

# Lecture I - Introduction

Programming with Python

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# About this Course

## About me

- Post-doctoral researcher from the University of Hamburg
- **Field:** Optimizing and simulating complex systems
- **Languages:** of choice: Julia, Python and Rust
- **Interest:** Modelling, Simulations, Machine Learning
- **Teaching:** OR, Algorithms, and Programming
- **Contact:** [vlcek@beyondsimulations.com](mailto:vlcek@beyondsimulations.com)

...

### Tip

I really appreciate active participation and interaction!

## Course Outline

- **Part I:** Introduction to Programming with Python
- **Part II:** Data Science Tools with Python
- **Part III:** Programming Projects

## Participation

- Prerequisite for course *Management Science* (Prof. Goel)
- Try actively participating in this course
- You will find it much (!) easier to follow Prof. Goel's course
- Materials will be provided in the KLU portal
- Slides are hosted at [beyondsimulations.github.io/Introduction-to-Python](https://beyondsimulations.github.io/Introduction-to-Python)

## Teaching

- **Lecture:** Presentation of tools and concepts, based on small examples and code snippets
- **Tutorial:** Hands-on examples to be solved in groups
- **Difficulty:** Difficult at first, but gradually easier

## Passing the Course

- Pass/fail course
- 75% attendance required for passing the course
- 2 assignments and 1 little project
- You will be given programming exercises to solve with Python
- You can group up (3 students) and work together
- Each student group submits one solution together

## Solution

- Provide a code solution to the problem (.py files)
- Code files need to be executable
- Detailed explanations of your code should be provided
- Use comments or docstrings in your code
- Provide a general (verbal) introduction to each problem

...

### Tip

I'd encourage you to start and submit your solution early

## Difficulty of the Course

- We'll cover the basics of programming (in Python) at first
- This is similar to learning a **new foreign language**
- First, you have to get used to the language and learn first words
- **Later**, you'll be able to apply the language and see results
- Similar to learning a language: *Practice, practice, practice!*

## What to expect

- Some **investment** in the beginning to see the **return** later
- You can ask questions and get support anytime
- After completing the course, you will be able to read code
- **and** write your own program using Python
- **That's quite something!**

## Goals of the Course

- Essential concepts and tools of modern programming
- Automated solutions for recurrent tasks
- Algorithm-based solutions of complex problems
- **Usage of AI** in a specific context

## Python as Language

- **Origins:** Conceived in late 1980s as a teaching and scripting language

- **Simple Syntax:** Python's syntax is straightforward and easy to learn
- **Versatility:** Used in web development, data analysis, artificial intelligence, and more
- **Community Support:** A large community of users and extensive documentation

## Help from AI

- You are allowed to use AI (GitHub Copilot, ChatGPT, LLama3 ...)
- These new tools are really powerful for learning Python!
- They can help you a lot to get started with programming

...

### Warning

But you should *not* simply use them to *replace* your learning.

# Why learn programming?

## **Analytics**

Photo by Choong Deng Xiang on Unsplash

## **Research**

Photo by National Cancer Institute on Unsplash

## **Visualization**

Photo by Clay Banks on Unsplash

## **Finance**

Photo by Ishant Mishra on Unsplash

## **Logistics**

Photo by Denys Nevozhai on Unsplash

# How to learn programming

## My Recommendation

1. Be present: Attend the lecture and participate
2. Put in some work: Repeat lecture notes and try to understand the examples yourself
3. Do coding: Run code examples on your own, play around, *google/find help*, modify, and solve problems on your own

...

### Tip

Great resources to start are books and small challenges. In my opinion both are much more helpful than watching videos! You can find a list of book recommendations at the end of the lecture. Small challenges to solve can for example be found on [Codewars](#).

## Don't give up!

- Programming is **problem solving**, don't get **frustrated** too easily at the start!
- Learn something new: Expect to **stretch** your comfort zone

## Learning Path

- The learning path can be quite steep!
- First of all help each other!
- Try to find help in lecture materials and books, the Python documentation, and online (e.g. Google, ChatGPT, StackOverflow, ...)
- In case you get frustrated with programming, read the following [helpful blog post about the challenges on medium.com](#)

## Errors

In case you find errors and typos in the lecture notes, please report them in the following form:  
<https://tally.so/r/w7oapa>

# Setting up Python

## Install Python

- You could download it from the [Python website](#) or with [Anaconda](#)
- **But I would recommend we start by installing Thonny**
- It is an open source IDE that runs on Windows, Linux and Mac
- It comes with a built-in Python interpreter and package management!

## What is an IDE?

- An **IDE** (Integrated Development Environment) is an application
- It allows you to write, run and debug code scripts
- Thonny is an IDE specifically for Python and aimed at beginners
- It does not use the latest Python and has the most features
- **But it is easy to use as beginner!**
- Other IDEs include for example [PyCharm](#) from JetBrains or [Visual Studio Code](#) from Microsoft

# Thonny

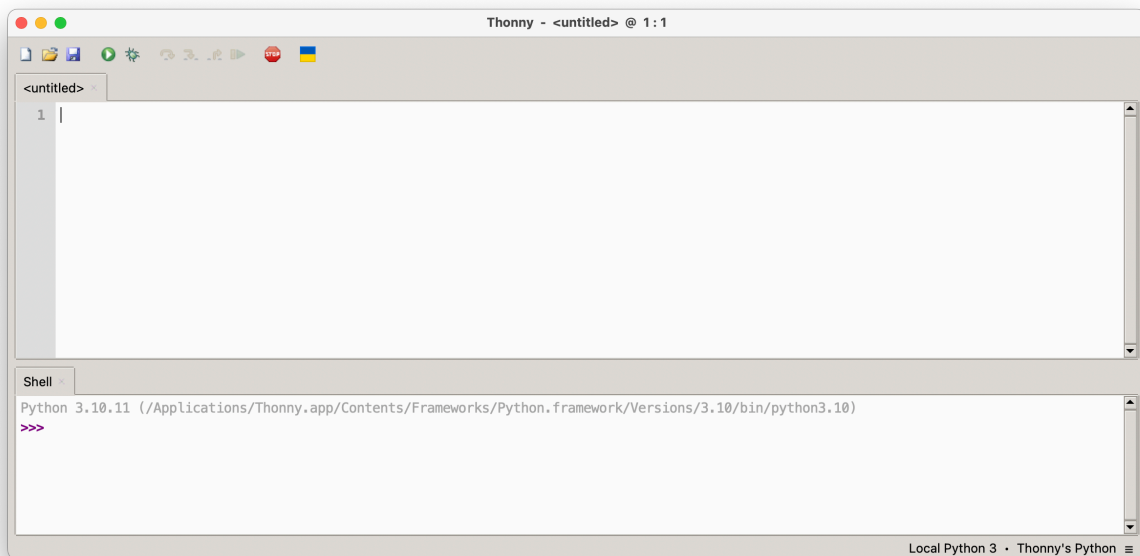


Figure 1: First start of Thonny

## Python on iPads

- Although you can run Python scripts from on your iPad, it is not recommended for the course
- Nonetheless, if you have no other option, you could use [Pythonista](#)
- It works locally on your iPad and can run most Python scripts

...

### Caution

Not all packages available in Python are available in Pythonista, thus you might need a computer to solve certain problems.



# First start of Pythonista

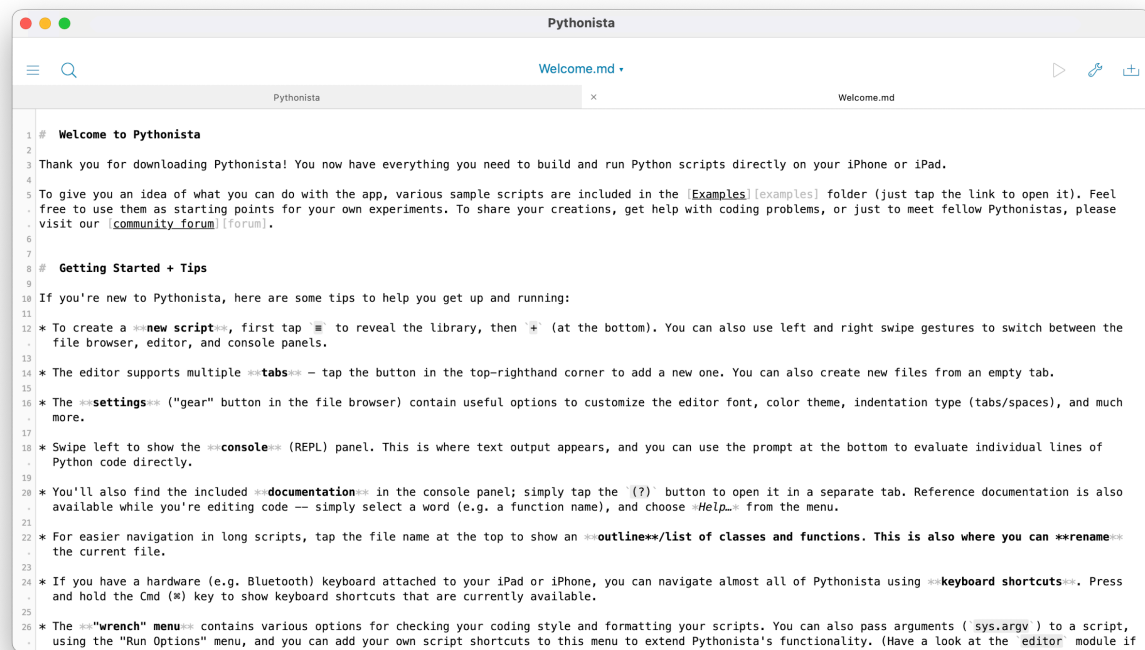


Figure 2: First start of Pythonista

# Your first code

## Hello, World!

Your Task: Create a directory for the course and create a new file called `hello_world.py` with the following code and save it:

```
# This is a comment in Python
print("Hello, World!")
```

...

Run the code with the green 'run' button at the top or by going to the line and pressing Shift+Enter:

...

```
# This is a comment in Python
print("Hello, World!")
```

Hello, World!

...

### Note

"Hello world" is a classic example to start with. It is often used as a test to check if your computer is working properly and that you have installed the necessary software.

## Hello, World in a Message

Your Task: Change the code in your `hello_world.py` file. Assign the string "Hello, World!" to a variable called `message` and print the variable.

...

- Use the equals sign (=)
- Variable name goes on the left
- Value to be assigned goes on the right

...

```
# Here we assign the string "Hello, World!" to variable message and print it
message = "Hello, World!"
print(message)
```

Hello, World!

## Hello, World in Parentheses

We can also mix " and ' in a string. We just have to be consistent:

```
# This code works
message = 'I shout "Hello, World!'"
print(message)
```

I shout "Hello, World!"

...

```
# This code does not!
message = 'I shout 'Hello, World!'"
print(message)
```

...

Try it yourself! What does happen, if you try to run this code?

## First Errors

SyntaxError: invalid syntax

- The code is not valid Python syntax
- This is likely the most common error that you will encounter!
- It happens when you make a mistake in your code, e.g., using an illegal character, missing a colon, parentheses or wrong quotations
- You can fix this by correcting the code and re-running
- **In the course of the lecture you will encounter many more errors!**

# Program

## What is a Program?

- A sequence of instructions telling a computer what to do
- Written in a programming language the computer can understand
- Basic operations in most languages:
  - **Input:** Get data from keyboard, file, network, sensors, etc.
  - **Output:** Display data on screen, save to file, send over network, etc.
  - **Processing:** Perform calculations, analyze data, make decisions, find patterns, etc.

## Key concepts

- Key concepts in most languages:
  - **Variables:** Store and manipulate data
  - **Conditional execution:** Check conditions and execute accordingly
  - **Loops:** Perform actions repeatedly, often with variations
  - **Functions:** Group instructions for reusability

## How Python executes code

- Python is an **interpreted language**
- The source code is executed line by line
- The interpreter checks the syntax and executes the code
- This is in contrast to compiled languages, where the code is compiled into machine code before execution

## Hello again, World!

Let's go back to our first program:

```
# Our first program
message = "Hello, World!"
print(message)
```

...

- **Comment:** In the first line we define a comment with #
  - It is not executed but used to explain what code does
- **Variable:** In the second line we define a variable `message`
  - It points to a string that contains the text "Hello, World!"
- **Function:** In the third line we call a function `print`

- It prints out whatever is stored in `message`

## **Don't worry!**

- Already confused?
- Don't worry about it for now!
- We'll learn more about variables and functions later

# Python's Syntax

## The Zen of Python

- Python's name originally comes from Monty Python
- Style is based on a philosophy called Zen of Python: A collection of 19 statements intended to communicate general principles

```
# Try this code in Python to see the Zen of Python
import this
```

## Variables

- A variable in Python is a name that points to a value
- Created by using the assignment operator =
- Python does not require a declaration of variable types before

```
a = 2 # Variable a assigned the value 2
b = "Time" # Variable b assigned the value "Time"
c = print # Variable c assigned the print function
c(b) # Now we can call the print function with c
```

Time

...

**But there are certain rules to variable names!**

## Variable Naming Conventions

- Must start with a letter or underscore \_
- Can contain letters, numbers and underscores
- Names are case sensitive, e.g., a and A are different!
- Cannot be a reserved word, e.g., for, if, def, etc
- Good names are short and meaningful for humans!

...

Question: Which of the following fulfill these conditions?  
a, \_duration, 1x, time\_left, 1\_minute, oneWorld, xy4792

# Functions

- Functions are named blocks of code
- Can take arguments `function([arguments])`
- Can return results or `None`

...

```
1 # Print is such a function
2 print("Hello, World!") # It takes an argument and prints it to the console
3 print("Hello", "World!", sep=", ") # It can also take multiple arguments
```

Hello, World!

Hello, World!

## Note

We will cover functions in more detail **later** in the course.

# Values and Types

## What are Values and Types?

- **Value:** Fundamental thing that a program manipulates
  - In Python, values are either numbers or strings
- **Type:** Type of a value
  - Determines what operations can be performed on it
  - `type()` is a function that returns the type of a value
  - It takes one argument (a value) and returns its type as string

## Strings

Back to our example of “Hello, World!”

```
1 # We define the variable message and assign it the value "Hello, World!"
2 message = "Hello, World!"
3
4 # We save its type in another variable called message_type
5 message_type = type(message)
6
7 # We print the value of our new variable
8 print(f"{message} is a {message_type}")
```

Hello, World! is a <class 'str'>

...

**Result:** “Hello, World” is a string - in short ‘str’.

...

But what about the f”?

## Formatted Strings

- **f-strings** are strings that start with `f`
- They contain **expressions** (here variables) in braces
- They are evaluated at run time and inserted into the string
- This is called **interpolation**

...



### Note

In older code bases, f strings were not available. Here, interpolation could be done as shown below with `print()` and `.format()`. But this method is less concise and arguably less readable.

```
print("{} is a {}".format(message, message_type))
```

Hello, World! is a <class 'str'>

## Specifying Formatted Strings

- We can further specify their format with `{<to_print>:<width>.<precision>f}`
- width can be a number specifying the width of the output
- `<`, `^`, `>` can be used before the width to align the text
- precision can be used to specify the number of decimals
- `.f` can be used to format floats

```
x = "hello"
print(f"{x:<10} has {len(x):>10.2f} characters.")
```

hello            has            5.00 characters.

## Expressions

- Produce a value when evaluated
- Can be used as part of larger expressions or statements
- Statements are expressions that don't produce a value
- Examples: arithmetic operations, function calls, variables

```
print(1 + 2) # Expression 1 + 2 produces the value 3
```

3

```
print("The result is", 1 + 2) # Expression embedded in a string
```

The result is 3

```
x = 1 # Statement that assigns the value 3 to x
y = x + 2 # Expression on the right side assigned to a variable y
print(f"Again, the result is {y}")
```

Again, the result is 3

## A step back: What is a String?

- Remember: "Hello, World" is a string - in short 'str'
- A string is a sequence of characters enclosed in quotes
- Examples: "Hello", 'World', "123", '1World23'

```
hello = "Hello"
world = 'World!'
print(hello, world, sep=", ") # We can specify the separator with the argument sep
```

Hello, World!

...

### Note

Strings are immutable, we can't change single characters in them once they are created.

## String Operations

But we can also do much more with strings!

E.g. string concatenation, indexing, slicing, length, repeat, etc.

```
two_strings = "Hello" + ", " + "World!" # String concatenation
print(two_strings)
```

Hello, World!

...

```
print(two_strings[0]) # Indexing starts at zero!
```

H

...

```
print(two_strings[0:4]) # To slice we need to specify the start and end index (excluded)
```

Hell

...

```
print(len(two_strings)) # With len we can find the length of our string
```

13

...

```
print("--x--"*3) # We can also repeat strings
```

--x----x----x--

## Booleans

- Booleans represent two values: True and False
- Internally they are represented as 1 and 0, respectively
- They are used for logical operations and control flow
- E.g.: if, while, for, elif, 'else'

...

```
x = True
y = False
print(x)
print(type(y))
```

True

<class 'bool'>

...

> More on them in our next lecture!

## Integers and Floats

- Integers are whole numbers, e.g.: 1, -3, 0 or 100
- Floats are decimal numbers, e.g.: 2.5, -4.789123, 0.0 or 1.234e2
- Bit size does not have to be specified (e.g.: 64 bits) in Python

...

```
x = 1
y = 1.2864e2
print(f"{x} is of type {type(x)}")
print(f"{y} is of type {type(y).__name__}")
```

```
1 is of type <class 'int'>
128.64 is of type float
```

...

### Warning

The interpreter will automatically convert booleans to integers to floats when necessary, **but not the other way around!**

# First Functions and Operators

## Arithmetic operators

```
...  
1 # We can separate multiple operations in one line with semicolons  
2 addition = 1 + 2; print(f"Result: addition is {addition}")  
3 subtraction = 1 - 2; print(f"Result: subtraction is {subtraction}")  
4 multiplication = 3 * 4; print(f"Result: multiplication is {multiplication}")  
5 division = 7 / 4; print(f"Result: division is {division}")  
6 floor_division = 7 // 4; print(f"Result: floor_division is {floor_division}")  
7 exponentiation = 9 ** 0.5; print(f"Result: exponentiation is {exponentiation}")  
8 modulo = 10 % 3; print(f"Result: modulo is {modulo}")
```

```
Result: addition is 3  
Result: subtraction is -1  
Result: multiplication is 12  
Result: division is 1.75  
Result: floor_division is 1  
Result: exponentiation is 3.0  
Result: modulo is 1  
...
```

### Note

Note, how the integers in the division are converted to floats before the division is performed.

## Precedence

- The operators are the same as in most other languages
- They can be combined with each other, and with variables
- Normal rules of precedence apply

```
...  
# Operator precedence works as on paper  
combined_operation = 2 + 3 * 4  
print(f"2 + 3 * 4 = {combined_operation}")
```

```
2 + 3 * 4 = 14  
...
```

```
# Parentheses change precedence as expected
parentheses_operation = (2 + 3) * 4
print(f"(2 + 3) * 4 = {parentheses_operation}")
```

(2 + 3) \* 4 = 20

## The input() Function

- Used to get user input as string from the console
- Syntax: `input([userprompt])`
- Displays optional prompt and waits for user input

```
...
name = input("What's your name? ")
print(f"Hello, {name}!")
```

...

### ! Important

The function always returns the input as **string**!

...

> Try it yourself!

## Type Conversion

Use type conversion for other data types

1. Integer: `int(input())`
2. Float: `float(input())`
3. Boolean: `bool(input())`
4. String: `str(input())`

```
...
# Converting to Integer
age = int(input("Enter your age: "))
next_year = age + 1
print(f"Next year, you'll be {next_year}")
```

```
...
# Converting to Float
height = float(input("Enter your height in meters: "))
height_in_cm = height * 100
print(f"Your height in centimeters: {height_in_cm}")
```

## The round() Function

```
# Hence, we can use the int() function to convert a float into an int
soon_int = 1.789
print(f"{soon_int} converted to {int(soon_int)} of type {type(int(soon_int))}")
```

```
1.789 converted to 1 of type <class 'int'>
```

```
...
```

```
# We can also use `round()` to round a float to an int
soon_int = 1.789
print(f"{soon_int} converted to {round(soon_int)} of type {type(round(soon_int))}")
```

```
1.789 converted to 2 of type <class 'int'>
```

```
...
```

```
# Or to a float with a certain number of decimals
no_int = 1.789
print(f"{no_int} converted to {round(no_int,1)} of type {type(round(no_int,1))}")
```

```
1.789 converted to 1.8 of type <class 'float'>
```

```
...
```

### Note

#### **And that's it for today's lecture!**

We now have covered the basics on the Python syntax, variables, and data types.

# Literature

## Interesting Books to start

- Downey, A. B. (2024). Think Python: How to think like a computer scientist (Third edition). O'Reilly. [Link to free online version](#)
- Elter, S. (2021). Schrödinger programmiert Python: Das etwas andere Fachbuch (1. Auflage). Rheinwerk Verlag.

...

### Note

Think Python is a great book to start with. It's available online for free [here](#). Schrödinger Programmiert Python is a great alternative for German students, as it is a very playful introduction to programming with lots of examples.

...

For more interesting literature to learn more about Python, take a look at the [literature list](#) of this course.