {}'.format(x, y))
elif x > y:
    print('{} is greater than {}'.format(x, y))
else:
    print('{} and {} are equal'.format(x, y))
```

```
# 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

Solve exercise 1

# 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

# Exercise 2

Solve exercise 2

# Exercise 3

Solve exercise 3

# Exercise 4

Solve exercise 4

# Exercise 5

Solve exercise 5

# Lists: []

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: def
  - User Functions with Return Values: return
  - Naming Conventions & Debugging
  - Conditionals: if/else/elif
  - Lists: []
  - Immutables: Tuples () and Strings
  - Iteration: for/while
  - Dictionaries: {}
- Persistence

# 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']
```

## 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]
```



## 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]
```

## 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.

## 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
<hr/>						
Anna		Tom		Ralph		Peter

## 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 elements in 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

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

## Changing elements in a list

- An element can be changed using [INDEX]

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

## Adding elements

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

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

## 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]
```



## 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']
```

## 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']
```

## 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']
```

# Immutable: Tuples () and Strings

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: def
  - User Functions with Return Values: return
  - Naming Conventions & Debugging
  - Conditionals: if/else/elif
  - Lists: []
  - Immutable: Tuples () and Strings
  - Iteration: for/while
  - Dictionaries: {}
- Persistence

# 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 (singleton) 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: for/while

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: def
  - User Functions with Return Values: return
  - Naming Conventions & Debugging
  - Conditionals: if/else/elif
  - Lists: []
  - Immutables: Tuples () and Strings
  - Iteration: for/while
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# 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 -> infinite 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
```

collatz conjecture

## 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

Solve exercise 6

# Exercise 7

Solve exercise 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 8

Solve exercise 8

# Dictionaries: {}

- General Introduction
- Introduction to Programming
- Fundamental Concepts
  - Types, Variables, Expressions, Operators, Comments
  - Functions: def
  - User Functions with Return Values: return
  - Naming Conventions & Debugging
  - Conditionals: if/else/elif
  - Lists: []
  - Immutables: Tuples () and Strings
  - Iteration: for/while
  - Dictionaries: {}
- Persistence



## 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 {}

```
eng2de = {}  
eng2de['one'] = 'eins'  
eng2de['two'] = 'zwei'
```

- 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
```

## Deleting entries

- Key-Value pairs can be deleted 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
```

## 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
```

## 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

Solve exercise 9

# Exercise 10

Solve exercise 10

# Exercise 11

Solve exercise 11

# Persistence

- General Introduction
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  - Dictionaries: `{}`
- 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

## Common procedure

- Open file
- Do something with the file
- Close the file - depending on syntax done automatically.

```
with open('my_file.txt', 'mode') as file:  
    # do some stuff
```

## 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  
with open('my_file.txt', 'r') as file:  
    # do some stuff
```

## Write

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

```
with open('my_file.txt', 'a') as file:  
    file.write('First line of the write operation')  
    file.write('This is a line with a new—line character at the end\n')  
    file.write('This is another line, on a new—line below the previous one  
        .\n')
```



## Read

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

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

## 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 to 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': 'eins', 'two': 'zwei'}
my_dict_as_string = json.dumps(my_dict)
print(my_dict_as_string)
```

## Convert JSON to dictionaries/lists

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

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

# Exercise 12

Solve exercise 12

# 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/>