PYTHON BASICS

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Training Syllabus

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11. Domain Specific
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    b. Django Web Framework, or
    c. Numerical Data Analytics
        i. Numpy
        ii. Pandas, or
    d. Data Science Analytics
        i. Web Scrapping & Crawling
        ii. Machine Learning, or
    e. Automation Tooling

Topic 1a: History of Python

Easy as ABC

- What do the alphabet and the programming language Python have in common? Right, both start with ABC.
- ABC is a general-purpose programming language and programming environment, which had been developed in the Netherlands, Amsterdam, at the CWI (Centrum Wiskunde & Informatica). The greatest achievement of ABC was to influence the design of Python.
- Python was conceptualized in the late 1980s.
- Guido van Rossum worked that time in a project at the CWI, called Amoeba, a distributed operating system.
- He experienced many frustrations with ABC and decided to try to design a simple scripting language that possessed some of ABC's better properties, but without its problems.
- He created a simple virtual machine, a simple parser, and a simple runtime. He made his own version of the various ABC parts that he liked.
- He created a basic syntax, used indentation for statement grouping instead of curly braces or begin-end blocks, and developed a small number of

powerful data types: a hash table (or dictionary), a list, strings, and numbers.

What about the name “Python”?

- Most people think about snakes, and even the logo depicts two snakes, but the origin of the name has its root in British humour.
- During Christmas vacation in 1989, he decided to write an interpreter for the new scripting language: a descendant of ABC.
- He chose Python as a working title for a “hobby” project, being in a slightly irreverent mood during Christmas’1989 (and a big fan of Monty Python's Flying Circus).

Development Steps of Python?

- Rossum published the first version of Python code in February 1991.
- Python version 1.0 was released in January 1994.
- In October 2000, Python 2.0 was introduced.
- Python flourished for another 8 years in the versions 2.x before the next major release as Python 3.0 was released in 2008.

- Python 3 is not backwards compatible with Python 2.x
- Some changes in Python 3.0:
  - Print is now a function
  - Views and iterators instead of lists
  - The division of two integers returns a float instead of an integer. "//" can be used to have the "old" behavior.
  - raw_input() in Python 2.x is changed to input() & the former is discontinued.
  - input() in Python 2.x is changed to eval(input)

Topic 1b: Introduction

Features

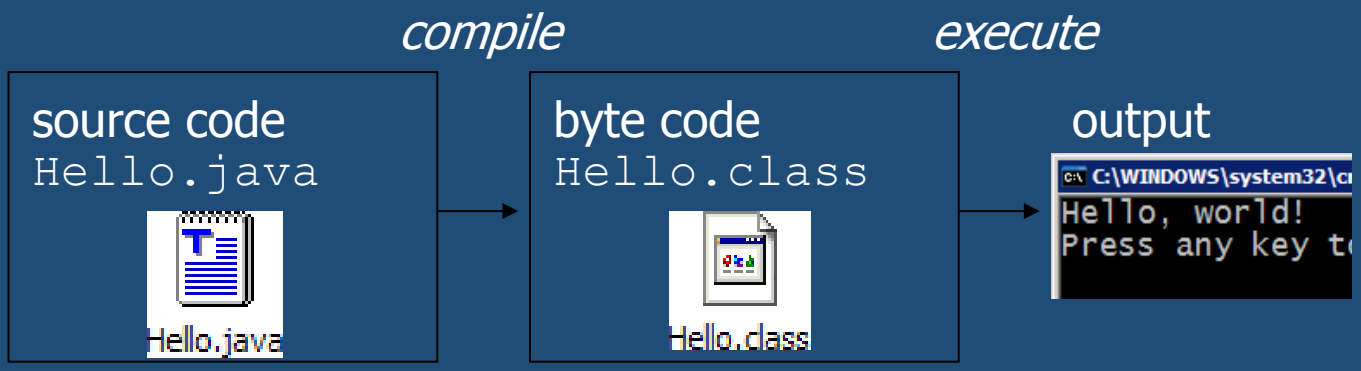
- Multi-purpose (Web, Data Science, Automation, etc.)
- Procedural and Object-Oriented
- Interpreted
- Interactive Shell
- Strongly typed and Dynamically typed
- Focus on readability and productivity
- Cross Platform (CPython, Jython, IronPython, PyPy)

Few Big Organizations using Python

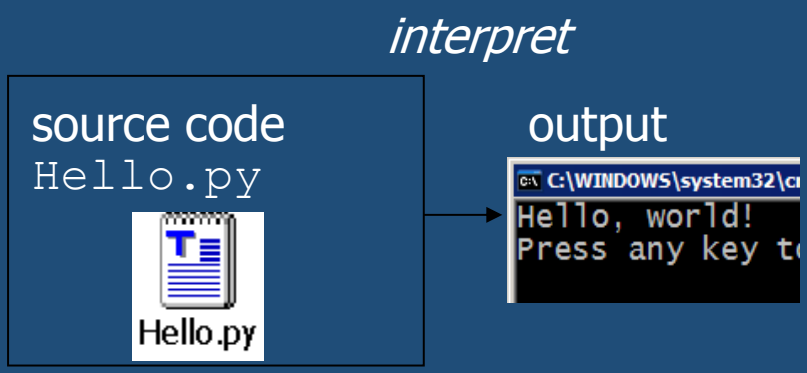
- Google
- NASA
- Netflix
- Dropbox
- YouTube
- New York University
- General Electric
- Juniper Networks
- Lego
- Nasdaq
- And the list goes on…

Compiled v/s Interpreted Language

- **Many languages require you to *compile* (translate) your program into a form that the machine understands.**



- **Python is instead directly *interpreted* into machine instructions.**



That's why Python is an interpreted language and not a compiled one. But, more insights on this topic will come in Topic 1d.

Topic 1c: Starting with Python

The Interpreter, an Interactive Shell

- The interactive shell is between the user and the operating system (e.g. Linux, Unix, Windows or others)
- The Python interpreter can be used from an interactive shell.
- The interactive shell is also interactive in the way that it stands between the commands or actions and their execution
- Python offers a comfortable command line interface with the Python shell, which is also known as the "Python interactive shell".

Setup

- We can access Python in four ways:
  - Download & install Python latest version from https://www.python.org/downloads/, and then launch IDLE. It is the interactive development environment for Python. We can access it from Windows Search Menu.
  - We can also launch Python – Command line directly after installation, instead of IDLE

- The Python interpreter can also be invoked by launching windows command prompt & typing the command "python" without any parameter followed by the "return" key at the shell prompt:

```
python
```

Python comes back with the following information

```
$ python
Python 2.7.11+ (default, Apr 17
2016, 14:00:29)
[GCC 5.3.1 20160413] on linux2
Type "help", "copyright",
"credits" or "license" for more
information.
>>>
```

This will need to set the environment variable in Advanced System Settings.

- Finally, other way is to download a Python IDE (Interactive Development Environment) such as PyCharm, Jupiter etc. These also have facilities for debugging a program using breakpoints.

- Recommended:
  - We will use IDLE for initial classes and then move to PyCharm IDE.

Let's try some simple commands

```
>>> hello
Traceback (most recent call
last):
  File "<stdin>", line 1, in
<module>
NameError: name 'hello' is not
defined
>>>
```

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

```
>>> "Hello World"
'Hello World'
>>> 3
3
>>>
```

- **How to quit the Python Shell?**
  - **Exit(), or**
  - **Quit()**

Let's try a simple calculator

```
>>> 4.567 * 8.323 * 17
646.1893969999999
>>>
```

- Python follows the usual order of operations in mathematical expressions.
- The standard order of operations is expressed in the following enumeration:
  - exponents and roots
  - multiplication and division
  - addition and subtraction
- This means that we don't need parenthesis in the expression "3 + (2 * 4)"

```
>>> 3 + 2 * 4
11
>>>
```

- The most recent output value is automatically stored by the interpreter in a special variable with the name "_" and can be used in other expressions like any other variable

```
>>> _ * 3
33
>>>
```

- **The underscore variable is only available in the Python shell. It's NOT available in Python scripts or programs.**

Let's try Basic Variables & Strings

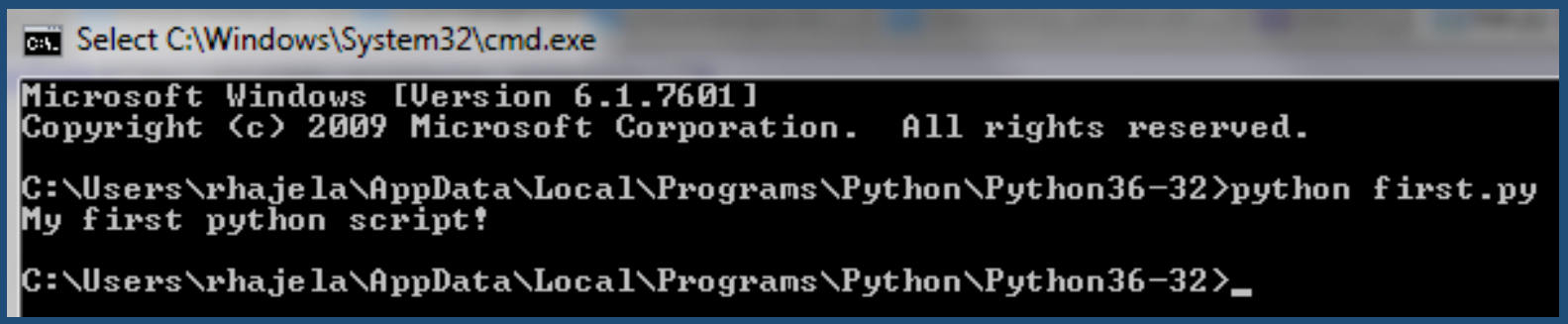
```
>>> maximal = 124
>>> width = 94
>>> print(maximal - width)
30
>>>
```

```
>>> "Hello" + " " + "World"
'Hello World'
```

```
>>> ".-." * 4
'.-..-..-..-.'
>>>
```

Topic 1d: Execute python script

First Python Script




```
print("My first python script!")
```

Python Internals

- As we have studied earlier that Python language is an interpreted programming or a script language.
- The truth is: Python is both an interpreted and a compiled language. But calling Python a compiled language would be misleading.
- What is a compiler?
  - A compiler is a computer program that transforms (translates) source code of a programming language (the source language) into another computer language (the target language), mostly assembly or machine code.
  - An interpreter is a computer program that executes instructions written in a programming language. It can either

  - execute the source code directly or
  - translates the source code in a first step into a more efficient representation and executes this code.
- People would assume that the compiler translates the Python code into machine language. Python code is translated into intermediate code, which has to be executed by a virtual machine, known as the PVM, the Python virtual machine.
- There is even a way of translating Python programs into Java byte code for the Java Virtual Machine (JVM). This can be achieved with Jython.
- Question: Do we have to compile our Python scripts to make them faster or how can we compile them? The answer is easy: No, you don't need to do anything because "Python" is doing the thinking for you automatically.
- But, if still we want to compile, can be achieved.

```
>>> import py_compile
>>>
py_compile.compile('my_first_si
mple_script.py')
>>>
```

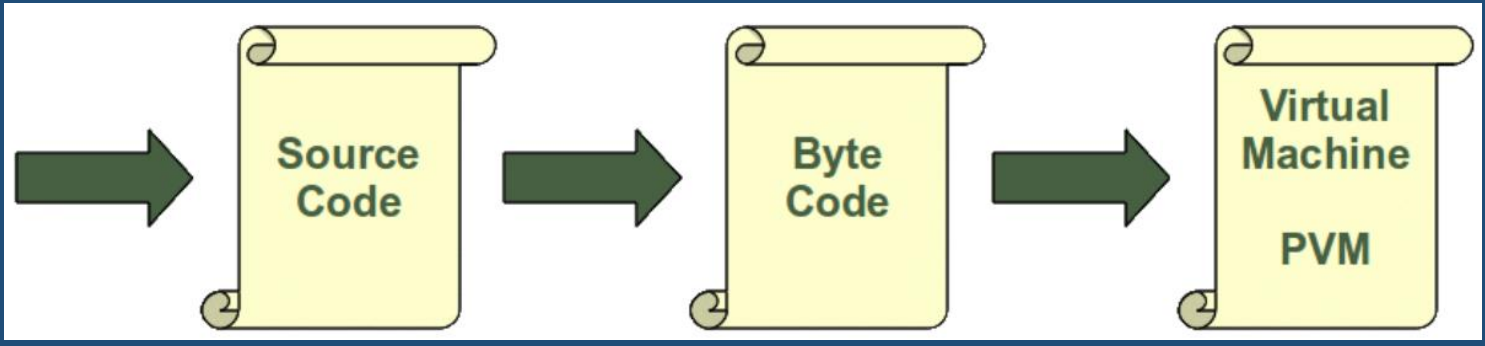
Or

```
python -m py_compile
my_first_simple_script.py
```

- As a result, there will be a new subdirectory "__pycache__" created, if it hasn't already existed. And also find a file "my_first_simple_script.cpython-34.pyc" in this subdirectory. This is the compiled version of our file in byte code.
- We can also compile all scripts as this:

```
monty@python:~/python$ python -
m compileall .
Listing . ...
```

- How does .pyc file generate? - If Python has write-access for the directory where the Python program resides, it will store the compiled byte code in a file that ends with a .pyc suffix. If Python has no write access, the program will work anyway. The byte code will be produced but discarded when the program exits.



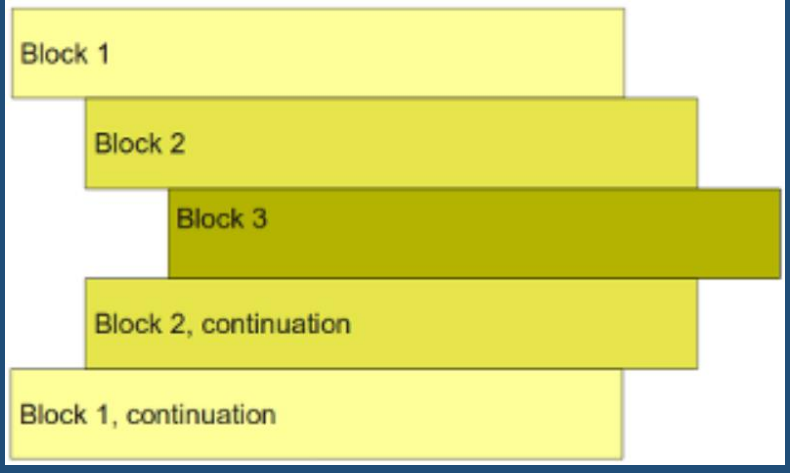
Topic 2a: Indentation

Blocks

- A block is a group of statements in a program or script. Usually it consists of at least one statement.
- A language, which allows grouping with blocks, is called a block structured language.
- Generally, blocks can contain blocks as well, so we get a nested block structure.
- A block in a script or program functions as a mean to group statements to be treated as if they were one statement.
- The first time, block structures had been formalized was in ALGOL, called a compound statement.
- Programming languages usually use certain methods to group statements into blocks:
  - Begin … end : ALGOL, Pascal etc.
  - do … done : Bourne and Bash Shell etc
  - Braces { … } : C, C++, Java, Perl

Indenting Code

- Python uses a different principle. Python programs get structured through indentation, i.e. code blocks are defined by their indentation.



- In Python, it’s a mandatory language requirement, not a matter of style.
- This principle makes it easier to read and understand other people's Python code.
- So, how does it work? All statements with the same distance to the right belong to the same block of code.
- If a block has to be more deeply nested, it is simply indented further to the right.
- Example:

```
print("Start")
a = 1
if a == 1:
    print("Step1")
    b = 3
    if b == 2:
        print("step2")
    else:
        print("step3")
    print("step4")
print("end")
```

Topic 2b: Data Types & Variables

Basic Difference from other languages

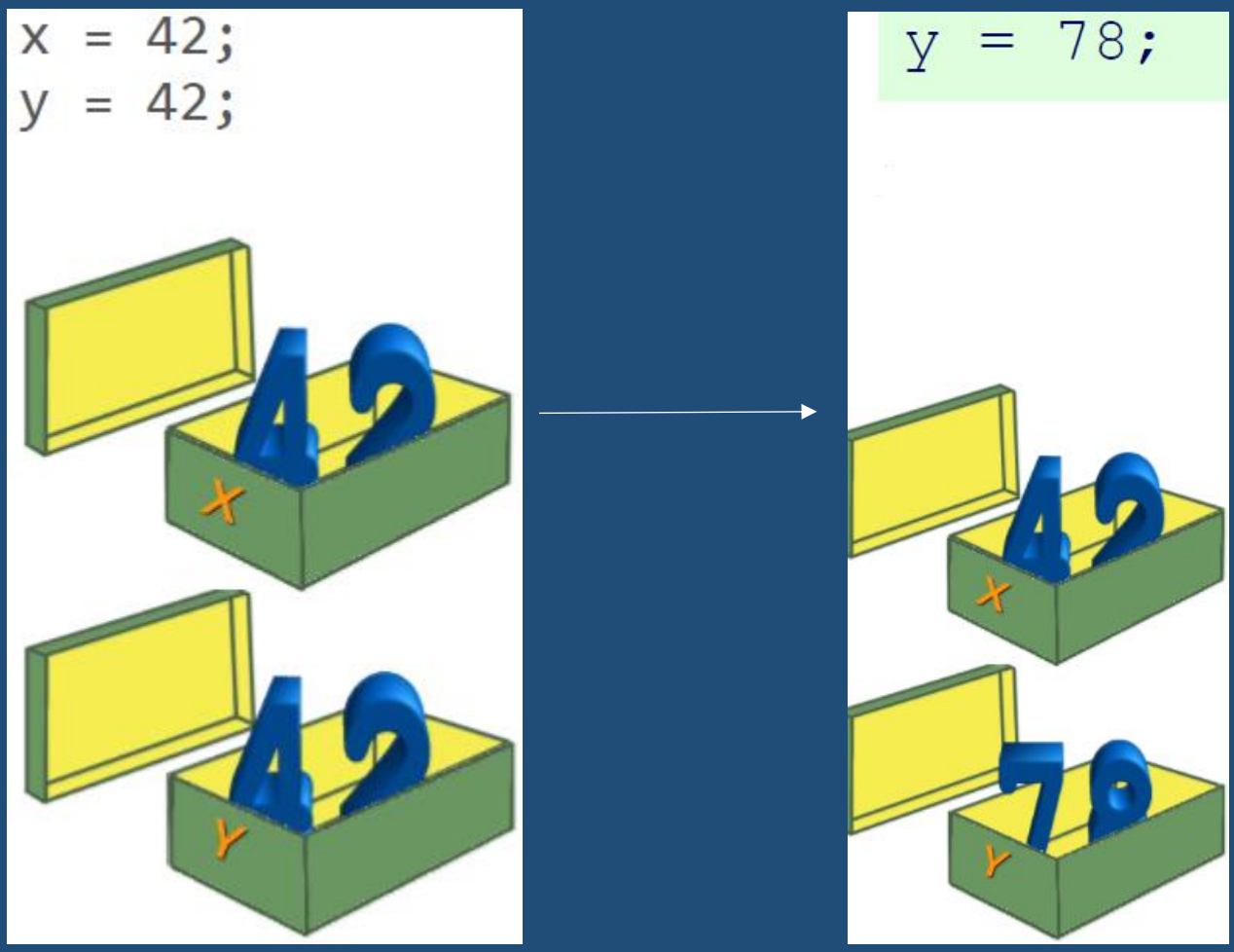
If you want to use lists or an arrays in C or C++, you will have to construe the data type list or associative arrays from scratch, i.e. design memory structure and the allocation management. You will have to implement the necessary search and access methods as well.

But, Python provides power data types like lists and associative arrays, called dict in Python, as a genuine part of the language.

General Concept of Variables in other languages

- What is a variable? As the name implies, a variable is something, which can change.
- A variable is a way of referring to a memory location used by a computer program.
- In many programming languages, a variable is a symbolic name for this physical location.
- This memory location contains values, like numbers, text or more complicated types.

- We can use this variable to tell the computer to save some data in this location or to retrieve some data from this location.
- So, a variable can be seen as a container to store data.
- These concepts about variables fits best to the way variables are implemented in C, C++ or Java.



- Such declarations make sure that the program reserves memory for two variables (memory locations) with the names x and y. Putting values into the variables can be realized with assignments.
- Variables should have unique data type. E.g. if a variable is of type integer, solely integers can be saved in the variable during the duration of the program.

Variables in Python

- It's a lot easier in Python. There is no declaration of variables required in Python.
- If there is need of a variable, you think of a name and start using it as a variable.
- Another remarkable aspect of Python: Not only the value of a variable may change during program execution but the type as well.
- You can assign an integer value to a variable, use it as an integer for a while and then assign a string to the same variable.
- In this line, we assign the value 42 to a variable:

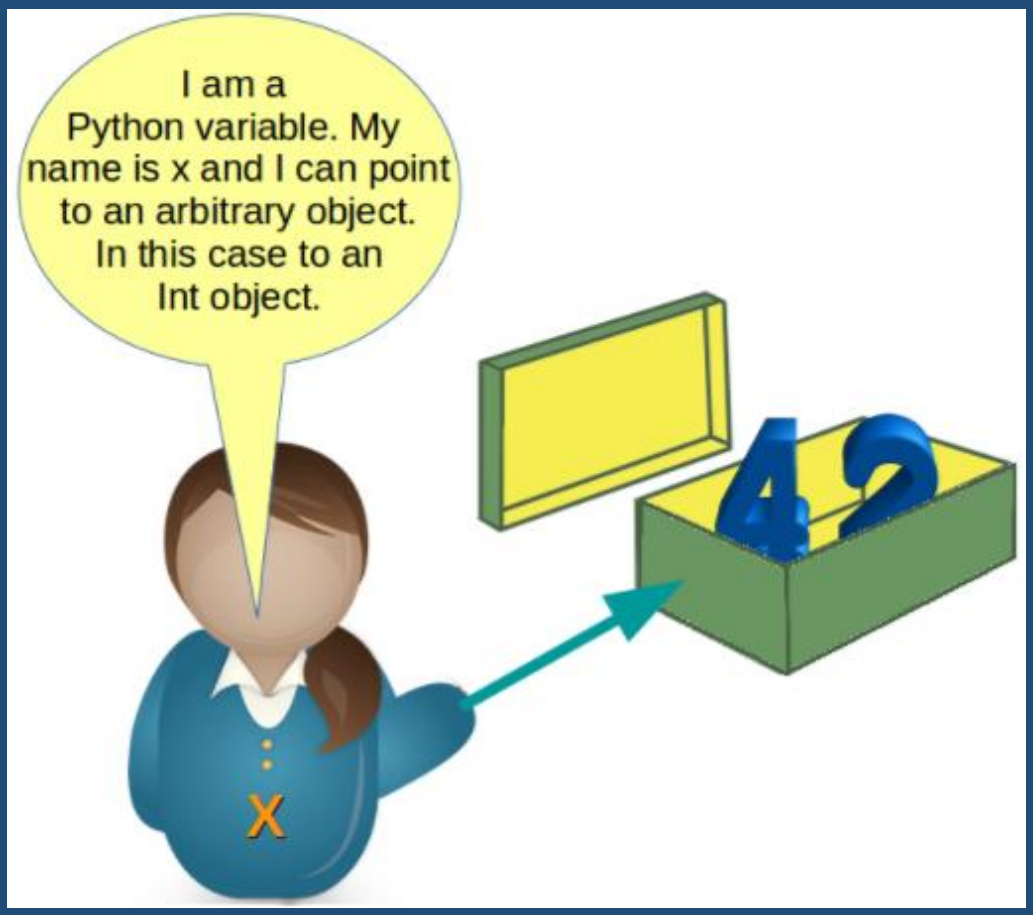
```
i = 42
```

- The equal "=" sign in the assignment shouldn't be seen as "is equal to". It should be read as "is set to", meaning in our example "the variable i is set to 42".

```
i = 42                          # data
type is implicitly set to
integer
i = 42 + 0.11                   # data
type is changed to float
i = "forty"                     # and
now it will be a string
```

Object References

Python variables are references to objects, but the actual data is contained in the objects.

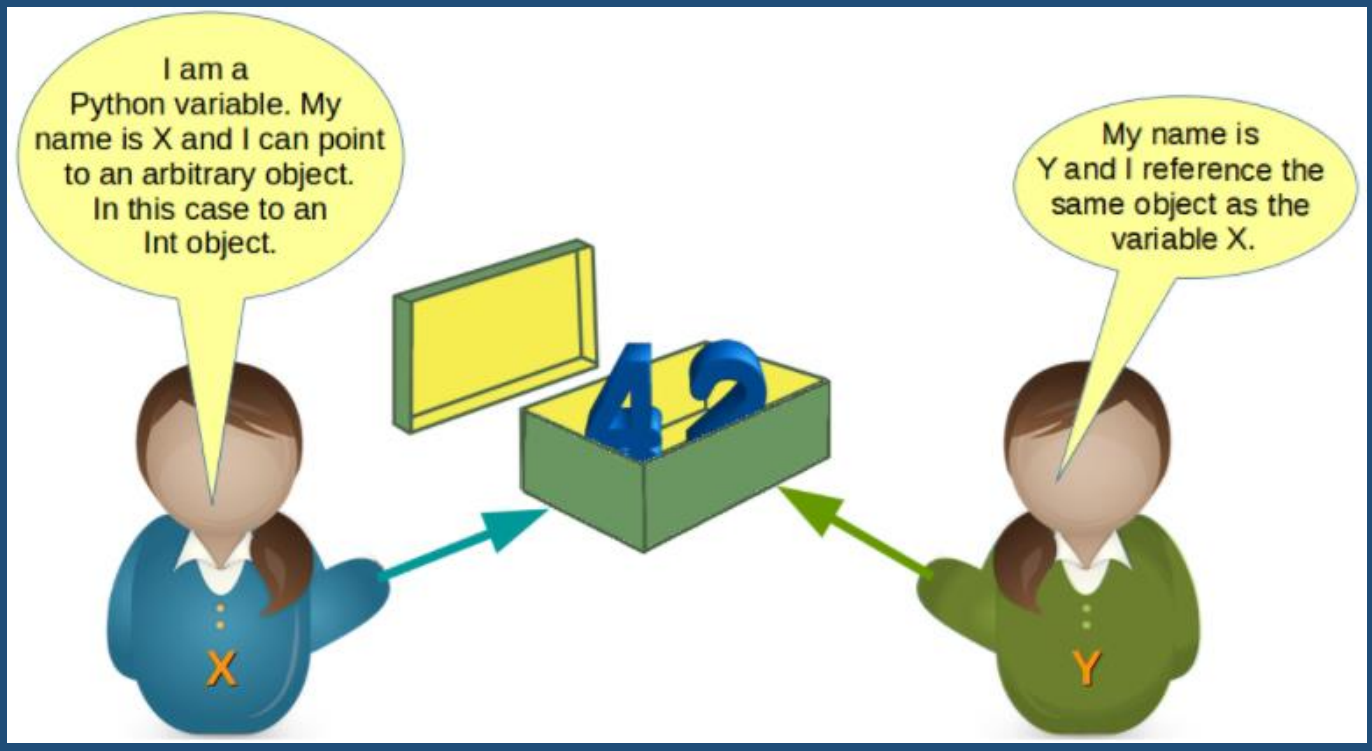


As variables are pointing to objects and objects can be of arbitrary data type, variables can't have types associated with them. This is a huge difference to C, C++ or Java, where a variable is associated with a fixed data type.

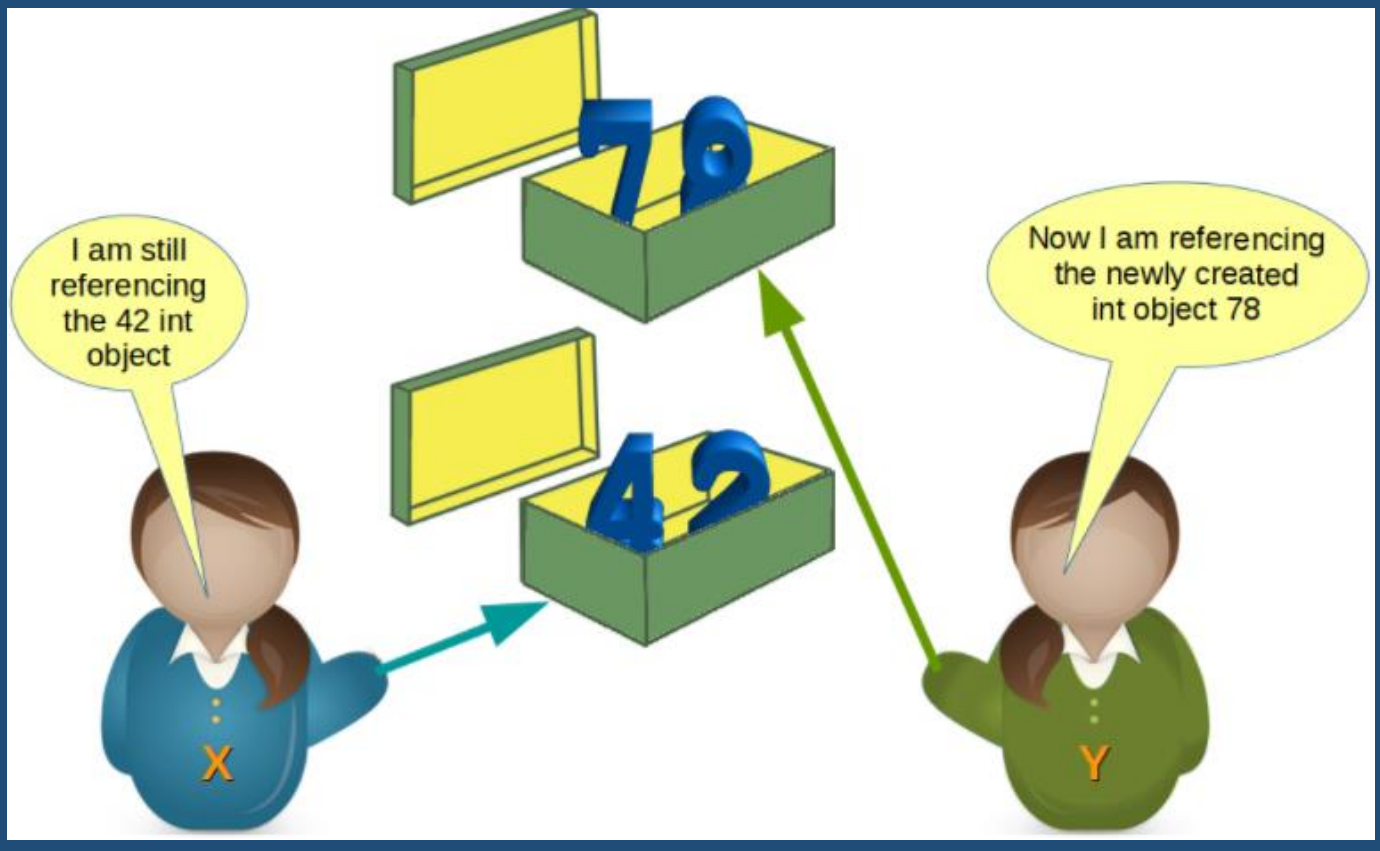
```
>>> x = 42
>>> print(x)
42
>>> x = "Now x references a
string"
>>> print(x)
Now x references a string
```

Examples

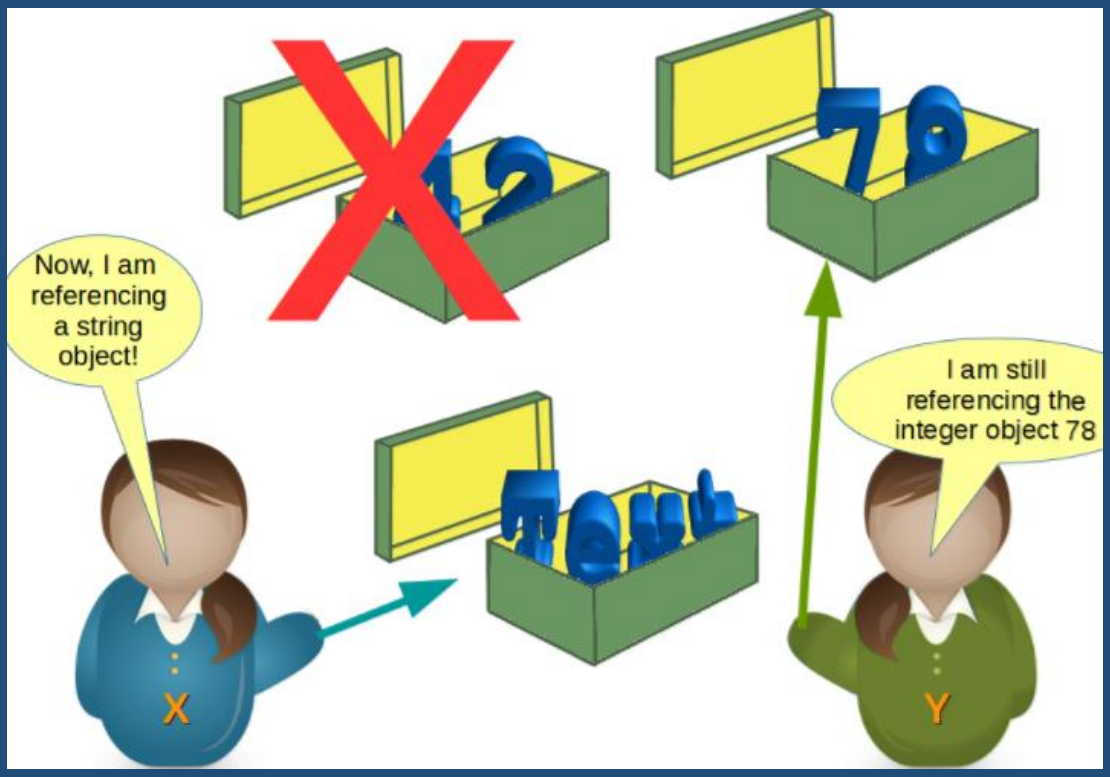
```
>>> x = 42
>>> y = x
```




```
y = 78
```



Now, let us do a string assignment to variable x.



id function as a proof

The identity function id() can be used for this purpose. Every instance (object or variable) has an identity, i.e. an integer that is unique within the script or program, i.e. other objects have different identities.

```
>>> x = 42
>>> id(x)
10107136
>>> y = x
>>> id(x), id(y)
(10107136, 10107136)
>>> y = 78
>>> id(x), id(y)
(10107136, 10108288)
>>>
```

Valid Variable Names

- A Python identifier is a name used to identify a variable, function, class, module or other object.
- A variable name and an identifier can consist of the uppercase letters "A" through "Z", the lowercase letters "a" through "z" , the underscore _ and, except for the first character, the digits 0 through 9.
- Identifiers are unlimited in length. Case is significant.

Python Keywords

```
and, as, assert, break, class, continue, def,
del, elif, else,
except, False, finally, for, from, global, if,
import, in, is,
lambda, None, nonlocal, not, or, pass, raise,
return, True, try,
while, with, yield
```

```
>>> help()

Welcome to Python 3.6's help utility!

If this is your first time using Python, you should definitely check out
the tutorial on the Internet at http://docs.python.org/3.6/tutorial/.

Enter the name of any module, keyword, or topic to get help on writing
Python programs and using Python modules.  To quit this help utility and
return to the interpreter, just type "quit".

To get a list of available modules, keywords, symbols, or topics, type
"modules", "keywords", "symbols", or "topics".  Each module also comes
with a one-line summary of what it does; to list the modules whose name
or summary contain a given string such as "spam", type "modules spam".
```

Numbers

There are four built-in data types for numbers:

- *Integer*
  - Normal Integers e.g. 4321
  - Octal Literals (base 8): A number prefixed by 0o (zero and a lowercase "o" or uppercase "O") will be interpreted as an octal number

```
>>> a = 0o10
>>> print(a)
8
```

  - Hexadecimal literals (base 16): Hexadecimal literals have to be prefixed either by "0x" or "0X"

```
>>> hex_number = 0xA0F
>>> print(hex_number)
2575
```

  - Binary literals (base 2): Binary literals can easily be written as well. They have to be prefixed by a leading "0", followed by a "b" or "B"

```
>>> x = 0b101010 >>> x 42 >>>
```

- The functions hex, bin, oct can be used to convert an integer number into the corresponding string representation of the integer number

```
>>> x = hex(19)
>>> x
'0x13'
>>> type(x)
<class 'str'>
>>> x = bin(65)
>>> x
'0b1000001'
>>> x = oct(65)
>>> x
'0o101'
>>> oct(0b101101)
'0o55'
>>>
```

- **Integers in Python3 can be of unlimited size**

```
>>> x =
787366098712738903245678234782358292837498729182728
>>> print(x)
787366098712738903245678234782358292837498729182728
>>> x * x * x
488123970070638215986770162105731315538827586091948617997871122950228891123960901918308618286311523282239313708275589787123005317148968569797875581092352
>>>
```

- ***Long Integers*: In Python3 there is only one "int" type, which contains both "int" and "long" from Python2.**

- *Floating-point numbers*. For example, 42.11
- *Complex Numbers*: Complex numbers are written as <real part> + <imaginary part>j

```
>>> x = 3 + 4j
>>> y = 2 - 3j
>>> z = x + y
>>> print(z)
(5+1j)
```

Integer Division

There are two kinds of division operators:

1. "true division" performed by "/"

```
>>> 10 / 3
3.3333333333333335
>>> 10.0 / 3.0
3.3333333333333335
>>> 10.5 / 3.5
3.0
```

2. "floor division" performed by "//"

```
>>> 9 // 3
3
>>> 10 // 3
3
>>> 11 // 3
3
>>> 12 // 3
4
>>> 10.0 // 3
3.0
>>> -7 // 3
-3
>>> -7.0 // 3
-3.0
```

Strings

There are different ways to define strings in Python:

```
>>> s = 'I am a string enclosed in single quotes.'
>>> s2 = "I am another string, but I am enclosed in double quotes"
```

Both s and s2 of the previous example are variables referencing string objects.

Examples:

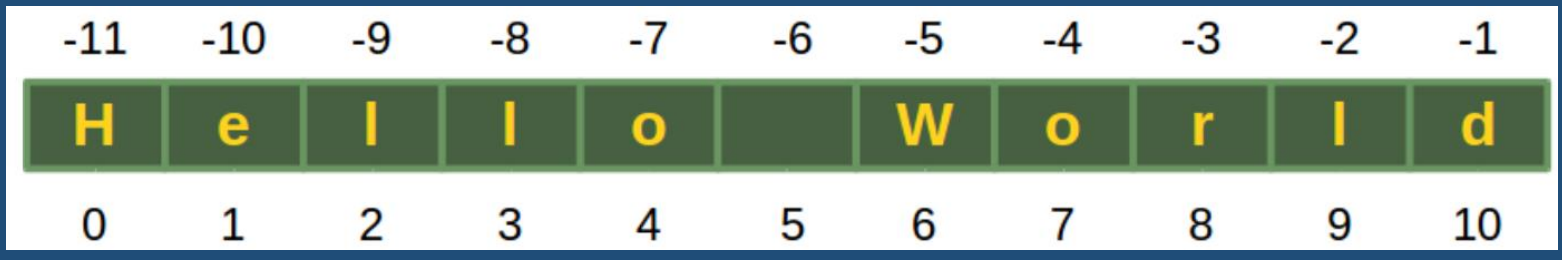
```
>>> s3 = 'It doesn\'t matter!'
```

```
>>> s3 = "It doesn't matter!"
```

```
>>> txt = "He said: \"It doesn't matter, if you enclose a string in single or double quotes!\""
```

```
txt = '''A string in triple quotes can extend over multiple lines like this one, and can contain
'single' and "double" quotes.'''
```

A string in Python consists of a series or sequence of characters - letters, numbers, and special characters. Strings can be subscripted or indexed.



```
>>> s = "Hello World"
>>> s[0]
'H'
>>> s[5]
' '
```

```
>>> s[-1]
'd'
>>> s[-2]
'l'
```

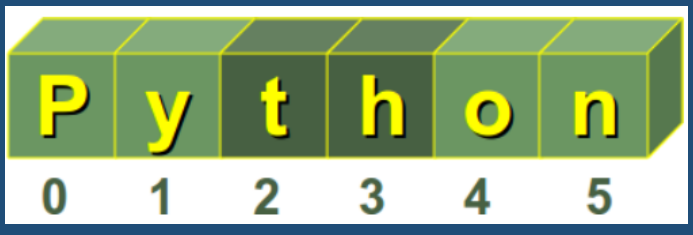
```
>>> s[len(s)-1]
'd'
```

Python strings cannot be changed. Trying to change an indexed position will raise an error:

```
>>> s = "Some things are immutable!"
>>> s[-1] = "."
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'str' object does not support item
assignment
```

Some Operators and functions for strings

- **Concatenation:**
  "Hello" + "World" will result in "HelloWorld"
- **Repetition:**
  "*-*" * 3 will result in "*--**-*"**
- **Indexing:**
  "Python"[0] will result in "P"
- **Slicing: “Python"[2:4] will result in "th"**



- **Size:**
  len("Python") will result in 6

A String Peculiarity

- If both a and b are strings, "a is b" checks if they have the same identity, i.e. share the same memory location.
- If "a is b" is True, then it trivially follows that "a == b" has to be True as well.
- Yet, "a == b" True doesn't imply that "a is b" is True as well!

Examples:

```
>>> a = "Linux"
>>> b = "Linux"
>>> a is b
True
```

```
>>> a = "Baden!"
>>> b = "Baden!"
>>> a is b
False
```

```
>>> a == b
True
```

```
>>> a = "Baden1"
>>> b = "Baden1"
>>> a is b
True
```

Escape Sequences in Strings

The backslash (\) character is used to escape characters, i.e. to "escape" the special meaning, which this character would otherwise have.

\\	Backslash (\)		
\'	Single quote (')		
\"	Double quote (")	\n	ASCII Linefeed (LF)

Topic 2c: Operators

Arithmetic and Comparison Operators

These are the various built-in operators, which Python has to offer for any operation on numeric types.

Operator	Description	Example
+, -	Addition, Subtraction	10 – 3
*, %	Multiplication, Modulo	27 % 7 -> Result: 6
/	Division	10 / 3 -> Result: 3

//	Floor Division
	The results of int(10 / 3) and 10 // 3 are equal. But the "//" division is more than two times as fast!
	`Import timeit`
	`print(timeit.timeit`
	`('for x in range(1, 100):y =100 // x',`
	`number=100000))`
		10 // 3 -> Result: 3
		10.0 // 3 ->Result: 3.0

+x, -x	Unary Minus and Unary Plus (Algebraic signs)	-3
**	Exponentiation	10 ** 3 ->Result: 1000
or, and, not	Boolean Or, And, Not	(a or b) and c
in	“Element of”	1 in [3, 2, 1]
<, <=, >, !=	Comparison operator	2 <= 3

Topic 2d: Lists and Strings

Introduction to Lists

A list in Python is an ordered group of items or elements. These list elements don't have to be of the same type. It can be an arbitrary mixture of elements like numbers, strings, other lists and so on.

The main properties of Python lists:

- **They are ordered**
- **They contain arbitrary objects**
- **Elements of a list can be accessed by an index**
- **They are arbitrarily nestable, i.e. they can contain other lists as sublists**
- **Variable size**
- **They are mutable, i.e. the elements of a list can be changed**

List	Description
[]	An empty list
[1,1,2,3,5,8]	A list of integers
[42, "What's the question?", 3.1415]	A list of mixed data types
["Stuttgart", "Freiburg"]	A list of strings

[["London","England", 7556900], ["Paris","France",2193031]]	A nested list
["High up", ["further down", ["and down", ["deep down", "the answer", 42]]]]	A deeply nested list

Accessing List elements

```
>>> languages = ["Python", "C", "C++", "Java",
"Perl"]
>>> print(languages[0] + " and " +
languages[1] + " are quite different!")
Python and C are quite different!
>>> print("Accessing the last element of the
list: " + languages[-1])
Accessing the last element of the list: Perl
```

Sublists

```
>>> person = [["Marc","Mayer"],["17, Oxford
Str", "12345","London"],"07876-7876"]
>>> name = person[0]
>>> print(name)
['Marc', 'Mayer']
>>> first_name = person[0][0]
>>> print(first_name)
Marc
>>> last_name = person[0][1]
>>> print(last_name)
Mayer
>>> address = person[1]
>>> street = person[1][0]
>>> print(street)
17, Oxford Str
```

```
>>> complex_list = [["a",["b",["c","x"]]]]
>>> complex_list = [["a",["b",["c","x"]]],42]
>>> complex_list[0][1]
['b', ['c', 'x']]
>>> complex_list[0][1][1][0]
'c'
```

Tuples

A tuple is an immutable list, i.e. a tuple cannot be changed in any way once it has been created.

A tuple is similar to lists, except that the set of elements is enclosed in parentheses instead of square brackets.

Where is the benefit of tuples?

- **Tuples are faster than lists.**
- **Knowing that some data doesn't have to be changed, we should use tuples instead of lists, because this protects our data against accidental changes.**
- **Main advantage is that tuples can be used as keys in dictionaries, while lists can't.**

```
>>> t = ("tuples", "are", "immutable")
>>> t[0]
'tuples'
>>> t[0]="assignments to elements are not
possible"
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support
item assignment
```

Slicing

To extract part of a string or a list, we can use the slice operator ":" in Python

```
>>> str = "Python is great"
>>> first_six = str[0:6]
>>> first_six
'Python'
>>> starting_at_five = str[5:]
>>> starting_at_five
'n is great'
>>> a_copy = str[:]
>>> without_last_five = str[0:-5]
>>> without_last_five
'Python is '
```

```
>>> cities = ["Vienna", "London", "Paris",
"Berlin", "Zurich", "Hamburg"]
>>> first_three = cities[0:3]
>>> # or easier:
...
>>> first_three = cities[:3]
>>> print(first_three)
['Vienna', 'London', 'Paris']
```

```
>>> all_but_last_two = cities[:-2]
>>> print(all_but_last_two)
['Vienna', 'London', 'Paris', 'Berlin']
```

Slicing works with three arguments as well. If the third argument is for example 3, only every third element of the list, string or tuple from the range of the first two arguments will be taken.

```
s[begin: end: step]
```

Example

```
>>> str = "Python under Linux is great"
>>> str[::3]
'Ph d n  e'
```

```
>>> s = "Toronto is the largest City in
Canada"
>>> t = "Python courses in Toronto by
Bodenseo"
>>> s = "".join(["".join(x) for x in
zip(s,t)])
>>> s
'TPoyrtohnotno  ciosu rtshees  lianr gTeosrto
nCtiot yb yi nB oCdaennasdeao'
```

```
>>> s
'TPoyrtohnotno  ciosu rtshees  lianr gTeosrto
nCtiot yb yi nB oCdaennasdeao'
>>> s[::2]
'Toronto is the largest City in Canada'
>>> s[1::2]
'Python courses in Toronto by Bodenseo'
```

Length

The length of a sequence, i.e. a list, a string or a tuple, can be determined with the function len().

For strings it counts the number of characters and for lists or tuples the number of elements are counted, whereas a sublist counts as 1 element.

```
>>> txt = "Hello World"
>>> len(txt)
```

```
11
>>> a = ["Swen", 45, 3.54, "Basel"]
>>> len(a)
4
```

Concatenation of Sequences

```
>>> firstname = "Homer"
>>> surname = "Simpson"
>>> name = firstname + " " + surname
>>> print(name)
Homer Simpson
```

```
>>> colours1 = ["red", "green","blue"]
>>> colours2 = ["black", "white"]
>>> colours = colours1 + colours2
>>> print(colours)
['red', 'green', 'blue', 'black', 'white']
```

augmented assignment "+=" e.g. s += t → s = s + t

Checking if an element is in list

```
>>> abc = ["a","b","c","d","e"]
>>> "a" in abc
True
>>> "a" not in abc
False
>>> "e" not in abc
False
>>> "f" not in abc
True
>>> str = "Python is easy!"
>>> "y" in str
True
>>> "x" in str
False
```

Repetitions

"*" operator is a kind of abbreviation for an n-times concatenation i.e. str * 4 → str + str + str + str

```
>>> 3 * "xyz-"
'xyz-xyz-xyz-'
>>> "xyz-" * 3
'xyz-xyz-xyz-'
>>> 3 * ["a","b","c"]
['a', 'b', 'c', 'a', 'b', 'c', 'a', 'b', 'c']
```

The augmented assignment for "*" can be used as well: s *= n is the same as s = s * n.

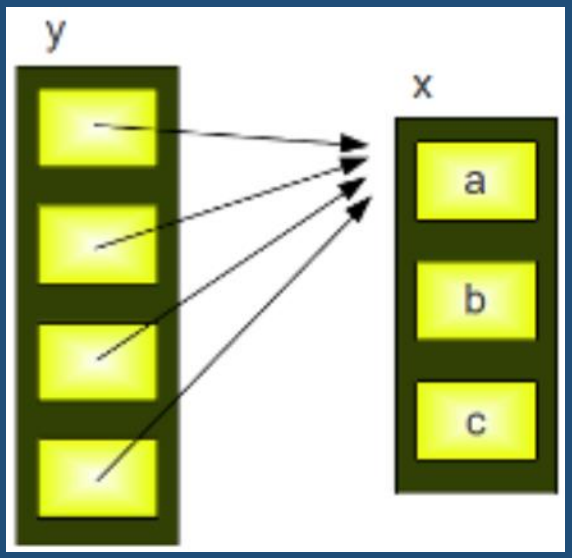
The Pitfalls of Repetitions

In our last example, we applied the repetition operator on strings and flat lists. Let us apply it to nested lists as well:

```
>>> x = ["a","b","c"]
>>> y = [x] * 4
>>> y
[['a', 'b', 'c'], ['a', 'b', 'c'], ['a', 'b',
'c'], ['a', 'b', 'c']]
>>> y[0][0] = "p"
>>> y
[['p', 'b', 'c'], ['p', 'b', 'c'], ['p', 'b',
'c'], ['p', 'b', 'c']]
```

We have assigned a new value to the first element of the first sublist of y, i.e. y[0][0] and we have "automatically" changed the first elements of all the sublists in y, i.e. y[1][0], y[2][0], y[3][0] .

The reason is that the repetition operator "* 4" creates 4 references to the list x: thus every element of y is changed, if we apply a new value to y[0][0].



Topic 2e: List Manipulations

Here we will learn how to append and insert objects to lists and also how to delete and remove elements by using 'remove' and 'pop'.

Pop and Append

- s.append(x) : This method appends an element to the end of the list “s”.

```
>>> lst = [3, 5, 7]
>>> lst.append(42)
>>> lst
[3, 5, 7, 42]
```

```
>>> lst = [3, 5, 7]
>>> lst = lst.append(42)
>>> print(lst)
None
```

This returns “None”, so it doesn’t make sense to reassign the return value

- s.pop(i) : This method returns the ith element of a list s. The element will be removed from the list as well.

```
>>> cities = ["Hamburg", "Linz",
"Salzburg", "Vienna"]
>>> cities.pop(0)
'Hamburg'
>>> cities
['Linz', 'Salzburg', 'Vienna']
>>> cities.pop(1)
'Salzburg'
>>> cities
['Linz', 'Vienna']
```

It raises an IndexError exception if the list is empty or the index is out of range.

- s.pop() : The method 'pop' can be called without an argument. In this case, the last element will be returned. So s.pop() is equivalent to s.pop(-1).

```
>>> cities = ["Amsterdam", "The Hague",
"Strasbourg"]
>>> cities.pop()
'Strasbourg'
>>> cities
['Amsterdam', 'The Hague']
```

Extend

How to add more than one element to a list? E.g., you want to add all the elements of one list to another one. Using append, the other list will be appended as a sublist.

```
>>> lst = [42,98,77]
>>> lst2 = [8,69]
>>> lst.append(lst2)
>>> lst
[42, 98, 77, [8, 69]]
```

But what we wanted to accomplish is the following: `[42, 98, 77, 8, 69]`

Python provides the method 'extend'. It extends a list by appending all the elements of an iterable like a list, a tuple or a string to a list:

```
>>> lst = [42,98,77]
>>> lst2 = [8,69]
>>> lst.extend(lst2)
>>> lst
[42, 98, 77, 8, 69]
```

The argument of extend doesn't have to be a list. It can be any iterable. This means that we can use tuples and strings as well:

```
>>> lst = ["a", "b", "c"]
>>> programming_language = "Python"
>>> lst.extend(programming_language)
>>> print(lst)
['a', 'b', 'c', 'P', 'y', 't', 'h', 'o', 'n']
```

Now with a tuple:

```
>>> lst = ["Java", "C", "PHP"]
>>> t = ("C#", "Jython", "Python",
"IronPython")
>>> lst.extend(t)
>>> lst
['Java', 'C', 'PHP', 'C#', 'Jython', 'Python',
'IronPython']
```

Extending and Appending list with “+”

There is an alternative to 'append' and 'extend'. '+' can be used to combine lists.

```
>>> level = ["beginner", "intermediate",
"advanced"]
>>> other_words = ["novice", "expert"]
>>> level + other_words
['beginner', 'intermediate', 'advanced',
'novice', 'expert']
```

But be careful. Never ever do the following:

```
>>> L = [3, 4]
>>> L = L + [42]
>>> L
[3, 4, 42]
```

Even though we get the same result, it is not an alternative to 'append' and 'extend':

```
>>> L = [3, 4]
>>> L.append(42)
>>> L
[3, 4, 42]
>>>
>>>
>>> L = [3, 4]
>>> L.extend([42])
>>> L
[3, 4, 42]
```

The augmented assignment (+=) is an alternative:

```
>>> L = [3, 4]
>>> L += [42]
>>> L
[3, 4, 42]
```

Let us compare in the following example the different approaches and calculate their run times.

```
import time
n= 100000
start_time = time.time()
l = []
for i in range(n):
    l = l + [i * 2]
print(time.time() - start_time)
start_time = time.time()
l = []
for i in range(n):
    l += [i * 2]
print(time.time() - start_time)
start_time = time.time()
l = []
for i in range(n):
    l.append(i * 2)
print(time.time() - start_time)
```

We can see that the "+" operator is too much slower than the append method. If we use the append method, we will simply append a further element to the list in each loop pass. In l = l + [i * 2], the list will be copied in every loop pass, the new element will be added to the copy of the list and result will be reassigned to the variable l. After this the old list will have to be removed by Python, because it is not referenced anymore.

Removing an element with remove

It is possible to remove with the method "remove" a certain value from a list without knowing the position.

```
s.remove(x)
```

This call will remove the first occurrence of x from the list.

```
>>> colours = ["red", "green", "blue",
"green", "yellow"]
>>> colours.remove("green")
>>> colours
['red', 'blue', 'green', 'yellow']
>>> colours.remove("green")
>>> colours
['red', 'blue', 'yellow']
>>> colours.remove("green")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: list.remove(x): x not in list
```

Find the position of an element

The method "index" can be used to find the position of an element within a list:

```
s.index(x[, i[, j]])
```

It returns the first index of the value x. A ValueError will be raised, if the value is not present. If the optional parameter i is given, the search will start at the index i. If j is also given, the search will stop at position j.

```
>>> colours = ["red", "green", "blue",
"green", "yellow"]
>>> colours.index("green")
1
>>> colours.index("green", 2)
3
>>> colours.index("green", 3,4)
3
>>> colours.index("black")
Traceback (most recent call last):
  File "", line 1, in
ValueError: 'black' is not in list
```

Insert

We need also a way to add elements to arbitrary positions inside of a list. This can be done with the method "insert":

```
s.insert(index, object)
```

An object "object" will be included in the list "s" and placed before the element s[index]

```
>>> lst = ["German is spoken", "in Germany,",
"Austria", "Switzerland"]
>>> lst.insert(3, "and")
>>> lst
['German is spoken', 'in Germany,', 'Austria',
'and', 'Switzerland']
```

The functionality of the method "append" can be simulated with insert in the following way:

```
>>> abc = ["a","b","c"]
>>> abc.insert(len(abc),"d")
>>> abc
['a', 'b', 'c', 'd']
```

Topic 2f: Shallow and Deep Copy

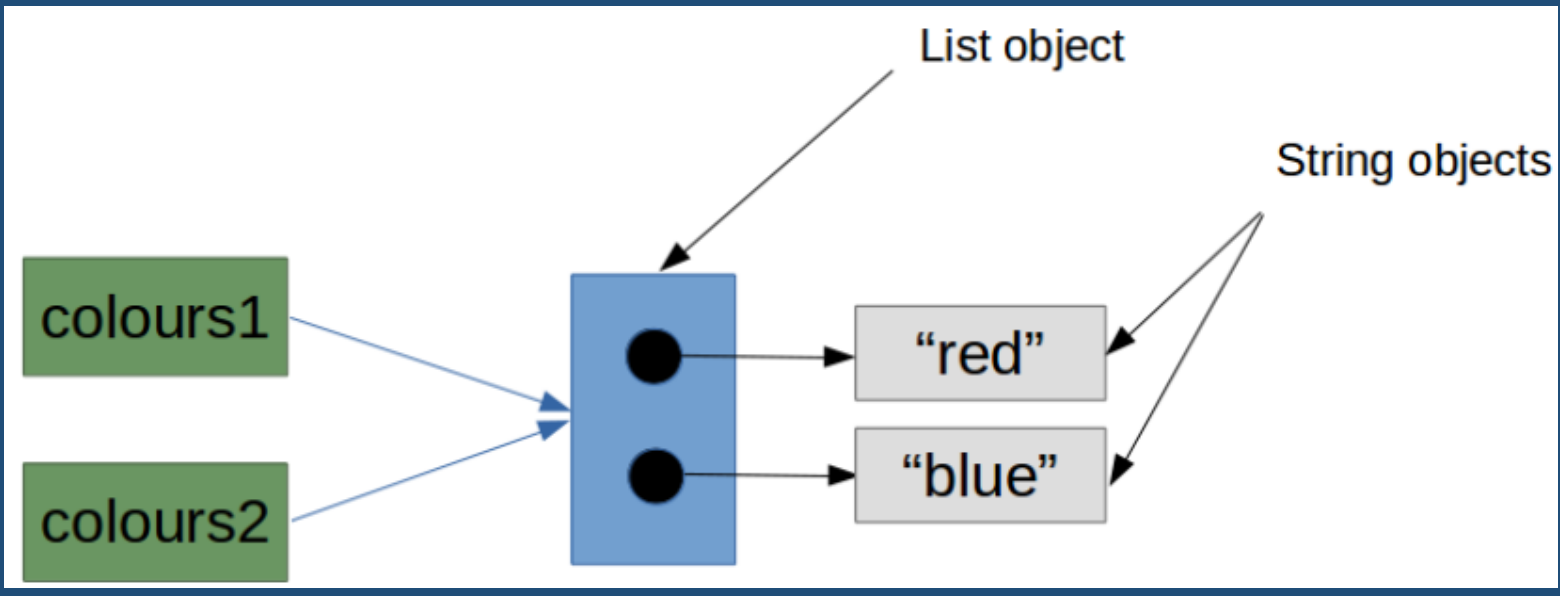
Here, Y points to the same memory location as X. When new value assigned to y, gets a separate memory location.

```
>>> x = 3
>>> y = x
>>> print(id(x), id(y))
9251744 9251744
>>> y = 4
>>> print(id(x), id(y))
9251744 9251776
>>> print(x,y)
3 4
```

Let us have a look at few crucial problems, which can occur when copying mutable objects, lists or dictionaries.

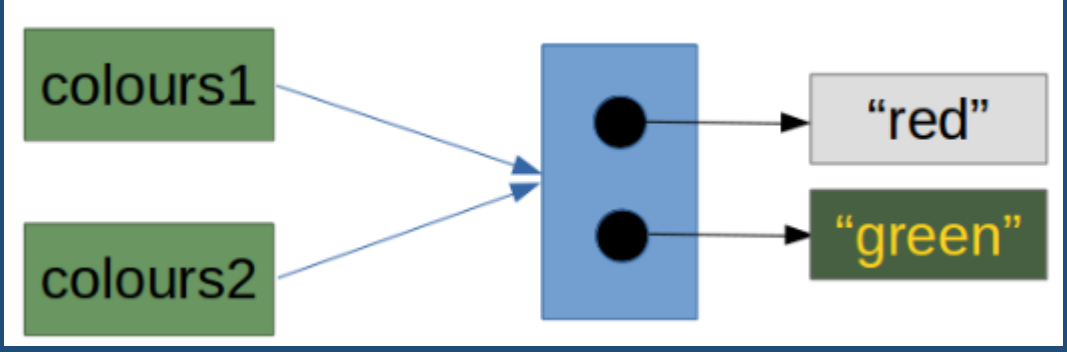
Copying a list

```
>>> colours1 = ["red", "blue"]
>>> colours2 = colours1
>>> print(colours1)
['red', 'blue']
>>> print(colours2)
['red', 'blue']
>>> print(id(colours1),id(colours2))
43444416 43444416
>>> colours2 = ["rouge", "vert"]
>>> print(colours1)
['red', 'blue']
>>> print(colours2)
['rouge', 'vert']
>>> print(id(colours1),id(colours2))
43444416 43444200
```



A simple list is assigned to colours1. This list is a so-called "shallow list", because it does not have a nested structure, i.e. no sublists are contained in the list. The id() function shows us that both variables point to the same list object, i.e. they share this object.

```
>>> colours1 = ["red", "blue"]
>>> colours2 = colours1
>>> print(id(colours1),id(colours2))
14603760 14603760
>>> colours2[1] = "green"
>>> print(id(colours1),id(colours2))
14603760 14603760
>>> print(colours1)
['red', 'green']
>>> print(colours2)
['red', 'green']
```



We assigned a new value to the second element of colours2, i.e. the element with the index 1. The list of colours1 has been "automatically" changed as well. This happened because we have two names for the same list.

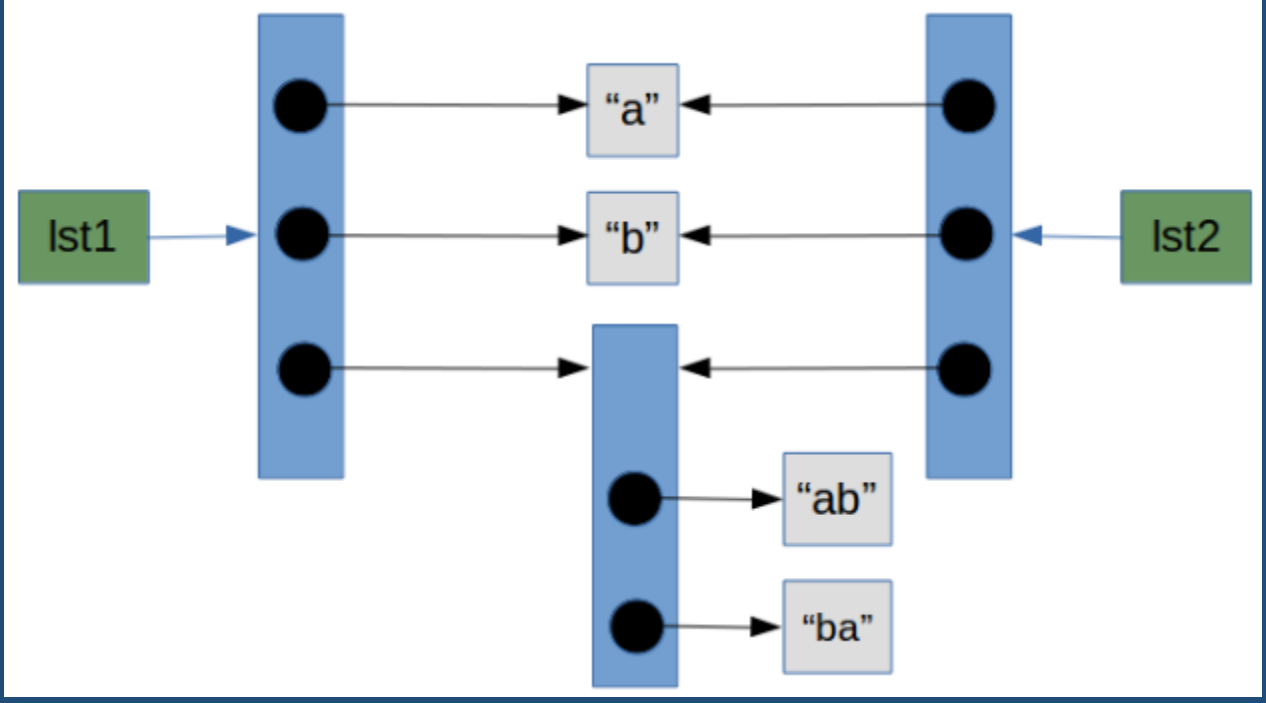
Copying with the Slice Operator

It's possible to completely copy shallow list structures with the slice operator without having any side effects

```
>>> list1 = ['a','b','c','d']
>>> list2 = list1[:]
>>> list2[1] = 'x'
>>> print(list2)
['a', 'x', 'c', 'd']
>>> print(list1)
['a', 'b', 'c', 'd']
```

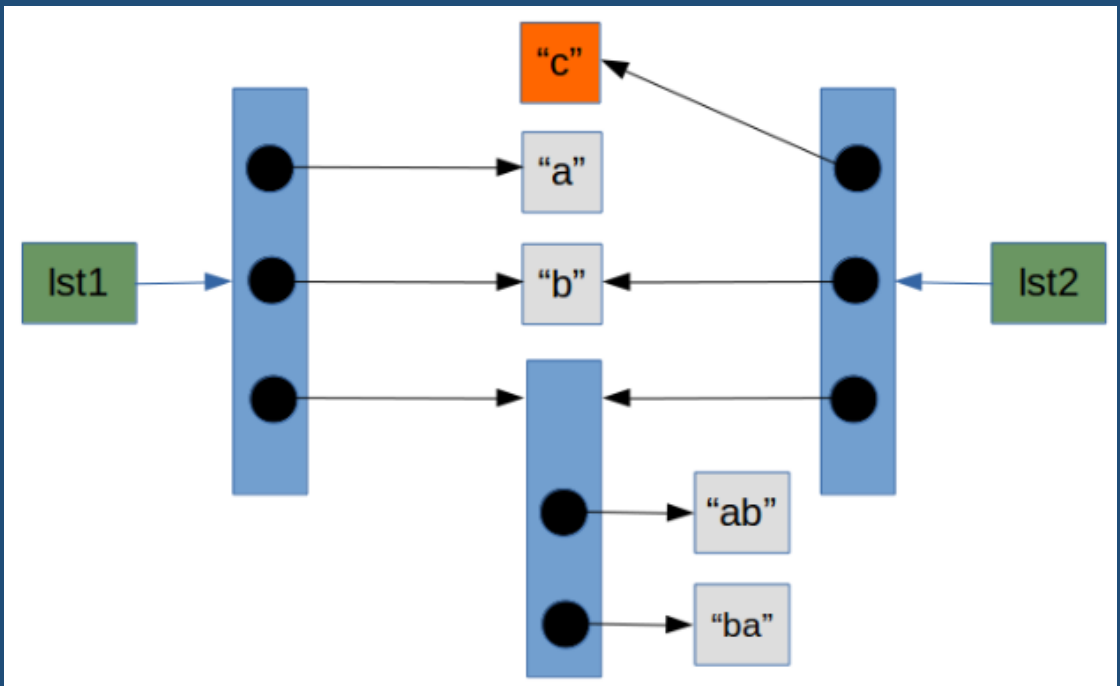
When a list contains sublists, another difficulty: The sublists are not copied but only the references to sublists. We create a shallow copy with the slicing operator.

```
>>> lst1 = ['a','b',['ab','ba']]
>>> lst2 = lst1[:]
```



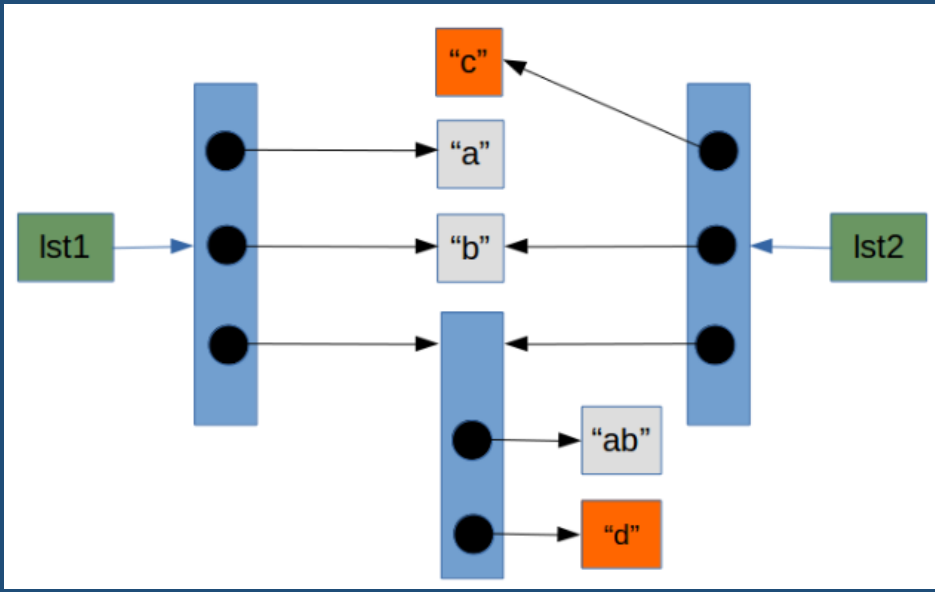
If you assign a new value to the 0th or the 1st index of one of the two lists, there will be no side effect.

```
>>> lst1 = ['a','b',['ab','ba']]
>>> lst2 = lst1[:]
>>> lst2[0] = 'c'
>>> print(lst1)
['a', 'b', ['ab', 'ba']]
>>> print(lst2)
['c', 'b', ['ab', 'ba']]
```



Problem arise if you change one of the elements of sublist

```
>>> lst2[2][1] = 'd'
>>> print(lst1)
['a', 'b', ['ab', 'd']]
>>> print(lst2)
['c', 'b', ['ab', 'd']]
```

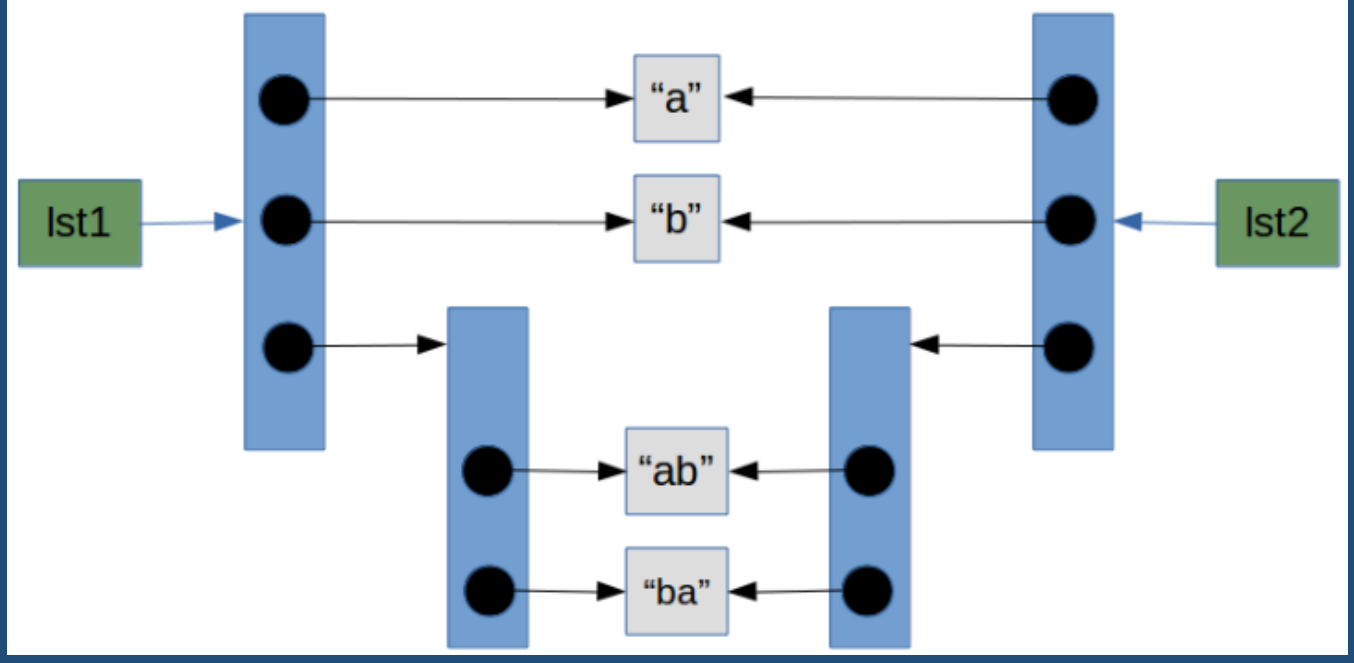


Using Method deepcopy from Module copy

It allows a complete or deep copy of an arbitrary list, i.e. shallow and other lists.

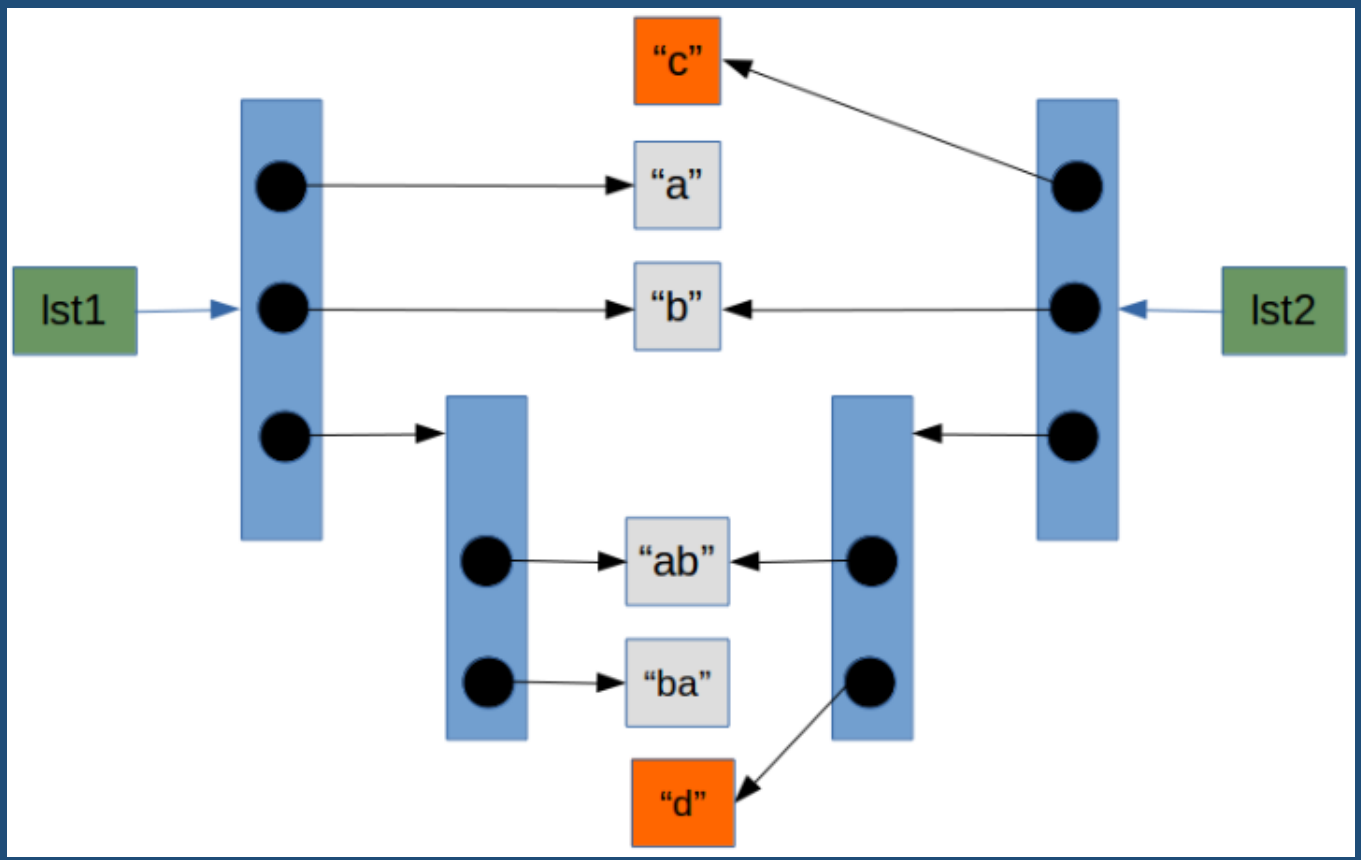
```
>>> from copy import deepcopy
>>>
>>> lst1 = ['a','b',['ab','ba']]
>>>
>>> lst2 = deepcopy(lst1)
>>>
>>> lst1
['a', 'b', ['ab', 'ba']]
>>> lst2
['a', 'b', ['ab', 'ba']]
```

```
>>> id(lst1)
139716507600200
>>> id(lst2)
139716507600904
>>> id(lst1[0])
139716538182096
>>> id(lst2[0])
139716538182096
>>> id(lst2[2])
139716507602632
>>> id(lst1[2])
139716507615880
```




```
>>> lst2[2][1] = "d"
>>> lst2[0] = "c"
>>> print(lst1)
['a', 'b', ['ab', 'ba']]
>>> print(lst2)
['c', 'b', ['ab', 'd']]
```

Now the data structure looks like this:



Topic 3a: Dictionaries

Introduction

Difference between lists and dictionaries? A list is an ordered sequence of objects, whereas dictionaries are unordered sets. The main difference is : items in dictionaries are accessed via keys and not their position.

Examples:

```
>>> city_population = {"New York
City":8550405, "Los Angeles":3971883,
"Toronto":2731571, "Chicago":2720546,
"Houston":2296224, "Montreal":1704694,
"Calgary":1239220, "Vancouver":631486,
"Boston":667137}
```

If we want to get the population of one of those cities, all we have to do is to use the name of the city as an index:

```
>>> city_population["New York City"]
8550405
>>> city_population["Toronto"]
2731571
>>> city_population["Boston"]
667137
```

If we try to access a key which is not contained in the dictionary, KeyError is raised

```
>>> city["Detroit"]
Traceback (most recent call last):
  File "<stdin>", line 1, in
KeyError: 'Detroit'
```

There is no ordering in dictionaries. That's why the output of the dictionary, doesn't reflect the "original ordering"

```
>>> city
{'Toronto': 2615060, 'Ottawa': 883391, 'Los
Angeles': 3792621, 'Chicago': 2695598, 'New
York City': 8175133, 'Boston': 62600,
'Washington': 632323, 'Montreal': 11854442}
```

Therefore it is neither possible to access an element of the dictionary by a number, like we did with lists:

```
>>> city[0]
Traceback (most recent call last):
  File "<stdin>", line 1, in
KeyError: 0
```

It's very easy to add another entry to existing dictionary

```
>>> city["Halifax"] = 390096
>>> city
{'Toronto': 2615060, 'Ottawa': 883391, 'Los
Angeles': 3792621, 'Chicago': 2695598, 'New
York City': 8175133, 'Halifax': 390096,
'Boston': 62600, 'Washington': 632323,
'Montreal': 11854442}
```

So, it's possible to create a dictionary incrementally by starting with an empty dictionary. How to define an empty dictionary?

```
>>> city = {}
>>> city
{}
```

Now, let us create English to French dictionary:

1. **English to German dictionary**

```
en_de = {"red" : "rot", "green" : "grün",
"blue" : "blau", "yellow":"gelb"}
print(en_de)
print(en_de["red"])
```

2. **Next, German to French dictionary**

```
de_fr = {"rot" : "rouge", "grün" : "vert",
"blau" : "bleu", "gelb":"jaune"}
```

3. **Now it's possible to translate English to French, even though we don't have English-French-dictionary**

```
print("The French word for red is: " +
de_fr[en_de["red"]])
```

We can use arbitrary types as values in a dictionary, but there is a restriction for the keys. Only immutable data types can be used as keys, i.e. no lists or dictionaries can be used. If you use a mutable data type as a key, you get an error message:

```
>>> dic = { [1,2,3]:"abc"}
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: list objects are unhashable
```

Tuple as keys are okay

```
>>> dic = { (1,2,3):"abc", 3.1415:"abc"}
>>> dic
{3.1415: 'abc', (1, 2, 3): 'abc'}
```

We can also create a dictionary of dictionaries

```
en_de = {"red" : "rot", "green" : "grün",
"blue" : "blau", "yellow":"gelb"}
de_fr = {"rot" : "rouge", "grün" : "vert",
"blau" : "bleu", "gelb":"jaune"}

dictionaries = {"en_de" : en_de, "de_fr" :
de_fr }
print(dictionaries["de_fr"]["blau"])
```

Operators on Dictionaries

Operator	Explanation
len(d)	returns the number of stored entries, i.e. the number of (key,value) pairs.
del d[k]	deletes the key k together with his value
k in d	True, if a key k exists in the dictionary d
k not in d	True, if a key k doesn't exist in the dictionary d

pop()

D.pop(k) removes the key k with its value from the dictionary D and returns this key's value, i.e. D[k].

```
>>> en_de = {"Austria":"Vienna",
"Switzerland":"Bern", "Germany":"Berlin",
"Netherlands":"Amsterdam"}
>>> capitals = {"Austria":"Vienna",
"Germany":"Berlin", "Netherlands":"Amsterdam"}
>>> capital = capitals.pop("Austria")
>>> print(capital)
Vienna
>>> print(capitals)
{'Netherlands': 'Amsterdam', 'Germany':
'Berlin'}
```

If the key is not found a KeyError is raised:

```
>>> capital = capitals.pop("Switzerland")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'Switzerland'
```

To prevent these errors, there is an elegant way. The method pop() has an optional second parameter, which can be used as a default value:

```
>>> capital = capitals.pop("Switzerland",
"Bern")
>>> print(capital)
Bern
>>> capital = capitals.pop("France", "Paris")
>>> print(capital)
Paris
>>> capital = capitals.pop("Germany",
"München")
>>> print(capital)
Berlin
```

popitem()

popitem() is a method of dict, which doesn't take any parameter and removes and returns an arbitrary (key,value) pair as a 2-tuple. If popitem() is applied on an empty dictionary, a KeyError will be raised.

```
>>> capitals = {"Springfield":"Illinois",
"Augusta":"Maine", "Boston": "Massachusetts",
"Lansing":"Michigan", "Albany":"New York",
"Olympia":"Washington", "Toronto":"Ontario"}
>>> (city, state) = capitals.popitem()
>>> (city, state)
('Olympia', 'Washington')
>>> print(capitals.popitem())
('Albany', 'New York')
>>> print(capitals.popitem())
('Boston', 'Massachusetts')
>>> print(capitals.popitem())
('Lansing', 'Michigan')
>>> print(capitals.popitem())
('Toronto', 'Ontario')
```

Accessing Non Existing Keys

If you try to access a key which doesn't exist, you will get an error message:

```
>>> locations = {"Toronto" : "Ontario",
"Vancouver":"British Columbia"}
>>> locations["Ottawa"]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'Ottawa'
```

You can prevent this by using the "in" operator:

```
>>> if "Ottawa" in locations:
print(locations["Ottawa"])
...
>>> if "Toronto" in locations:
print(locations["Toronto"])
...
Ontario
```

Another method to access the values via the key consists in using the get() method. get() is not raising an error, if an index doesn't exist. In this case it will return None. It's also possible to set a default value, which will be returned, if an index doesn't exit:

```
>>> proj_language = {"proj1":"Python",
"proj2":"Perl", "proj3":"Java"}
>>> proj_language["proj1"]
'Python'
>>> proj_language["proj4"]
Traceback (most recent call last):
  File "<stdin>", line 1, in
KeyError: 'proj4'
>>> proj_language.get("proj2")
'Perl'
>>> proj_language.get("proj4")
>>> print(proj_language.get("proj4"))
None
>>> # setting a default value:
>>> proj_language.get("proj4", "Python")
'Python'
```

Important Methods

A dictionary can be copied with the method copy():

```
>>> w = words.copy()
>>> words["cat"]="chat"
>>> print(w)
{'house': 'Haus', 'cat': 'Katze'}
>>> print(words)
{'house': 'Haus', 'cat': 'chat'}
```

This copy is a shallow and not a deep copy.

The content of a dictionary can be cleared with the method clear(). The dictionary is not deleted, but set to an empty dictionary:

```
>>> w.clear()
>>> print(w)
{}
```

Update: Merging Dictionaries

update() method merges keys and values of one dictionary into another, overwriting values of same key:

```
>>> knowledge = {"Frank": {"Perl"}, "Monica":
{"C","C++"}}
>>> knowledge2 = {"Guido":{"Python"}, "Frank":
{"Perl", "Python"}}
>>> knowledge.update(knowledge2)
>>> knowledge
{'Frank': {'Python', 'Perl'}, 'Guido':
{'Python'}, 'Monica': {'C', 'C++'}}
```

Iterating over a Dictionary

No method is needed to iterate over keys of a dictionary:

```
>>> d = {"a":123, "b":34, "c":304, "d":99}
>>> for key in d:
...     print(key)
...
b
c
a
d
```

```
>>> for key in d.keys():
...     print(key)
...
b
c
a
d
```

```
>>> for value in d.values():
...     print(value)
...
34
304
123
99
```

The above-right loop is equivalent to the following:

```
for key in d:
        print(d[key])
```

but less efficient.

Lists from Dictionaries

keys() creates a list, which consists of the keys of the dictionary. values() produces a list consisting of the values. items() creates a list consisting of 2-tuples of (key,value)-pairs:

```
>>> w = {"house":"Haus", "cat":"", "red":"rot"}
>>> items_view = w.items()
>>> items = list(items_view)
>>> items
[('house', 'Haus'), ('cat', ''), ('red', 'rot')]
>>>
>>> keys_view = w.keys()
>>> keys = list(keys_view)
>>> keys
['house', 'cat', 'red']
>>>
>>> values_view = w.values()
>>> values = list(values_view)
>>> values
['Haus', '', 'rot']
>>> values_view
dict_values(['Haus', '', 'rot'])
>>> items_view
dict_items([('house', 'Haus'), ('cat', ''), ('red', 'rot')])
>>> keys_view
dict_keys(['house', 'cat', 'red'])
```

Turn Lists into Dictionaries

We have two lists, one containing the dishes and the other one the corresponding countries:

```
>>> dishes = ["pizza", "sauerkraut", "paella", "hamburger"]
>>> countries = ["Italy", "Germany", "Spain", "USA"]
```

Now we will create a dictionary, which assigns a dish to a country. For this purpose we need the function zip(). The result is a list iterator. This means that we have to wrap a list() casting function around the zip call to get a list:

```
>>> country_specialities_iterator = zip(countries, dishes)
>>> country_specialities_iterator
<zip object at 0x7fa5f7cad408>
>>> country_specialities = list(country_specialities_iterator)
>>> print(country_specialities)
[('Italy', 'pizza'), ('Germany', 'sauerkraut'), ('Spain', 'paella'),
('USA', 'hamburger')]
```

```
>>> country_specialities_dict =
dict(country_specialities)
>>> print(country_specialities_dict)
{'USA': 'hamburger', 'Germany': 'sauerkraut',
'Spain': 'paella', 'Italy': 'pizza'}
```

But it's inefficient, we created a list of 2-tuples to turn list into dict. This can be done directly by applying dict to zip:

```
>>> dishes = ["pizza", "sauerkraut", "paella",
"hamburger"]
>>> countries = ["Italy", "Germany", "Spain",
"USA"]
>>> dict(zip(countries, dishes))
{'USA': 'hamburger', 'Germany': 'sauerkraut',
'Spain': 'paella', 'Italy': 'pizza'}
```

Topic 3b: Set and Frozensets

Introduction

A set contains an unordered collection of unique and immutable objects. To create a set, use the built-in set function with a sequence or another iterable object:

```
>>> x = set("A Python Tutorial")
>>> x
{'A', ' ', 'i', 'h', 'l', 'o', 'n', 'P', 'r',
'u', 't', 'a', 'y', 'T'}
>>> type(x)
<class 'set'>
```

```
>>> x = set(["Perl", "Python", "Java"])
>>> x
{'Python', 'Java', 'Perl'}
```

```
>>> cities = set(("Paris", "Lyon",
"London","Berlin","Paris","Birmingham"))
>>> cities
{'Paris', 'Birmingham', 'Lyon', 'London',
'Berlin'}
```

Sets doesn't allow mutable objects.

```
>>> cities = set((("Python","Perl"), ("Paris",
"Berlin", "London")))
>>> cities = set((["Python","Perl"], ["Paris",
"Berlin", "London"]))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unhashable type: 'list'
```

To define a set, we can only use curly braces also:

```
>>> adjectives =
{"cheap","expensive","inexpensive","economical
"}
>>> adjectives
{'inexpensive', 'cheap', 'expensive',
'economical'}
```

Frozensets

Though sets can't contain mutable objects, sets are mutable:

```
>>> cities = set(["Frankfurt",
"Basel","Freiburg"])
>>> cities.add("Strasbourg")
>>> cities
{'Freiburg', 'Basel', 'Frankfurt',
'Strasbourg'}
```

Frozensets are like sets except that they cannot be changed, i.e. they are immutable:

```
>>> cities = frozenset(["Frankfurt",
"Basel","Freiburg"])
>>> cities.add("Strasbourg")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: 'frozenset' object has no
attribute 'add'
```

Set Operations

- *add(element)*

  A method which adds an element, which has to be immutable, to a set.

```
>>> colours = {"red","green"}
>>> colours.add("yellow")
>>> colours
{'green', 'yellow', 'red'}
>>> colours.add(["black","white"])
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unhashable type: 'list'
```

  Of course, an element will only be added, if it is not already contained in the set. If it is already contained, the method call has no effect.

- *clear()*

  All elements will be removed from a set.

```
>>> cities = {"Stuttgart", "Konstanz",
"Freiburg"}
>>> cities.clear()
>>> cities
set()
```

- *copy()*

  Creates a shallow copy, which is returned.

```
>>> more_cities =
{"Winterthur","Schaffhausen","St.
Gallen"}
>>> cities_backup = more_cities.copy()
>>> more_cities.clear()
>>> cities_backup
{'St. Gallen', 'Winterthur',
'Schaffhausen'}
```

- ***difference()***

  This method returns the difference of two or more sets as a new set.

```
>>> x = {"a","b","c","d","e"}
>>> y = {"b","c"}
>>> z = {"c","d"}
>>> x.difference(y)
{'a', 'e', 'd'}
>>> x.difference(y).difference(z)
{'a', 'e'}
```

```
>>> x - y
{'a', 'e', 'd'}
>>> x - y - z
{'a', 'e'}
```

- ***difference_update()***

  This method removes all elements of another set from this set. x.difference_update(y) is same as "x = x - y"

```
>>> x = {"a","b","c","d","e"}
>>> y = {"b","c"}
>>> x.difference_update(y)
>>>
>>> x = {"a","b","c","d","e"}
>>> y = {"b","c"}
>>> x = x - y
>>> x
{'a', 'e', 'd'}
```

- *discard(el)*

  An element el will be removed from the set, if it is contained in the set. If el is not a member of the set, nothing will be done.

```
>>> x = {"a","b","c","d","e"}
>>> x.discard("a")
>>> x
{'c', 'b', 'e', 'd'}
>>> x.discard("z")
>>> x
{'c', 'b', 'e', 'd'}
```

- *remove(el)*

  works like discard(), but if el is not a member of the set, a KeyError will be raised.

```
>>> x = {"a","b","c","d","e"}
>>> x.remove("a")
>>> x
{'c', 'b', 'e', 'd'}
>>> x.remove("z")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: 'z'
```

- *union(s)*

  This method returns the union of two sets as a new set, i.e. all elements that are in either set.

```
>>> x = {"a","b","c","d","e"}
>>> y = {"c","d","e","f","g"}
>>> x.union(y)
{'d', 'a', 'g', 'c', 'f', 'b', 'e'}
```

This can be abbreviated with the pipe operator "|":

```
>>> x = {"a","b","c","d","e"}
>>> y = {"c","d","e","f","g"}
>>> x | y
{'d', 'a', 'g', 'c', 'f', 'b', 'e'}
```

- *intersection(s)*

  Returns the intersection of the instance set and the set s as a new set. In other words: A set with all the elements which are contained in both sets is returned.

```
>>> x = {"a","b","c","d","e"}
>>> y = {"c","d","e","f","g"}
>>> x.intersection(y)
{'c', 'e', 'd'}
```

```
>>> x = {"a","b","c","d","e"}
>>> y = {"c","d","e","f","g"}
>>> x  & y
{'c', 'e', 'd'}
```

- *pop()*

  pop() removes and returns an arbitrary set element. The method raises a KeyError if the set is empty

```
>>> x = {"a","b","c","d","e"}
>>> x.pop()
'a'
>>> x.pop()
'c'
```

Topic 3c: Tuples

Introduction

A tuple is a sequence of immutable Python objects. Tuples are sequences, just like lists. The differences between tuples and lists are, tuples cannot be changed unlike lists and tuples use parentheses instead of square brackets.

```
tup1 = ('physics', 'chemistry', 1997, 2000);
tup2 = (1, 2, 3, 4, 5 );
tup3 = "a", "b", "c", "d";
```

```
tup1 = ();
```

To write a tuple containing a single value you have to include a comma – `tup1 = (50,);`

Tuples Operations

```
tup1 = ('physics', 'chemistry', 1997, 2000);
tup2 = (1, 2, 3, 4, 5, 6, 7 );
print "tup1[0]: ", tup1[0];
print "tup2[1:5]: ", tup2[1:5];
```

Python Expression	Results	Description
len((1, 2, 3))	3	Length
(1, 2, 3) + (4, 5, 6)	(1, 2, 3, 4, 5, 6)	Concatenation
('Hi!',) * 4	('Hi!', 'Hi!', 'Hi!', 'Hi!')	Repetition
3 in (1, 2, 3)	True	Membership
for x in (1, 2, 3): print x,	1 2 3	Iteration

cmp(tuple1, tuple2)
Compares elements of both tuples.

len(tuple)
Gives the total length of the tuple.

max(tuple)
Returns item from the tuple with max value.

min(tuple)
Returns item from the tuple with min value.

tuple(seq)
Converts a list into tuple.

Topic 3d: Input from Keyboard

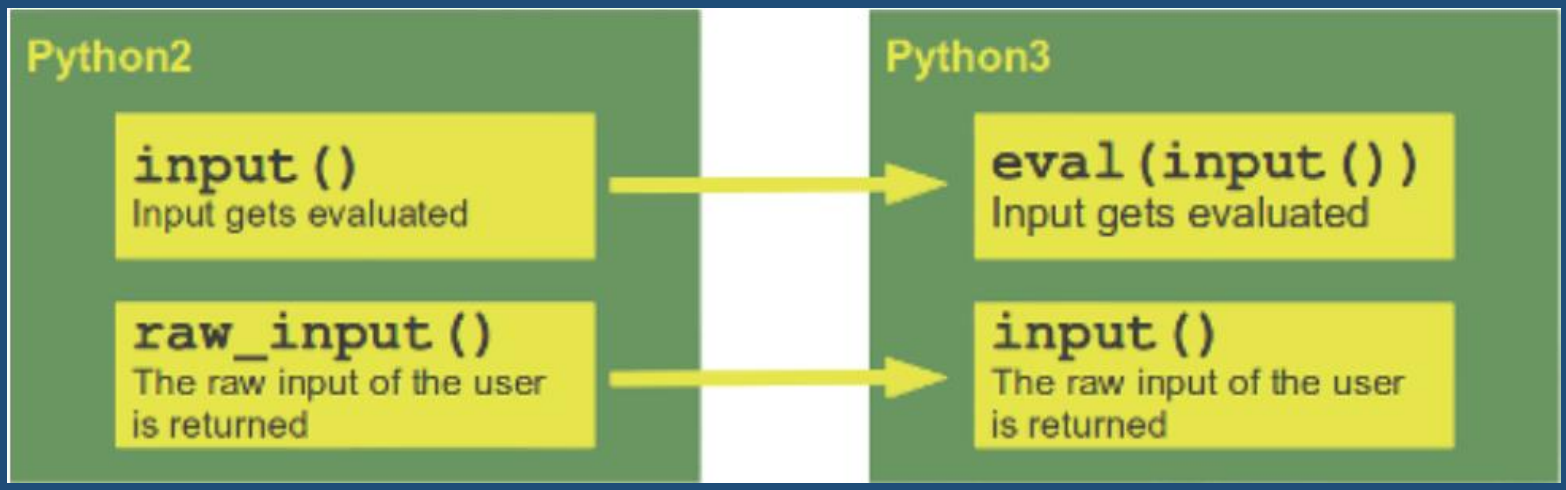
Introduction

For accepting input from user, Python provides the function input(). If the input function is called, the program flow will be stopped until the user has given an input and has ended the input with the return key.

```
name = input("What's your name? ")
print("Nice to meet you " + name + "!")
age = input("Your age? ")
print("So, you are already " + age + " years
old, " + name + "!")
```

The input of the user will be returned as a string without any changes. If this raw input has to be transformed into another data type needed by the algorithm, we can use either a casting function or the eval function.

Differences to Python2



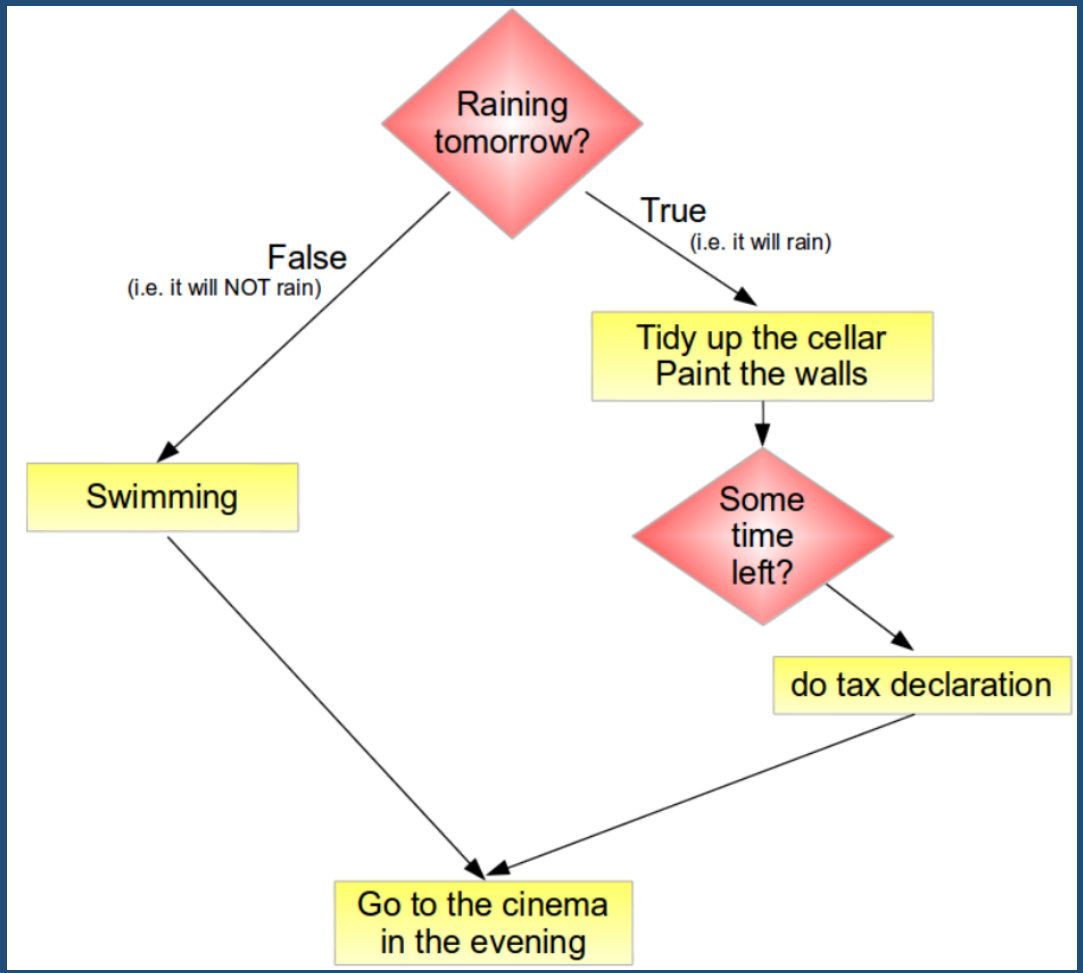
Topic 4a: If-else Block

Introduction

Imagine a situation of events / decisions like this:

```
If it rains tomorrow, I will do the following:
    - tidy up the cellar
    - paint the walls
    - If there is some time left, I will
          - do my tax declaration
Otherwise, I will do the following:
    - go swimming
go to the cinema with my wife in the evening
```

Such a work flow is often formulated in the programming environment as a so-called flow chart or programming flowchart:



How would other programming language pseudo code be:

```
if (raining_tomorrow) {
    tidy_up_the_cellar();
    paint_the_walls();
    if (time_left)
        do_taxes();
} else
    enjoy_swimming();
    go_cinema();
```

The code may be all right for the interpreter or the compiler of the language, but it can be written in a way, which is badly structured for humans.

In Python, blocks are created with indentations. We could say "What you see is what you get!"

```
if raining_tomorrow:
    tidy_up_the_cellar()
    paint_the_walls()
    if time_left:
        do_taxes()
else:
    enjoy_swimming()
go_cinema()
```

Conditional Statements in Python

if-statements are used to change the flow of control in a Python program. This makes it possible to decide at run-time whether or not to run one block of code or another.

```
if condition:
    statement
    statement
    # ... some more indented statements if
necessary
```

The indented block of code is executed only if the condition "condition" is evaluated to True, meaning that it is logically true.

Examples:

```
person = input("Nationality? ")
if person == "french":
    print("Préférez-vous parler français?")
```

```
person = input("Nationality? ")
if person == "french" or person == "French":
    print("Préférez-vous parler français?")
```

```
person = input("Nationality? ")
if person == "french" or person == "French" :
    print("Préférez-vous parler français?")
if person == "italian" or person == "Italian"
:
    print("Preferisci parlare italiano?")
```

```
person = input("Nationality? ")
if person == "french" or person == "French" :
    print("Préférez-vous parler français?")
elif person == "italian" or person ==
"Italian":
    print("Preferisci parlare italiano?")
else:
    print("You are neither Italian nor
French,")
    print("so we have to speak English with
each other.")
```

So, the general form of if statement in Python looks like:

```
if condition_1:
    statement_block_1
elif condition_2:
    statement_block_2

...

elif another_condition:
    another_statement_block
else:
    else_block
```

The ternary if

```
max = a if (a > b) else b
```

Expression is "max shall be a if a is greater than b else b".

```
max = (a if (a > b) else b) * 2.45 - 4
```

Here if is used in an expression, which can be used within another expression

Examples:

```
x = float(input("1st Number: "))
y = float(input("2nd Number: "))
z = float(input("3rd Number: "))

if x > y and x > z:
    maximum = x
elif y > x and y > z:
    maximum = y
else:
    maximum = z

print("The maximal value is: " + str(maximum))
```

```
x = float(input("1st Number: "))
y = float(input("2nd Number: "))
z = float(input("3rd Number: "))

if x > y:
    if x > z:
        maximum = x
    else:
        maximum = z
else:
    if y > z:
        maximum = y
    else:
        maximum = z

print("The maximal value is: " + str(maximum))
```

```
x = float(input("1st Number: "))
y = float(input("2nd Number: "))
z = float(input("3rd Number: "))

maximum = max((x,y,z))

print("The maximal value is: " + str(maximum))
```

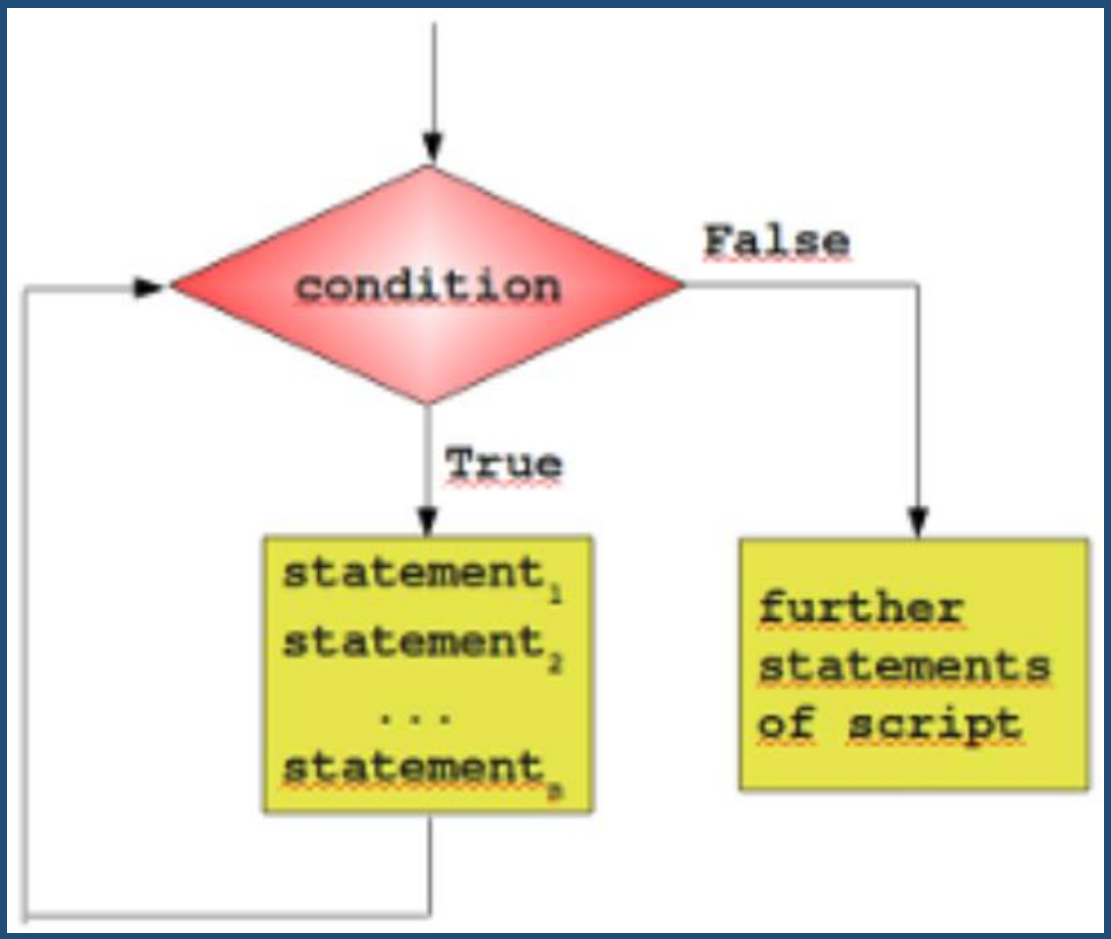
Topic 4b: Loops

Introduction

Python supplies two kinds of loops:

1. the while loop (condition-controlled loop)
   A loop will be repeated until a given condition changes, i.e. changes from True to False or from False to True, depending on the kind of loop.
2. the for loop (collection-controlled loop)
   This is a special construct which allow looping through the elements of a "collection", which can be a dictionary, list or other sequence.

While Loop



Examples:

```
n = 100

s = 0
counter = 1
while counter <= n:
    s = s + counter
    counter += 1

print("Sum of 1 until %d: %d" % (n,s))
```

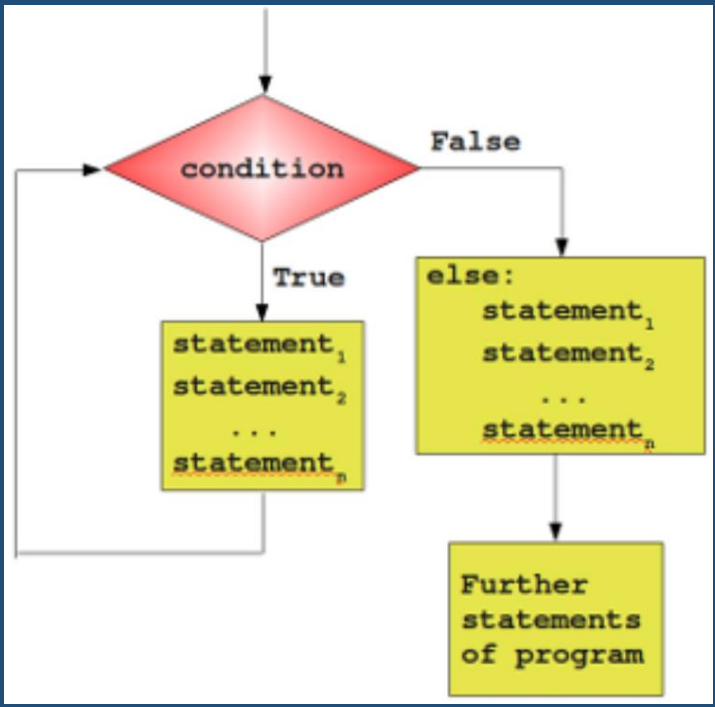
```
import sys

text = ""
while 1:
    c = sys.stdin.read(1)
    text = text + c
    if c == '\n':
        break

print("Input: %s" % text)
```

While with Else Part

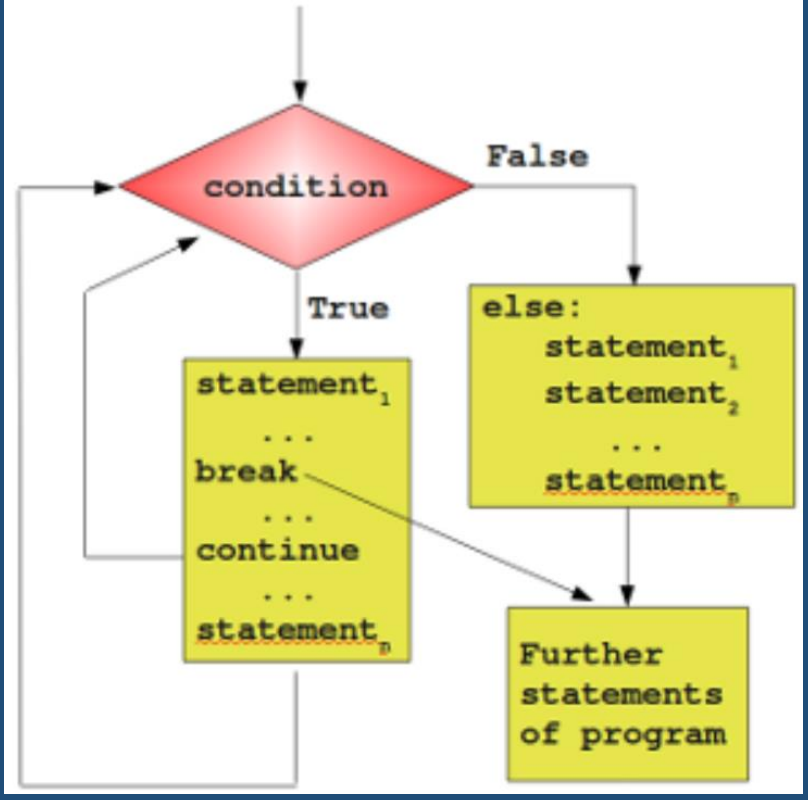
Similar to the if statement, the while loop of Python has also an optional else part.




```
while condition:
        statement_1
        ...
        statement_n
else:
        statement_1
        ...
        statement_n
```

Premature Termination of a While Loop

So far, a while loop only ends, if the condition in the loop head is fulfilled. With the help of a break statement a while loop can be left prematurely, i.e. the loop will be immediately left.




```
import random

n = 20

to_be_guessed = int(n *
random.random()) + 1

guess = 0

while guess != to_be_guessed:

    guess = int(input("New number: "))

    if guess > 0:

        if guess > to_be_guessed:

            print("Number too large")

        elif guess < to_be_guessed:

            print("Number too small")

    else:

        print("Sorry that you're giving up!")

        break

else:

    print("Congratulation. You made it!")
```

"break" shouldn't be confused with continue statement. "continue" stops the current iteration of the loop and starts the next iteration by checking the condition.

Note: If a loop is left by break, the else part is not executed.

Topic 4c: For Loop

Introduction

Python for loop is an iterator based for loop. It steps through the items of lists, tuples, strings, the keys of dictionaries and other iterables. General Syntax is:

```
for <variable> in <sequence>:
        <statements>
else:
        <statements>
```

The items of the sequence object are assigned one after the other to the loop variable. For each item the loop body is executed.

Examples:

```
>>> languages = ["C", "C++", "Perl", "Python"]
>>> for x in languages:
...     print(x)
...
C
C++
Perl
Python
```

If a break statement has to be executed in the program flow of the for loop, the loop will be exited and the program flow will continue with the first statement following the for loop, if there is any at all.

```
edibles = ["ham", "spam","eggs","nuts"]
for food in edibles:
    if food == "spam":
        print("No more spam please!")
        break
    print("Great, delicious " + food)
else:
    print("I am so glad: No spam!")
print("Finally, I finished stuffing myself")
```

```
edibles = ["ham", "spam", "eggs","nuts"]
for food in edibles:
    if food == "spam":
        print("No more spam please!")
        continue
    print("Great, delicious " + food)
    # here can be the code for enjoying our
food :-)
else:
    print("I am so glad: No spam!")
print("Finally, I finished stuffing myself")
```

The range() function

The built-in function range() is the right function to iterate over a sequence of numbers. It generates an iterator of arithmetic progressions:

Example:

```
range(begin,end, step)
```

```
>>> list(range(4,50,5))
[4, 9, 14, 19, 24, 29, 34, 39, 44, 49]
```

```
>>> list(range(42,-12,-7))
[42, 35, 28, 21, 14, 7, 0, -7]
```

```
fibonacci = [0,1,1,2,3,5,8,13,21]
for i in range(len(fibonacci)):
    print(i,fibonacci[i])
print()
```

The following program calculates all pythagorean numbers less than a maximal number. Three integers satisfying a2+b2=c2 are called Pythagorean numbers.

```
from math import sqrt
n = int(input("Maximal Number? "))
for a in range(1,n+1):
    for b in range(a,n):
        c_square = a**2 + b**2
        c = int(sqrt(c_square))
        if ((c_square - c**2) == 0):
            print(a, b, c)
```

List Iteration with Side Effects

If loop over a list, avoid changing the list in the loop body.

```
colours = ["red"]
for i in colours:
    if i == "red":
        colours += ["black"]
    if i == "black":
        colours += ["white"]
print(colours)
```

```
colours = ["red"]
for i in colours[:]:
    if i == "red":
        colours += ["black"]
    if i == "black":
        colours += ["white"]
print(colours)
```

Using slicing operator, even if changing list, the elements to be looped will remain the same during the iterations.

Topic 4d: Iterators & Iterables

Introduction

We have seen that we can loop or iterate over various Python objects like lists, tuples and strings for example.

```
for city in ["Berlin", "Vienna", "Zurich"]:
    print(city)
for city in ("Python", "Perl", "Ruby"):
    print(city)
for char in "Iteration is easy":
    print(char)
```

This form of looping can be seen as iteration. Iteration is not restricted to explicit for loops. If you call function sum e.g. on a list of integer values, - you do iteration as well.

So what is the difference between an iterable and an iterator?

- In one perspective they are the same: You can iterate with a for loop over iterators and iterables.
- Every iterator is also an iterable, but not every iterable is an iterator.
- E.g. a list is iterable but a list is not an iterator!

An iterator can be created from an iterable by using the function 'iter'.Iterators are objects with a '__next__' method, which will be used when the function 'next' is called.

So what is going on behind the scenes, when a for loop is executed?

- **The for statement calls iter() on the object (which should be a so-called container object), which it is supposed to loop over.**
- **If this call is successful, the iter call will return return an iterator object that defines the method __next__() which accesses elements of the object one at a time.**
- **The __next__() method will raise a StopIteration exception, if there are no further elements available.**

```
cities = ["Berlin", "Vienna", "Zurich"]
iterator_obj = iter(cities)
print(iterator_obj)
print(next(iterator_obj))
print(next(iterator_obj))
print(next(iterator_obj))
```

The following function 'iterable' will return True, if the object 'obj' is an iterable and False otherwise.

```
def iterable(obj):
    try:
        iter(obj)
        return True
    except TypeError:
        return False

for element in [34, [4, 5], (4, 5), {"a":4},
"dfsdf", 4.5]:
    print(element, "iterable: ",
iterable(element))
```

Topic 5a: Output with Print

Introduction

One of the most frequently occurring errors will be related to print, because print is a function in Python 3.x

```
>>> print 42
  File "", line 1
    print 42
          ^
SyntaxError: invalid syntax
```

```
>>> print(42)
42
```

The arguments of the print function are the following:

```
print(value1, ..., sep=' ', end='\n',
file=sys.stdout, flush=False)
```

The print function can print an arbitrary number of values ("value1, value2, ..."), which are separated by commas. These values are separated by blanks.

Examples:

```
>>> print("a","b")
a b
>>> print("a","b",sep="")
ab
>>> print(192,168,178,42,sep=".")
192.168.178.42
>>> print("a","b",sep=":-)")
a:-)b
```

```
>>> print("a = ", a)
a =  3.564
>>> print("a = \n", a)
a =
 3.564
```

By default, A print call is ended by a newline. To change this behaviour, we can assign an arbitrary string to the

keyword parameter "end". This string will be used for ending the output of the values of a print call:

```
>>> for i in range(4):
...     print(i)
...
0
1
2
3
```

```
>>> for i in range(4):
...     print(i, end=" ")
...
0 1 2 3 >>>
>>> for i in range(4):
...     print(i, end=" :-) ")
...
0 :-) 1 :-) 2 :-) 3 :-) >>>
```

The output of the print function is send to the standard output stream (sys.stdout) by default. By redefining the keyword parameter "file" we can send the output into a different stream e.g. sys.stderr or a file:

```
>>> fh = open("data.txt","w")
>>> print("42 is the answer, but what is the
question?", file=fh)
>>> fh.close()
```

We don't get any output in the interactive shell. Output is sent to the file "data.txt". It's also possible to redirect the output to the standard error channel this way:

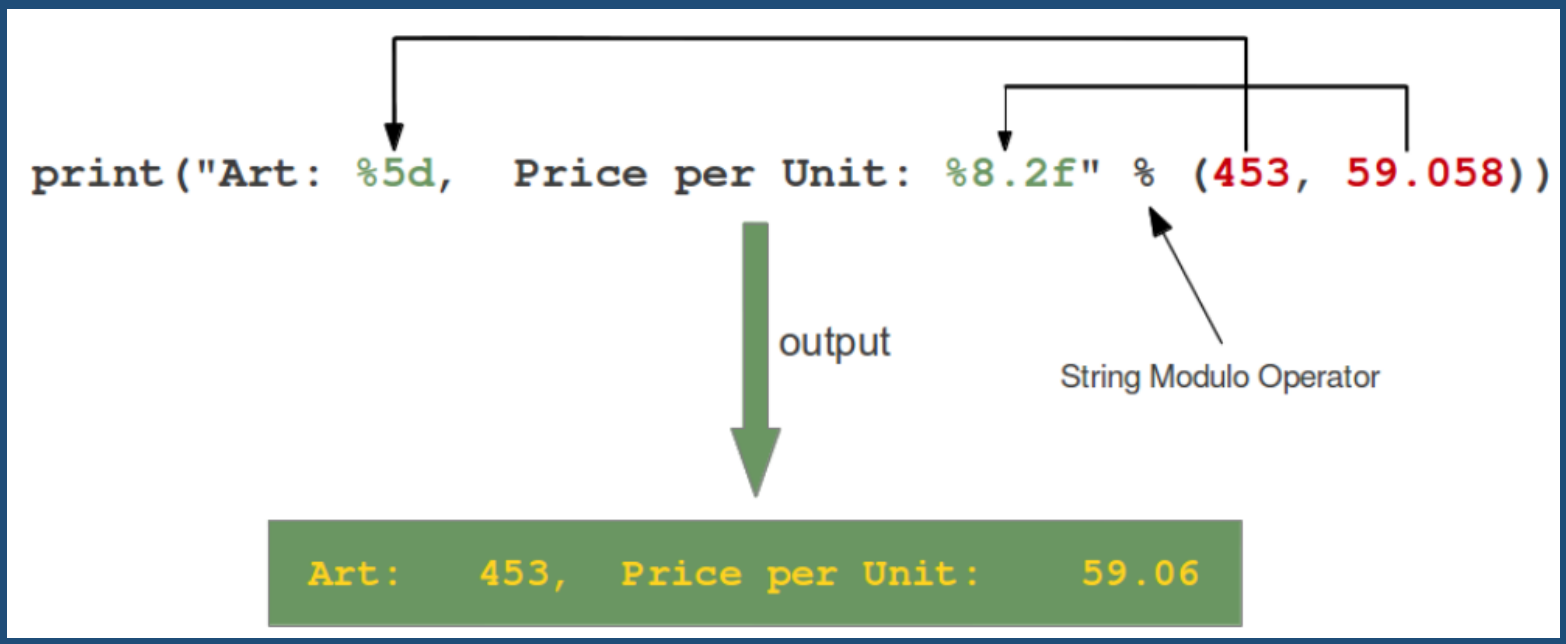
```
>>> import sys
>>> # output into sys.stderr:
...
>>> print("Error: 42", file=sys.stderr)
Error: 42
```

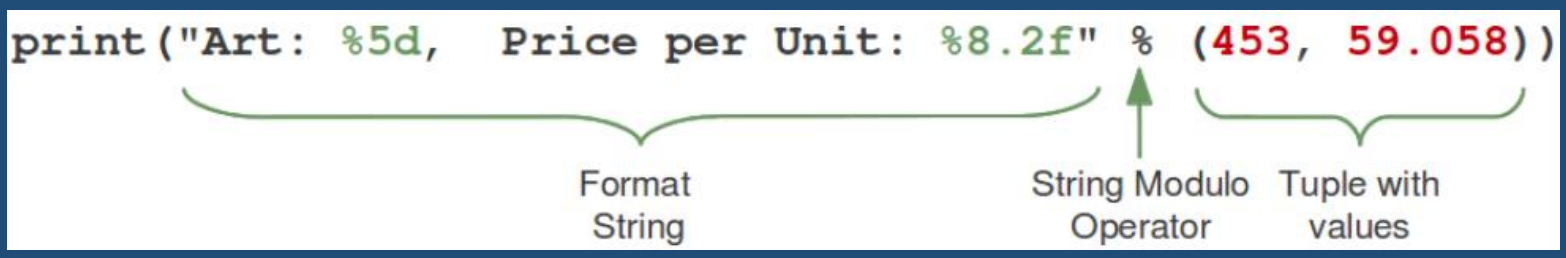
Topic 5b: String Modulo

Introduction

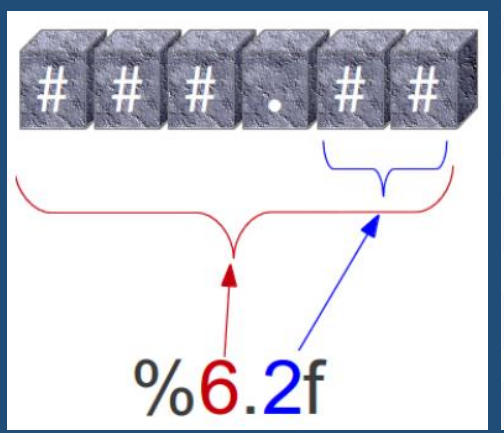
String Modulo "%" is the string formatter in Python.

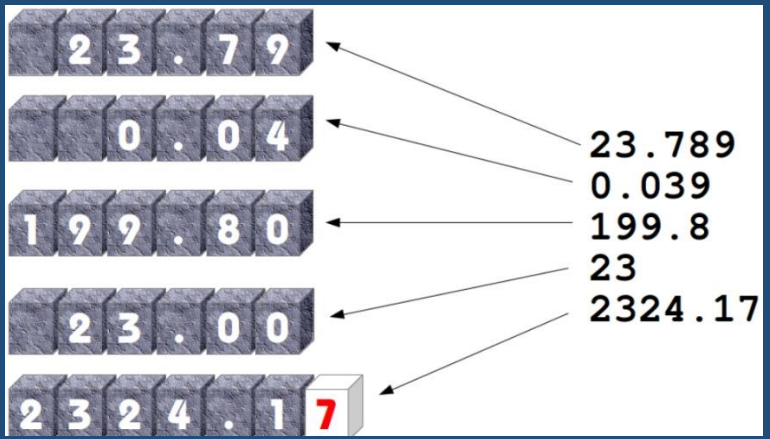
For the same purpose str.format() can also be used.





The format string contains placeholders. There are two of those in our example: "%5d" & "%8.2f". The general syntax for format placeholder is: `%[flags][width][.precision]type`





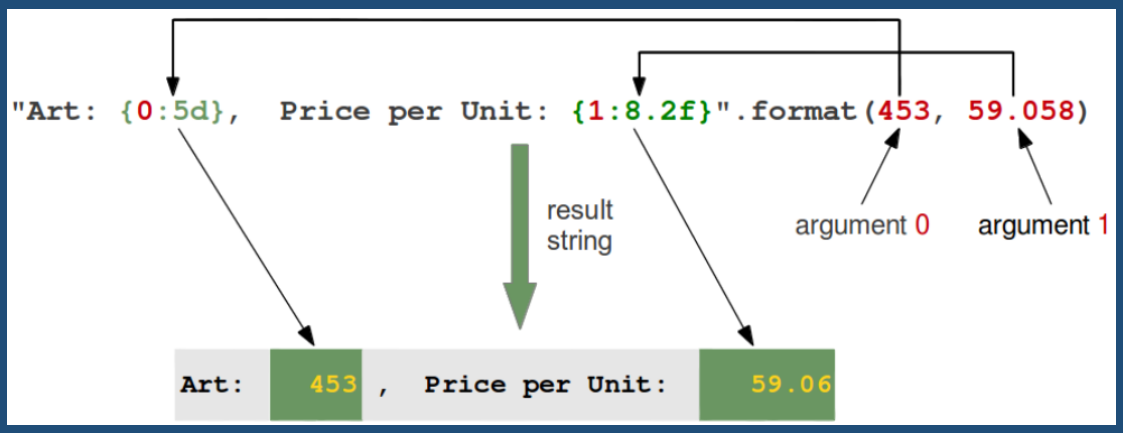
Topic 5c: Format Method

Introduction

The format method was added in Python 2.6. The general form of this method looks like this:

```
template.format(p0, p1, ..., k0=v0, k1=v1, ...)
```

The template (or format string) is a string which contains one or more format codes (fields to be replaced) embedded in constant text. The "fields to be replaced" are surrounded by curly braces {}.

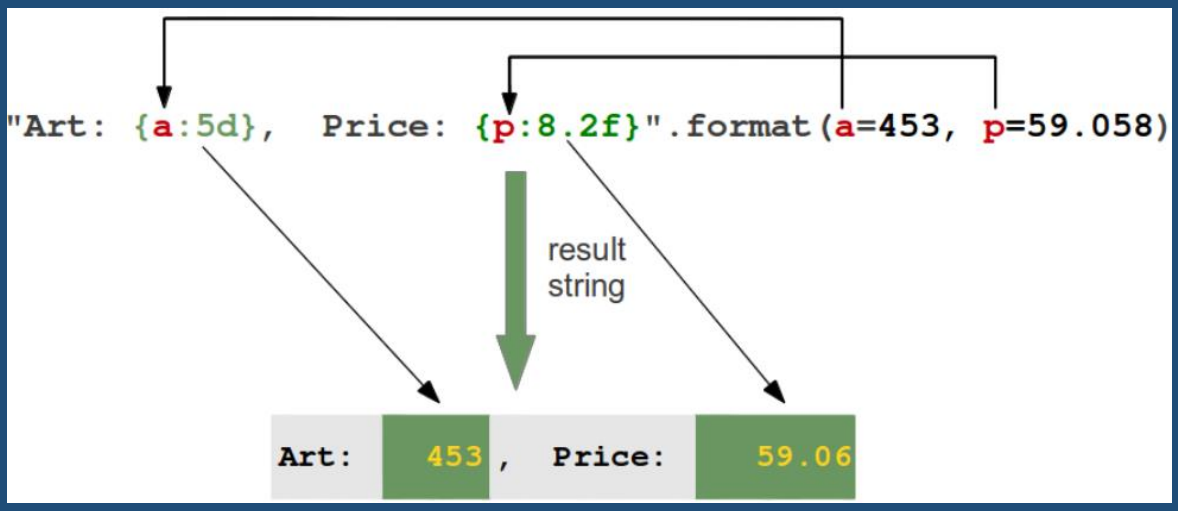


Examples of positional parameters:

```
>>> "First argument: {0}, second one:
{1}".format(47,11)
'First argument: 47, second one: 11'
>>> "Second argument: {1}, first one:
{0}".format(47,11)
'Second argument: 11, first one: 47'
>>> "Second argument: {1:3d}, first one:
{0:7.2f}".format(47.42,11)
'Second argument:  11, first one:   47.42'
>>> "First argument: {}, second one:
{}".format(47,11)
'First argument: 47, second one: 11'
>>> # arguments can be used more than once:
...
>>> "various precisions: {0:6.2f} or
{0:6.3f}".format(1.4148)
'various precisions:   1.41 or  1.415'
```

Keyword parameters used with the format method:

```
>>> "Art: {a:5d},  Price:
{p:8.2f}".format(a=453, p=59.058)
'Art:   453,  Price:    59.06'
```



It's possible to left or right justify data with this method:

```
>>> "{0:<20s} {1:6.2f}".format('Spam & Eggs:',
6.99)
'Spam & Eggs:            6.99'
>>> "{0:>20s} {1:6.2f}".format('Spam & Eggs:',
6.99)
'         Spam & Eggs:   6.99'
```

Dictionaries in “format”

```
>>> print("The capital of {0:s} is
{1:s}".format("Ontario","Toronto"))
The capital of Ontario is Toronto
```

```
>>> print("The capital of {province} is
{capital}".format(province="Ontario",capi
tal="Toronto"))
The capital of Ontario is Toronto
```

```
>>> print("The capital of {province} is
{capital}".format(province="Ontario",capi
tal="Toronto"))
The capital of Ontario is Toronto
```

```
>>> data =
dict(province="Ontario",capital="Toronto")
>>> data
{'province': 'Ontario', 'capital': 'Toronto'}
>>> print("The capital of {province} is
{capital}".format(**data))
The capital of Ontario is Toronto
```

The double "*" in front of data turns data automatically into the form 'province="Ontario",capital="Toronto"'.

```
capital_country = {"United States" :
"Washington",
                   "US" : "Washington",
                   "Canada" : "Ottawa",
                   "Germany": "Berlin",
                   "France" : "Paris",
                   "England" : "London",
                   "UK" : "London",
                   "Switzerland" : "Bern",
                   "Austria" : "Vienna",
                   "Netherlands" :
"Amsterdam"}

print("Countries and their capitals:")
for c in capital_country:
    format_string = c + ": {" + c + "}"

print(format_string.format(**capital_country))
```

Using local variable names in “format”

"locals" is a function, which returns a dictionary with the current scope's local variables, i.e- the local variable names are the keys of this dictionary and the corresponding values are the values of these variables:

```
>>> a = 42
>>> b = 47
>>> def f(): return 42
...
>>> locals()
{'a': 42, 'b': 47, 'f': <function f at
0xb718ca6c>, '__builtins__': <module
'builtins' (built-in)>, '__package__': None,
'__name__': '__main__', '__doc__': None}
```

Continuing with above example, we can create following output, in which we use the local variables a, b and f:

```
>>> print("a={a}, b={b} and f=
{f}".format(**locals()))
a=42, b=47 and f=<function f at 0xb718ca6c>
```

Formatted String Literals

Python 3.6 introduces formatted string literals. They are prefixed with an 'f'. The formatting syntax is similar to the format strings accepted by str.format(). Like the format string of format method, they contain replacement fields formed with curly braces. The replacement fields are expressions, which are evaluated at run time, and then formatted using the format() protocol.

```
>>> price = 11.23
>>> f"Price in Euro: {price}"
'Price in Euro: 11.23'
>>> f"Price in Swiss Franks: {price * 1.086}"
'Price in Swiss Franks: 12.195780000000001'
>>> f"Price in Swiss Franks: {price *
1.086:5.2f}"
'Price in Swiss Franks: 12.20'
>>> for article in ["bread", "butter", "tea"]:
...     print(f"{article:>10}:")
...
     bread:
    butter:
       tea:
```

Topic 6a: Functions

Introduction

A Function is a structuring element in programming languages to group a set of statements so they can be utilized more than once in a program. A function in Python is defined by a def statement. The syntax is:

```
def function-name(Parameter list):
    statements, i.e. the function body
```

- **The parameter list consists of none or more parameters & called arguments if function is called.**
- **Function bodies can contain one or more return statement. They can be situated anywhere in the function body.**
- **A return statement ends the execution of the function call and "returns" the result.**
- **If the return statement is without an expression or no return statement, the special value None is returned.**

```
def fahrenheit(T_in_celsius):
    """ returns the temperature in degrees
Fahrenheit """
    return (T_in_celsius * 9 / 5) + 32

for t in (22.6, 25.8, 27.3, 29.8):
    print(t, ": ", fahrenheit(t))
```

Doc String

The first statement in the body of a function is usually a string which can be accessed with function_name. __doc__. This statement is called Docstring.

```
def Hello(name="everybody"):
    """ Greets a person """
    print("Hello " + name + "!")

print("The docstring of the function Hello: "
+ Hello.__doc__)
```

Examples

```
def sumsub(a, b, c=0, d=0):
    return a - b + c - d

print(sumsub(12,4))
print(sumsub(42,15,d=10))
```

```
def Hello(name="everybody"):
    """ Greets a person """
    print("Hello " + name + "!")

Hello("Peter")
Hello()
```

```
def no_return(x,y):
    c = x + y

res = no_return(4,5)
print(res)
```

```
def return_sum(x,y):
    c = x + y
    return c

res = return_sum(4,5)
print(res)
```

```
def empty_return(x,y):
    c = x + y
    return

res = empty_return(4,5)
print(res)
```

```
def fib_intervall(x):
    """ returns the largest fibonacci
    number smaller than x and the lowest
    fibonacci number higher than x"""
    if x < 0:
        return -1
    (old,new, lub) = (0,1,0)
    while True:
        if new < x:
            lub = new
            (old,new) = (new,old+new)
        else:
            return (lub, new)
while True:
    x = int(input("Your number: "))
    if x <= 0:
        break
    (lub, sup) = fib_intervall(x)
    print("Largest Fibonacci Number smaller than x: " + str(lub))
    print("Smallest Fibonacci Number larger than x: " + str(sup))
```

Local and Global Variables

Variable names are by default local to the function, in which they get defined.

```
def f():
    s = "Perl"
    print(s)
s = "Python"
f()
print(s)
```

```
def f():
    s = "Perl"
    print(s)
s = "Python"
f()
print(s)
```

```
def f():
    print(s)
    s = "Perl"
    print(s)
s = "Python"
f()
print(s)
```

```
def f():
    global s
    print(s)
    s = "dog"
    print(s)
s = "cat"
f()
print(s)
```

In the third example above, variable s is ambigious in f(), i.e. first print in f() the global s could be used with the value "Python". After this we define a local variable s with the assignment s = "Perl".

Now, in the fourth example, we made the variable s global inside of the script on the left side. Therefore anything we do to s inside of the function body of f is done to the global variable s outside of f.

More Examples

```
def arithmetic_mean(first, *values):
    """ This function calculates the
arithmetic mean of a non-empty
        arbitrary number of numerical values
"""

    return (first + sum(values)) / (1 +
len(values))

print(arithmetic_mean(45,32,89,78))
print(arithmetic_mean(8989.8,78787.78,3453,787
78.73))
print(arithmetic_mean(45,32))
print(arithmetic_mean(45))
```

This is great, but if we have a list of numerical values, we can use "*" to unpack the list when calling the function.

```
x = [3, 5, 9]
arithmetic_mean(x)
arithmetic_mean(x[0], x[1], x[2])
arithmetic_mean(*x)
```

```
>>> def f(**kwargs):
...     print(kwargs)
...
>>> f()
{}
>>> f(de="German",en="English",fr="French")
{'fr': 'French', 'de': 'German', 'en':
'English'}
```

Topic 6b: Recursive Function

Recursion is a method of programming in which a function calls itself one or more times in its body. Usually, it is returning the return value of this function call.

```
def factorial(n):
    print("factorial has been called with n =
" + str(n))
    if n == 1:
        return 1
    else:
        res = n * factorial(n-1)
        print("intermediate result for ", n, "
* factorial(" ,n-1, "): ",res)
        return res

print(factorial(5))
```

Exercise:

Create a deeply nested sublist and print each and every element using simple function or a recursive function.

Hint – use isinstance() built-in function

Topic 6c: Parameters & Arguments

Call by Value v/s Call by Reference

The evaluation strategy for arguments, i.e. how the arguments from a function call are passed to the parameters of the function, differs in each programming language. The most common evaluation strategies are "call by value" and "call by reference":

- Call by Value:
  The argument expression is evaluated, and the result of this evaluation is bound to the corresponding variable in the function. So, its value will be assigned (copied) to the corresponding parameter. This ensures that the variable in the caller's scope will be unchanged when the function returns.
- Call by Reference:
  Here, function gets an implicit reference to the argument, rather than a copy of its value. Thus, the function can modify the argument, i.e. the value of the variable in the caller's scope can be changed.
  We save computation time and memory space, as arguments do not need to be copied. But need to be careful as that variables can be "accidentally" changed in the function call.

And what about Python?

Python uses a mechanism, which is known as "Call-by-Object", sometimes also called "Call by Object Reference" or "Call by Sharing".

```
def ref_demo(x):
    print("x=",x," id=",id(x))
    x=42
    print("x=",x," id=",id(x))
```

```
>>> x = 9
>>> id(x)
9251936
>>> ref_demo(x)
x= 9  id= 9251936
x= 42  id= 9252992
>>> id(x)
9251936
```

Examples:

```
>>> def no_side_effects(cities):
...     print(cities)
...     cities = cities + ["Birmingham",
"Bradford"]
...     print(cities)
...
>>> locations = ["London", "Leeds", "Glasgow",
"Sheffield"]
>>> no_side_effects(locations)
['London', 'Leeds', 'Glasgow', 'Sheffield']
['London', 'Leeds', 'Glasgow', 'Sheffield',
'Birmingham', 'Bradford']
>>> print(locations)
['London', 'Leeds', 'Glasgow', 'Sheffield']
```

```
>>> def side_effects(cities):
...     print(cities)
...     cities += ["Birmingham", "Bradford"]
...     print(cities)
...
>>> locations = ["London", "Leeds", "Glasgow",
"Sheffield"]
>>> side_effects(locations)
['London', 'Leeds', 'Glasgow', 'Sheffield']
['London', 'Leeds', 'Glasgow', 'Sheffield',
'Birmingham', 'Bradford']
>>> print(locations)
['London', 'Leeds', 'Glasgow', 'Sheffield',
'Birmingham', 'Bradford']
```

```
>>> def side_effects(cities):
...     print(cities)
...     cities += ["Paris", "Marseille"]
...     print(cities)
...
>>> locations = ["Lyon", "Toulouse", "Nice",
"Nantes", "Strasbourg"]
>>> side_effects(locations[:])
['Lyon', 'Toulouse', 'Nice', 'Nantes',
'Strasbourg']
['Lyon', 'Toulouse', 'Nice', 'Nantes',
'Strasbourg', 'Paris', 'Marseille']
>>> print(locations)
['Lyon', 'Toulouse', 'Nice', 'Nantes',
'Strasbourg']
```

Variable length of Parameters

The asterisk "*" is used in Python to define a variable number of arguments. The asterisk character has to precede a variable identifier in the parameter list.

```
>>> def varpafu(*x): print(x)
...
>>> varpafu()
()
>>> varpafu(34,"Do you like Python?", "Of
course")
(34, 'Do you like Python?', 'Of course')
```

```
>>> def locations(city, *other_cities):
print(city, other_cities)
...
>>> locations("Paris")
Paris ()
>>> locations("Paris", "Strasbourg", "Lyon",
"Dijon", "Bordeaux", "Marseille")
Paris ('Strasbourg', 'Lyon', 'Dijon',
'Bordeaux', 'Marseille')
```

A * can appear in function calls as well

```
>>> def f(x,y,z):
...     print(x,y,z)
...
>>> p = (47,11,12)
>>> f(*p)
(47, 11, 12)
```

```
>>> f(p[0],p[1],p[2])
(47, 11, 12)
```

Topic 6d: Namespaces

Introduction

Namespace is a naming system for making names unique. In Python, they are implemented as dictionaries by a mapping from names, i.e. the keys of the dictionary, to objects, i.e. the values. Namespaces have different lifetimes, as per the points of time they are created.

Some namespaces in Python:

1. global names of a module
   The global namespace of a module is generated when the module is read in. Module namespaces normally last until the script ends, i.e. the interpreter quits.
2. local names in a function or method invocation :
   When a function is called, a local namespace is created for this function. This namespace is deleted either if the function ends, i.e. returns, or if the function raises an exception, which is not dealt with within the function.
3. built-in names: This namespace contains built-in fuctions, created when the Python interpreter starts up, and is never deleted.

Topic 6e: Global & Local Variables

Introduction

While in many or most other programming languages variables are treated as global if not otherwise declared, Python deals with variables the other way around. They are local, if not otherwise declared.

The driving reason behind this approach is that global variables are generally bad practice and should be avoided. In most cases where we are tempted to use a global variable, it's better to utilize a parameter for getting a value into function or return value to get it out.

So when you define variables inside a function definition, they are local to this function by default. This means that anything you will do to such a variable in the body of the function will have no effect on other variables outside of the function, even if they have the same name.

Examples:

```
def f():
    print(s)
s = "I love Paris in the summer!"
f()
```

```
def f():
    s = "I love London!"
    print(s)

s = "I love Paris!"
f()
print(s)
```

```
>>> def f():
...     print(s)
...     s = "I love London!"
...     print(s)
...
>>> s = "I love Paris!"
>>> f()
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 2, in f
UnboundLocalError: local variable 's'
referenced before assignment
```

```
def f():
    global s
    print(s)
    s = "Only in spring, but London is great
as well!"
    print(s)


s = "I am looking for a course in Paris!"
f()
print(s)
```

```
def f():
    s = "I am globally not known"
    print(s)

f()
print(s)
```

```
def f():
    x = 42
    def g():
        global x
        x = 43
    print("Before calling g: " + str(x))
    print("Calling g now:")
    g()
    print("After calling g: " + str(x))

f()
print("x in main: " + str(x))
```

Nonlocal Variables

Python3 introduced nonlocal variables as a new kind of variables. nonlocal variables have a lot in common with global variables. One difference to global variables lies in the fact that it is not possible to change variables from the module scope, i.e. variables which are not defined inside of a function, by using the nonlocal statement.

```
def f():
    global x
    print(x)

x = 3
f()
```

```
def f():
    nonlocal x
    print(x)

x = 3
f()
```

```
def f():
    x = 42
    def g():
        nonlocal x
        x = 43
    print("Before calling g: " + str(x))
    print("Calling g now:")
    g()
    print("After calling g: " + str(x))

x = 3
f()
print("x in main: " + str(x))
```

```
def f():
    #x = 42
    def g():
        nonlocal x
        x = 43
    print("Before calling g: " + str(x))
    print("Calling g now:")
    g()
    print("After calling g: " + str(x))

x = 3
f()
print("x in main: " + str(x))
```

```
def f():
    #x = 42
    def g():
        global x
        x = 43
    print("Before calling g: " + str(x))
    print("Calling g now:")
    g()
    print("After calling g: " + str(x))

x = 3
f()
print("x in main: " + str(x))
```

Topic 6f: Decorators

Introduction

A decorator in Python is any callable Python object that is used to modify a function or a class. A reference to a function "func" or a class "C" is passed to a decorator and the decorator returns a modified function or class. The modified functions or classes usually contain calls to the original function "func" or class "C".

First Steps to Decorators

```
>>> def succ(x):
...     return x + 1
...
>>> successor = succ
>>> successor(10)
11
>>> succ(10)
11
```

```
>>> del succ
>>> successor(10)
11
```

Functions inside Functions

```
def f():

    def g():
        print("Hi, it's me 'g'")
        print("Thanks for calling me")

    print("This is the function 'f'")
    print("I am calling 'g' now:")
    g()


f()
```

Functions as Parameters

```
def g():
    print("Hi, it's me 'g'")
    print("Thanks for calling me")

def f(func):
    print("Hi, it's me 'f'")
    print("I will call 'func' now")
    func()

f(g)
```

```
import math

def foo(func):
    print("The function " + func.__name__ + "
was passed to foo")
    res = 0
    for x in [1, 2, 2.5]:
        res += func(x)
    return res

print(foo(math.sin))
print(foo(math.cos))
```

Functions returning Functions

```
def f(x):
    def g(y):
        return y + x + 3
    return g

nf1 = f(1)
nf2 = f(3)

print(nf1(1))
print(nf2(1))
```

```
def polynomial_creator(a, b, c):
    def polynomial(x):
        return a * x**2 + b * x + c
    return polynomial

p1 = polynomial_creator(2, 3, -1)
p2 = polynomial_creator(-1, 2, 1)

for x in range(-2, 2, 1):
    print(x, p1(x), p2(x))
```

First Decorator

```
def our_decorator(func):
    def function_wrapper(x):
        print("Before calling " + func.__name__)
        func(x)
        print("After calling " + func.__name__)
    return function_wrapper

def foo(x):
    print("Hi, foo has been called with " + str(x))

print("We call foo before decoration:")
foo("Hi")

print("We now decorate foo with f:")
foo = our_decorator(foo)

print("We call foo after decoration:")
foo(42)
```

Correct decoration occurs in the line before function header. “@” is followed by the decorator function name.

```
def our_decorator(func):
    def function_wrapper(x):
        print("Before calling " + func.__name__)
        func(x)
        print("After calling " + func.__name__)
    return function_wrapper

@our_decorator
def foo(x):
    print("Hi, foo has been called with " + str(x))

foo("Hi")
```

```
def our_decorator(func):
    def function_wrapper(x):
        print("Before calling " + func.__name__)
        res = func(x)
        print(res)
        print("After calling " + func.__name__)
    return function_wrapper

@our_decorator
def succ(n):
    return n + 1

succ(10)
```

```
from math import sin, cos

def our_decorator(func):
    def function_wrapper(x):
        print("Before calling " + func.__name__)
        res = func(x)
        print(res)
        print("After calling " + func.__name__)
    return function_wrapper

sin = our_decorator(sin)
cos = our_decorator(cos)

for f in [sin, cos]:
    f(3.1415)
```

The following examples uses a decorator to count the number of times a function has been called & Fibonacci.

```
def call_counter(func):
    def helper(x):
        helper.calls += 1
        return func(x)
    helper.calls = 0

    return helper

@call_counter
def succ(x):
    return x + 1

print(succ.calls)
for i in range(10):
    succ(i)

print(succ.calls)
```

```
def memoize(f):
    memo = {}
    def helper(x):
        if x not in memo:
            memo[x] = f(x)
        return memo[x]
    return helper

@memoize
def fib(n):
    if n == 0:
        return 0
    elif n == 1:
        return 1
    else:
        return fib(n-1) + fib(n-2)

print(fib(40))
```

Topic 7a: Read and Write Files

Introduction

The syntax for reading and writing files in Python is similar to programming languages like C, C++, Java, Perl, and others but a lot easier to handle. So, first example, how to read a data from a file.

```
fobj = open("ad_lesbiam.txt")
for line in fobj:
    print(line.rstrip())
fobj.close()
```

The "r" is optional. open() command with just file name is opened for reading by default. It returns a file object, which offers attributes and methods.

Next, how to write a file.

```
fh = open("example.txt", "w")
fh.write("To write or not to write\nthat is
the question!\n")
fh.close()
```

Especially if you are writing to a file, you should never forget to close the file handle again. Otherwise you will risk to end up in a non consistent state of your data.

Another way to read / write a file is using “with” statement. The advantage is that the file will be

automatically closed after the indented block after the with has finished execution.

```
with open("example.txt", "w") as fh:
    fh.write("To write or not to write\nthat
is the question!\n")
```

```
with open("ad_lesbiam.txt") as fobj:
    for line in fobj:
        print(line.rstrip())
```

Example for simultaneously reading and writing:

```
fobj_in = open("ad_lesbiam.txt")
fobj_out = open("ad_lesbiam2.txt","w")
i = 1
for line in fobj_in:
    print(line.rstrip())
    fobj_out.write(str(i) + ": " + line)
    i = i + 1
fobj_in.close()
fobj_out.close()
```

There is one possible problem: What happens if we open a file for writing, and this file already exists.

As soon as an open() with a "w" has been executed, the file will be removed.

If you want to append something to an existing file, you have to use "a" instead of "w".

Reading in one go

So far we worked on files line by line by using a for loop. Very often, especially if the file is not too large, it's more convenient to read the file into a complete data structure, e.g. a string or a list. The file can be closed after reading and the work is accomplished on this data structure.

```
>>> poem = open("ad_lesbiam.txt").readlines()
>>> print(poem)
```

Another convenient way to read in a file might be the method read() of open. With this method we can read the complete file into a string.

```
>>> poem = open("ad_lesbiam.txt").read()
>>> print(poem[16:34])
VIVAMUS mea Lesbia
>>> type(poem)
<type 'str'>
```

This string contains the complete content of the file, which includes the carriage returns and line feeds.

Resetting the file's current position

It's possible to set - or reset - a file's position to a certain position, also called the offset. To do this, we use the method seek. The parameter of seek determines the offset which we want to set the current position to.

```
>>> fh = open("buck_mulligan.txt")
>>> fh.tell()
0
>>> fh.read(7)
'Stately'
>>> fh.tell()
7
>>> fh.read()
', plump Buck Mulligan came from the
stairhead, bearing a bowl of\nlather on which
a mirror and a razor lay crossed.\n'
>>> fh.tell()
122
>>> fh.seek(9)
9
>>> fh.read(5)
'plump'
```

It's also possible to set the file position relative to the current position by using tell correspondingly

```
>>> fh = open("buck_mulligan.txt")
>>> fh.read(15)
'Stately, plump '
>>> # set the current position 6 characters to
the left:
...
>>> fh.seek(fh.tell() -6)
9
>>> fh.read(5)
'plump'
>>> # now, we will advance 29 characters to
the
>>> # 'right' relative to the current
position:
...
>>> fh.seek(fh.tell() + 29)
43
>>> fh.read(10)
'stairhead,'
```

Read and Write to the same file

If the file doesn't exist, it will be created. If we want to open an existing file for read & write, we should better use "r+", as this will not delete the content of the file.

```
fh = open('colours.txt', 'w+')
fh.write('The colour brown')

# Go to the 12th byte in the file, counting
starts with 0
fh.seek(11)
print(fh.read(5))
print(fh.tell())
fh.seek(11)
fh.write('green')
fh.seek(0)
content = fh.read()
print(content)
```

Pickle Module

How we can save data in an easy way that our program can reread them at a later date again. We are "pickling" the data, so that nothing gets lost.

Python offers for this purpose a module, which is called "pickle". With the algorithms of the pickle module we can serialize and de-serialize Python object structures.

"Pickling" denotes the process which converts a Python object hierarchy into a byte stream, and "unpickling" on the other hand is the inverse operation, i.e. the byte stream is converted back into an object hierarchy.

Examples

```
>>> import pickle
>>>
>>> cities = ["Paris", "Dijon", "Lyon",
"Strasbourg"]
>>> fh = open("data.pkl", "bw")
>>> pickle.dump(cities, fh)
>>> fh.close()
```

```
>>> import pickle
>>> f = open("data.pkl", "rb")
>>> villes = pickle.load(f)
>>> print(villes)
['Paris', 'Dijon', 'Lyon', 'Strasbourg']
```

```
>>> import pickle
>>> fh = open("data.pkl","bw")
>>> programming_languages = ["Python", "Perl",
"C++", "Java", "Lisp"]
>>> python_dialects = ["Jython", "IronPython",
"CPython"]
>>> pickle_object = (programming_languages,
python_dialects)
>>> pickle.dump(pickle_object,fh)
>>> fh.close()
```

```
>>> import pickle
>>> f = open("data.pkl","rb")
>>> (languages, dialects) = pickle.load(f)
>>> print(languages, dialects)
['Python', 'Perl', 'C++', 'Java', 'Lisp']
['Jython', 'IronPython', 'CPython']
```

Topic 7b: Modules

Introduction

What a Python module is. To put it in a nutshell: every file, which has the file extension .py and consists of proper Python code, can be seen or is a module.

```
import math
```

```
import math, random
```

```
from math import sin, pi
```

```
>>> math.pi
3.141592653589793
>>> math.sin(math.pi/2)
1.0
>>> math.cos(math.pi/2)
6.123031769111886e-17
>>> math.cos(math.pi)
-1.0
```

```
>>> from math import *
>>> sin(3.01) + tan(cos(2.1)) + e
2.296883711382604
>>> e
2.718281828459045
```

```
>>> import fibonacci
>>> fibonacci.fib(7)
13
```

Execute Module as Script

```
if __name__ == "__main__":
    import sys
    fib(int(sys.argv[1]))
```

```
$ python fibo.py 50
1 1 2 3 5 8 13 21 34
```

If it is imported, the code in the if block is not executed.

```
>>> import math as mathematics
>>> print(mathematics.cos(mathematics.pi))
-1.0
```

```
import sys
print(sys.builtin_module_names)
```

Module Search Path

```
import sys
print(sys.builtin_module_names)
```

```
>>> import numpy
>>> numpy.__file__
'/usr/lib/python3/dist-
packages/numpy/__init__.py'
>>>
>>> import random
>>> random.__file__
'/usr/lib/python3.5/random.py'
```

```
>>> import math
>>> dir(math)
```

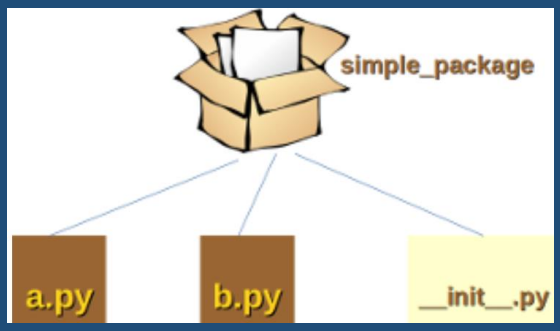
```
>>> import math
>>> cities = ["New York", "Toronto", "Berlin",
"Washington", "Amsterdam", "Hamburg"]
>>> dir()
```

Topic 7c: Packages

Introduction

A package is basically a directory with Python files and a file with the name __init__.py. This means that every directory inside of the Python path, which contains a file named __init__.py, will be treated as a python package.

Packages are a way of structuring Python's module namespace by using "dotted module names". A.B stands for a submodule named B in a package named A. Two different packages like P1 and P2 can both have modules with the same name.




```
>>> from simple_package import a, b
>>> a.bar()
Hello, function 'bar' from module 'a' calling
>>> b.foo()
Hello, function 'foo' from module 'b' calling
```

```
sound
|-- effects
|   |-- echo.py
|   |-- __init__.py
|   |-- reverse.py
|   `-- surround.py
|-- filters
|   |-- equalizer.py
|   |-- __init__.py
|   |-- karaoke.py
|   `-- vocoder.py
|-- formats
|   |-- aiffread.py
|   |-- aiffwrite.py
|   |-- auread.py
|   |-- auwrite.py
|   |-- __init__.py
|   |-- wavread.py
|   `-- wavwrite.py
`-- __init__.py
```

```
>>> import sound
sound package is getting imported!
>>> sound
<module 'sound' from
'/home/bernd/packages/sound/__init__.py'>
>>> sound.effects
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: module 'sound' has no
attribute 'effects'
```

```
>>> import sound.effects
effects package is getting imported!
>>> sound.effects
<module 'sound.effects' from
'/home/bernd/packages/sound/effects/__init__.p
y'>
```

It is possible to have it done automatically when importing the sound module. For this purpose, we have to add the code line import sound.effects into the file __init__.py of the directory sound.

```
"""An empty sound package

This is the sound package, providing hardly
anything!"""

import sound.effects
print("sound package is getting imported!")
```

```
>>> import sound
effects package is getting imported!
sound package is getting imported!
```

It is also possible to automatically import the package formats, when we are importing the effects package.

```
from .. import formats
```

```
>>> import sound
formats package is getting imported!
effects package is getting imported!
sound package is getting imported!
```

To import module karaoke from the package filters when we import the effects package. Add “from ..filters import karaoke” into the __init__.py file of the directory effects.

```
"""An empty effects package

This is the effects package, providing hardly
anything!"""

from .. import formats
from ..filters import karaoke
print("effects package is getting imported!")
```

```
>>> import sound
formats package is getting imported!
filters package is getting imported!
Module karaoke.py has been loaded!
effects package is getting imported!
sound package is getting imported!
```

```
>>> sound.filters.karaoke.func1()
Funktion func1 has been called!
```

Python provides a mechanism to give an explicit index of the subpackages and modules of a packages, which should be imported. We can define a list named __all__ in the __init__.py file of the sound directory.

```
__all__ = ["formats", "filters", "effects",
"foobar"]
```

```
>>> from sound import *
sound package is getting imported!
formats package is getting imported!
filters package is getting imported!
effects package is getting imported!
The module foobar is getting imported
```

```
>>> dir()
['__builtins__', '__doc__', '__loader__',
'__name__', '__package__', '__spec__',
'effects', 'filters', 'foobar', 'formats']
```

```
__all__ = ["echo", "surround", "reverse"]
```

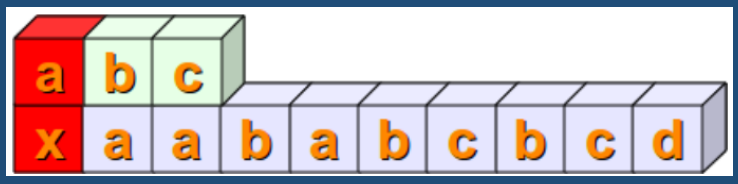
```
>>> from sound.effects import *
sound package is getting imported!
effects package is getting imported!
Module echo.py has been loaded!
Module surround.py has been loaded!
Module reverse.py has been loaded!
>>>
>>> dir()
['__builtins__', '__doc__', '__loader__',
'__name__', '__package__', '__spec__', 'echo',
'reverse', 'surround']
```

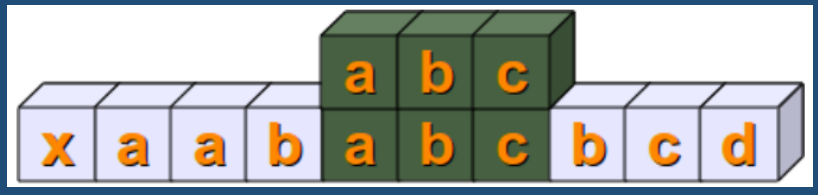
Topic 8a: Regular Expressions

Introduction

Regular Expressions are used in programming languages to filter texts or textstrings. It's possible to check, if a text or a string matches a regular expression.

```
>>> s = "Regular expressions easily explained!"
>>> "easily" in s
True
```





Examples:

```
>>> import re
>>> x = re.search("cat","A cat and a rat can't
be friends.")
>>> print(x)
<_sre.SRE_Match object at 0x7fd4bf238238>
>>> x = re.search("cow","A cat and a rat can't
be friends.")
>>> print(x)
None
```

```
>>> if re.search("cat","A cat and a rat can't
be friends."):
...     print("Some kind of cat has been found
:-)")
... else:
...     print("No cat has been found :-)")
...
Some kind of cat has been found :-)
>>> if re.search("cow","A cat and a rat can't
be friends."):
...     print("Cats and Rats and a cow.")
... else:
...     print("No cow around.")
...
No cow around.
```

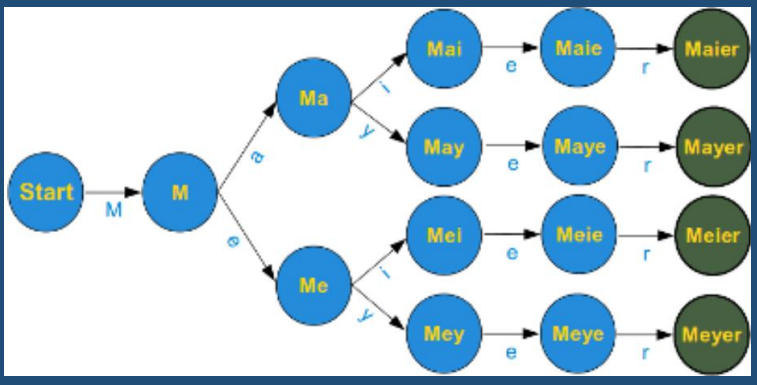
Any Character

Square brackets, "[" and "]", are used to include a character class. [xyz] means either an "x", an "y" or a "z".

```
r"M[ae][iy]er"
```

```
import re

fh = open("simpsons_phone_book.txt")
for line in fh:
    if re.search(r"J.*Neu",line):
        print(line.rstrip())
fh.close()
```



More Examples:

```
>>> import re
>>> line = "He is a German called Mayer."
>>> if re.search(r"M[ae][iy]er",line):
print("I found one!")
...
I found one!
```

```
>>> import re
>>> s1 = "Mayer is a very common Name"
>>> s2 = "He is called Meyer but he isn't
German."
>>> print(re.search(r"M[ae][iy]er", s1))
<_sre.SRE_Match object at 0x7fc59c5f26b0>
>>> print(re.search(r"M[ae][iy]er", s2))
<_sre.SRE_Match object at 0x7fc59c5f26b0>
>>> print(re.match(r"M[ae][iy]er", s1))
<_sre.SRE_Match object at 0x7fc59c5f26b0>
>>> print(re.match(r"M[ae][iy]er", s2))
None
```

```
>>> import re
>>> s1 = "Mayer is a very common Name"
>>> s2 = "He is called Meyer but he isn't
German."
>>> print(re.search(r"^M[ae][iy]er", s1))
<_sre.SRE_Match object at 0x7fc59c5f26b0>
>>> print(re.search(r"^M[ae][iy]er", s2))
None
```

```
>>> print(re.search(r"^M[ae][iy]er", s,
re.MULTILINE))
<_sre.SRE_Match object at 0x7fc59c5f26b0>
>>> print(re.search(r"^M[ae][iy]er", s, re.M))
<_sre.SRE_Match object at 0x7fc59c5f26b0>
>>> print(re.match(r"^M[ae][iy]er", s, re.M))
None
```

```
>>> print(re.search(r"Python\.$","I like
Python."))
<_sre.SRE_Match object at 0x7fc59c5f26b0>
>>> print(re.search(r"Python\.$","I like
Python and Perl."))
None
>>> print(re.search(r"Python\.$","I like
Python.\nSome prefer Java or Perl."))
None
>>> print(re.search(r"Python\.$","I like
Python.\nSome prefer Java or Perl.", re.M))
<_sre.SRE_Match object at 0x7fc59c5f26b0>
```

Optional Items

```
r"M[ae][iy]e?r"
```

```
r"Feb(ruary)? 2011"
```

```
r"[0-9]*"
```

Exercise:

Write a regular expression which matches strings which starts with a sequence of digits - at least one digit - followed by a blank.

Capturing Groups

```
>>> import re
>>> mo = re.search("[0-9]+", "Customer number:
232454, Date: February 12, 2011")
>>> mo.group()
'232454'
>>> mo.span()
(17, 23)
>>> mo.start()
17
>>> mo.end()
23
>>> mo.span()[0]
17
>>> mo.span()[1]
23
```

```
>>> import re
>>> mo = re.search("([0-9]+).*: (.*)",
"Customer number: 232454, Date: February 12,
2011")
>>> mo.group()
'232454, Date: February 12, 2011'
>>> mo.group(1)
'232454'
>>> mo.group(2)
'February 12, 2011'
>>> mo.group(1,2)
('232454', 'February 12, 2011')
```

```
import re
fh = open("tags.txt")
for i in fh:
     res = re.search(r"<([a-z]+)>(.*)</\1>",i)
     print(res.group(1) + ": " + res.group(2))
```

Named Backreferences

```
>>> import re
>>> s = "Sun Oct 14 13:47:03 CEST 2012"
>>> expr = r"\b(?P<hours>\d\d):(?
P<minutes>\d\d):(?P<seconds>\d\d)\b"
>>> x = re.search(expr,s)
>>> x.group('hours')
'13'
>>> x.group('minutes')
'47'
>>> x.start('minutes')
14
>>> x.end('minutes')
16
>>> x.span('seconds')
(17, 19)
```

Advanced Regular Expressions

```
re.findall(pattern, string[, flags])
```

```
>>> t="A fat cat doesn't eat oat but a rat
eats bats."
>>> mo = re.findall("[force]at", t)
>>> print(mo)
['fat', 'cat', 'eat', 'oat', 'rat', 'eat']
```

```
>>> import re
>>> courses = "Python Training Course for
Beginners: 15/Aug/2011 - 19/Aug/2011;Python
Training Course Intermediate: 12/Dec/2011 -
16/Dec/2011;Python Text Processing
Course:31/Oct/2011 - 4/Nov/2011"
>>> items = re.findall("[^:]*:[^;]*;?",
courses)
```

```
>>> import re
>>> str = "Course location is London or
Paris!"
>>> mo = re.search(r"location.*
(London|Paris|Zurich|Strasbourg)",str)
>>> if mo: print(mo.group())
...
location is London or Paris
```

```
>>> import re
>>> regex = r"[A-z]{1,2}[0-9R][0-9A-Z]? [0-9]
[ABD-HJLNP-UW-Z]{2}"
>>> address = "BBC News Centre, London, W12
7RJ"
>>> compiled_re = re.compile(regex)
>>> res = compiled_re.search(address)
>>> print(res)
<_sre.SRE_Match object at 0x174e578>
```

Splitting a String

```
>>> line = "James;Miller;teacher;Perl"
>>> line.split(";")
['James', 'Miller', 'teacher', 'Perl']
```

```
>>> mammon = "The god of the world's leading
religion. The chief temple is in the holy city
of New York."
>>> mammon.split(" ",3)
['The', 'god', 'of', "the world's leading
religion. The chief temple is in the holy city
of New York."]
```

```
>>> mammon = "The god  \t of the world's
leading religion. The chief temple is in the
holy city of New York."
>>> mammon.split(" ",5)
['The', 'god', '', '\t', 'of', "the world's
leading religion. The chief temple is in the
holy city of New York."]
```

```
>>> mammon.split(None,5)
['The', 'god', 'of', 'the', "world's",
'leading religion. The chief temple is in the
holy city of New York.']
```

```
>>> import re
>>> lines = ["surname: Obama, prename: Barack,
profession: president", "surname: Merkel,
prename: Angela, profession: chancellor"]
>>> for line in lines:
...     re.split(",* *\w*: ", line)[1:]
...
['Obama', 'Barack', 'president']
['Merkel', 'Angela', 'chancellor']
```

```
>>> import re
>>> str = "yes I said yes I will Yes."
>>> res = re.sub("[yY]es","no", str)
>>> print(res)
no I said no I will no.
```

Topic 8b: Lambda & other Operators

Lambda function

The lambda operator or lambda function is a way to create small anonymous functions, i.e. functions without a name. These functions are throw-away functions, i.e. they are just needed where they have been created.

```
lambda argument_list: expression
```

The argument list consists of a comma separated list of arguments and the expression is an arithmetic expression using these arguments.

```
>>> sum = lambda x, y : x + y
>>> sum(3,4)
7
```

Lambda functions are mainly used in combination with the functions filter() & map()

The map() Function

```
r = map(func, seq)
```

- The first argument func is the name of a function and the second a sequence (e.g. a list) seq. map() applies the function func to all the elements of the sequence seq.

- **Before Python3, map() used to return a list, where each element of the result list was the result of the function func applied on the corresponding element of the list or tuple "seq". With Python 3, map() returns an iterator.**

```
>>> def fahrenheit(T):
...     return ((float(9)/5)*T + 32)
...
>>> def celsius(T):
...     return (float(5)/9)*(T-32)
...
>>> temperatures = (36.5, 37, 37.5, 38, 39)
>>> F = map(fahrenheit, temperatures)
>>> C = map(celsius, F)
>>>
>>> temperatures_in_Fahrenheit =
list(map(fahrenheit, temperatures))
>>> temperatures_in_Celsius =
list(map(celsius, temperatures_in_Fahrenheit))
>>> print(temperatures_in_Fahrenheit)
[97.7, 98.60000000000001, 99.5, 100.4, 102.2]
>>> print(temperatures_in_Celsius)
[36.5, 37.00000000000001, 37.5,
38.00000000000001, 39.0]
```

In the example above, by using lambda, we wouldn't have had to define and name functions fahrenheit() & celsius().

```
>>> C = [39.2, 36.5, 37.3, 38, 37.8]
>>> F = list(map(lambda x: (float(9)/5)*x +
32, C))
>>> print(F)
[102.56, 97.7, 99.14, 100.4,
100.03999999999999]
>>> C = list(map(lambda x: (float(5)/9)*(x-
32), F))
>>> print(C)
[39.2, 36.5, 37.300000000000004,
38.00000000000001, 37.8]
```

map() can be applied to more than one list. The lists don't have to have the same length. map() will apply its lambda function to the elements of the argument lists.

```
>>> a = [1, 2, 3, 4]
>>> b = [17, 12, 11, 10]
>>> c = [-1, -4, 5, 9]
>>> list(map(lambda x, y : x+y, a, b))
[18, 14, 14, 14]
>>> list(map(lambda x, y, z : x+y+z, a, b, c))
[17, 10, 19, 23]
>>> list(map(lambda x, y, z : 2.5*x + 2*y - z,
a, b, c))
[37.5, 33.0, 24.5, 21.0]
```

If one list has less elements than the others, map will stop, when the shortest list has been consumed

```
>>> a = [1, 2, 3]
>>> b = [17, 12, 11, 10]
>>> c = [-1, -4, 5, 9]
>>>
>>> list(map(lambda x, y, z : 2.5*x + 2*y - z,
a, b, c))
[37.5, 33.0, 24.5]
```

```
from math import sin, cos, tan, pi

def map_functions(x, functions):
    """ map an iterable of functions on the
the object x """
    res = []
    for func in functions:
        res.append(func(x))
    return res

family_of_functions = (sin, cos, tan)
print(map_functions(pi, family_of_functions))
```

Filtering

This function offers an elegant way to filter out all the elements of a sequence "sequence", for which the function function returns True. i.e. an item will be produced by the iterator result of filter(function, sequence) if item is included in the sequence "sequence" and if function(item) returns True.

In the following example, we filter out first the odd and then the even elements of the sequence of the first 11 Fibonacci numbers

```
>>> fibonacci = [0,1,1,2,3,5,8,13,21,34,55]
>>> odd_numbers = list(filter(lambda x: x % 2,
fibonacci))
>>> print(odd_numbers)
[1, 1, 3, 5, 13, 21, 55]
>>> even_numbers = list(filter(lambda x: x % 2
== 0, fibonacci))
>>> print(even_numbers)
[0, 2, 8, 34]
>>>
>>>
>>> # or alternatively:
...
>>> even_numbers = list(filter(lambda x: x % 2
-1, fibonacci))
>>> print(even_numbers)
[0, 2, 8, 34]
```

Topic 8c: List Comprehension

Introduction

List comprehension is an elegant way to define and create list in Python. A simple example is as follows:

```
>>> Celsius = [39.2, 36.5, 37.3, 37.8]
>>> Fahrenheit = [ ((float(9)/5)*x + 32) for x
in Celsius ]
>>> print(Fahrenheit)
[102.56, 97.70000000000003,
99.14000000000001, 100.03999999999999]
```

```
>>> [(x,y,z) for x in range(1,30) for y in
range(x,30) for z in range(y,30) if x**2 +
y**2 == z**2]
[(3, 4, 5), (5, 12, 13), (6, 8, 10), (7, 24,
25), (8, 15, 17), (9, 12, 15), (10, 24, 26),
(12, 16, 20), (15, 20, 25), (20, 21, 29)]
```

```
>>> colours = [ "red", "green", "yellow",
"blue" ]
>>> things = [ "house", "car", "tree" ]
>>> coloured_things = [ (x,y) for x in colours
for y in things ]
>>> print(coloured_things)
[('red', 'house'), ('red', 'car'), ('red',
'tree'), ('green', 'house'), ('green', 'car'),
('green', 'tree'), ('yellow', 'house'),
('yellow', 'car'), ('yellow', 'tree'),
('blue', 'house'), ('blue', 'car'), ('blue',
'tree')]
```

Generator Comprehension

They are simply like a list comprehension but with parentheses - round brackets - instead of (square) brackets around it. A generator comprehension returns a generator instead of a list.

```
>>> x = (x **2 for x in range(20))
>>> print(x)
 at 0xb7307aa4>
>>> x = list(x)
>>> print(x)
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81, 100, 121,
144, 169, 196, 225, 256, 289, 324, 361]
```

Set Comprehension

A set comprehension is similar to a list comprehension, but returns a set and not a list. Syntactically, we use curly brackets instead of square brackets to create a set.

```
>>> from math import sqrt
>>> n = 100
>>> sqrt_n = int(sqrt(n))
>>> no_primes = {j for i in range(2, sqrt_n+1)
for j in range(i*2, n, i)}
>>> no_primes
{4, 6, 8, 9, 10, 12, 14, 15, 16, 18, 20, 21,
22, 24, 25, 26, 27, 28, 30, 32, 33, 34, 35,
36, 38, 39, 40, 42, 44, 45, 46, 48, 49, 50,
51, 52, 54, 55, 56, 57, 58, 60, 62, 63, 64,
65, 66, 68, 69, 70, 72, 74, 75, 76, 77, 78,
80, 81, 82, 84, 85, 86, 87, 88, 90, 91, 92,
93, 94, 95, 96, 98, 99}
>>> primes = {i for i in range(n) if i not in
no_primes}
>>> print(primes)
{0, 1, 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31,
37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 79,
83, 89, 97}
```

Recursive Function along with List Comprehension

This Python script uses a recursive function along with list comprehension to calculate the prime numbers.

```
from math import sqrt
def primes(n):
    if n == 0:
        return []
    elif n == 1:
        return []
    else:
        p = primes(int(sqrt(n)))
        no_p = {j for i in p for j in
range(i*2, n+1, i)}
        p = {x for x in range(2, n + 1) if x
not in no_p}
    return p

for i in range(1,50):
    print(i, primes(i))
```

Difference between version 2.x v/s 3.x

```
>>> x = "This value will be changed in the
list comprehension"
>>> res = [x for x in range(3)]
>>> res
[0, 1, 2]
>>> x
2
>>> res = [i for i in range(5)]
>>> i
4
```

```
$ python3
Python 3.2 (r32:88445, Mar 25 2011, 19:28:28)
[GCC 4.5.2] on linux2
Type "help", "copyright", "credits" or
"license" for more information.
>>> x = "Python 3 fixed the dirty little
secret"
>>> res = [x for x in range(3)]
>>> print(res)
[0, 1, 2]
>>> x
'Python 3 fixed the dirty little secret'
```

Topic 8d: Iterators & Generators

Introduction

An iterator can be seen as a pointer to a container, e.g. a list structure that can iterate over all the elements of this container. But we shouldn't be mistaken: A list is not an iterator, but it can be used like an iterator.

Generators are a special kind of function, which enable us to implement or generate iterators.

```
>>> cities = ["Paris", "Berlin", "Hamburg",
"Frankfurt", "London", "Vienna", "Amsterdam",
"Den Haag"]
>>> for location in cities:
...     print("location: " + location)
...
location: Paris
location: Berlin
location: Hamburg
location: Frankfurt
location: London
location: Vienna
location: Amsterdam
location: Den Haag
```

```
>>> expertises = ["Novice", "Beginner",
"Intermediate", "Proficient", "Experienced",
"Advanced"]
>>> expertises_iterator = iter(expertises)
>>> next(expertises_iterator)
'Novice'
>>> next(expertises_iterator)
'Beginner'
>>> next(expertises_iterator)
'Intermediate'
>>> next(expertises_iterator)
'Proficient'
>>> next(expertises_iterator)
'Experienced'
>>> next(expertises_iterator)
'Advanced'
>>> next(expertises_iterator)
Traceback (most recent call last):
  File "", line 1, in
StopIteration
```

```
other_cities = ["Strasbourg", "Freiburg",
"Stuttgart",
                "Vienna / Wien", "Hannover",
"Berlin",
                "Zurich"]

city_iterator = iter(other_cities)
while city_iterator:
    try:
        city = next(city_iterator)
        print(city)
    except StopIteration:
        break
```

```
>>> capitals = { "France":"Paris",
"Netherlands":"Amsterdam", "Germany":"Berlin",
"Switzerland":"Bern", "Austria":"Vienna"}
>>> for country in capitals:
...     print("The capital city of " + country
+ " is " + capitals[country])
...
The capital city of Switzerland is Bern
The capital city of Netherlands is Amsterdam
The capital city of Germany is Berlin
The capital city of France is Paris
```

Generators

- A generator is a function which returns a generator object. This generator object can be seen like a function which produces a sequence of results instead of a single object.
- This sequence of values is produced by iterating over it, e.g. with a for loop. The values, on which can be iterated, are created by using the yield statement.
- The fundamental difference between generators & functions:
  - Functions always start their execution at the beginning of the function body, regardless where they had left in previous calls. They don't have any static or persistent values.
  - Whereas in generator, the execution will continue in the state in which the generator was left after the last yield. This means that all the local variables still exists, because they are automatically saved between calls.

```
def city_generator():
    yield("London")
    yield("Hamburg")
    yield("Konstanz")
    yield("Amsterdam")
    yield("Berlin")
    yield("Zurich")
    yield("Schaffhausen")
    yield("Stuttgart")
```

```
>>> from city_generator import city_generator
>>> city = city_generator()
>>> print(next(city))
London
>>> print(next(city))
Hamburg
>>> print(next(city))
Konstanz
>>> print(next(city))
Amsterdam
>>> print(next(city))
Berlin
>>> print(next(city))
Zurich
>>> print(next(city))
Schaffhausen
>>> print(next(city))
Stuttgart
>>> print(next(x))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
StopIteration
```

The generators offer a comfortable method to generate iterators, and that's why they are called generators.

```
def fibonacci(n):
    """ A generator for creating the Fibonacci
numbers """
    a, b, counter = 0, 1, 0
    while True:
        if (counter > n):
            return
        yield a
        a, b = b, a + b
        counter += 1
f = fibonacci(5)
for x in f:
    print(x, " ", end="") #
print()
```

Since Python 3.3, generators can also use return statements, but a generator still needs at least one yield statement to be a generator! A return statement inside of a generator is equivalent to raise StopIteration()

```
>>> def gen():
...     yield 1
...     raise StopIteration(42)
...
>>>
>>> g = gen()
>>> next(g)
1
>>> next(g)
Traceback (most recent call last):
  File "", line 1, in
  File "", line 3, in gen
StopIteration: 42
```

Topic 8e: Exception Handling

Introduction

An exception is an error that happens during the execution of a program. Error handling is generally resolved by saving the state of execution at the moment the error occurred and interrupting the normal flow of the program to execute a special function or piece of code, which is known as the exception handler.

```
>>> n = int(input("Please enter a number: "))
Please enter a number: 23.5
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: invalid literal for int() with
base 10: '23.5'
```

```
while True:
    try:
        n = input("Please enter an integer: ")
        n = int(n)
        break
    except ValueError:
        print("No valid integer! Please try
again ...")
print("Great, you successfully entered an
integer!")
```

Multiple Except Clauses

A try statement may have more than one except clause for different exceptions. But at most one except clause will be executed.

```
try:
    f = open('integers.txt')
    s = f.readline()
    i = int(s.strip())
except (IOError, ValueError):
    print("An I/O error or a ValueError
occurred")
except:
    print("An unexpected error occurred")
    raise
```

```
def f():
    x = int("four")

try:
    f()
except ValueError as e:
    print("got it :-) ", e)


print("Let's get on")
```

```
def f():
    try:
        x = int("four")
    except ValueError as e:
        print("got it in the function :-) ",
e)

try:
    f()
except ValueError as e:
    print("got it :-) ", e)


print("Let's get on")
```

Try adding "raise" in f() at the end, so that the exception will be propagated to the caller.

It's also possible to create Exceptions yourself:

```
>>> raise SyntaxError("Sorry, my fault!")
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
SyntaxError: Sorry, my fault!
```

Clean-up actions (try … finally)

The try statement can be followed by a finally clause. Finally clauses are called clean-up or termination clauses, because they must be executed under all circumstances, regardless if an exception occurred in a try block or not.

```
try:
    x = float(input("Your number: "))
    inverse = 1.0 / x
finally:
    print("There may or may not have been an
exception.")
print("The inverse: ", inverse)
```

```
try:
    x = float(input("Your number: "))
    inverse = 1.0 / x
except ValueError:
    print("You should have given either an int
or a float")
except ZeroDivisionError:
    print("Infinity")
finally:
    print("There may or may not have been an
exception.")
```

Else clause

The try ... except statement has an optional else clause. An else block has to be positioned after all the except clauses. An else clause will be executed if the try clause doesn't raise an exception.

```
import sys
file_name = sys.argv[1]
text = []
try:
    fh = open(file_name, 'r')
except IOError:
    print('cannot open', file_name)
else:
    text = fh.readlines()
    fh.close()

if text:
    print(text[100])
```

Topic 8f: Python Tests

Introduction

There are usually two types of errors:

- Syntax Error, or
- Semantic Error

```
x = int(input("x? "))
y = int(input("y? "))

if x > 10:
    if y == x:
        print("Fine")
else:
    print("So what?")
```

```
x = int(input("x? "))
y = int(input("y? "))

if x > 10:
    if y == x:
        print("Fine")
    else:
        print("So what?")
```

- What is Unit test?
- As the name implies it's used for testing units or components of the code i.e. functions. The underlying concept is to simplify the testing of large programming systems by testing "small" units.
- Individual units of source code are tested to determine if they meet the requirements, i.e. return the expected output. A unit can be seen as the smallest testable part of a program, which are often functions or methods from classes. Testing one unit should be independent from the other units.

Simple Unit Test Example

```
if fib(0) == 0 and fib(10) == 55 and fib(50)
== 12586269025:
    print("Test for the fib function was
successful!")
else:
    print("The fib function is returning wrong
values!")
```

```
$ python3 fibonacci.py
Test for the fib function was successful!
```

```
$ python3 fibonacci.py
"The fib function is returning wrong values!
```

Doctest Module

doctest is a test framework that comes prepackaged with Python. The doctest module searches for pieces of text that look like interactive Python sessions inside of the documentation parts of a module, and then executes (or reexecutes) the commands of those sessions to verify that they work exactly correct.

```
import doctest

def fib(n):
    """
    Calculates the n-th Fibonacci number iteratively

    >>> fib(0)
    0
    >>> fib(1)
    1
    >>> fib(10)
    55
    >>> fib(15)
    610
    >>>

    """
    a, b = 0, 1
    for i in range(n):
        a, b = b, a + b
    return a

if __name__ == "__main__":
    doctest.testmod()
```

```
$ python3 fibonacci_doctest.py
**********************************************************
File "fibonacci_doctest.py", line 8, in __main__.fib
Failed example:
    fib(0)
Expected:
    0
Got:
    1
**********************************************************
File "fibonacci_doctest.py", line 12, in __main__.fib
Failed example:
    fib(10)
Expected:
    55
Got:
    89
**********************************************************
File "fibonacci_doctest.py", line 14, in __main__.fib
Failed example:
    fib(15)
Expected:
    610
Got:
    987
**********************************************************
1 items had failures:
   3 of   4 in __main__.fib
***Test Failed*** 3 failures.
```

unittest Module

The Python module unittest is a unit testing framework. It contains the core framework classes that form the basis of the test cases and suites (TestCase, TestSuite and so on), and also a text-based utility class for running the tests and reporting the results (TextTestRunner)

```
import unittest
from fibonacci import fib

class FibonacciTest(unittest.TestCase):

    def testCalculation(self):
        self.assertEqual(fib(0), 0)
        self.assertEqual(fib(1), 1)
        self.assertEqual(fib(5), 5)
        self.assertEqual(fib(10), 55)
        self.assertEqual(fib(20), 6765)

if __name__ == "__main__":
    unittest.main()
```

```
def fib(n):
    """ Iterative Fibonacci Function """
    a, b = 0, 1
    for i in range(n):
        a, b = b, a + b
    if n == 20:
        a = 42
    return a
```

```
$ python3 fibonacci_unittest.py
F
======================================================================
FAIL: testCalculation (__main__.FibonacciTest)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "fibonacci_unittest.py", line 7, in testCalculation
    self.assertEqual(fib(0), 0)
AssertionError: 1 != 0

----------------------------------------------------------------------
Ran 1 test in 0.000s

FAILED (failures=1)
```

```
$ python3 fibonacci_unittest.py
.
----------------------------------
Ran 1 test in 0.000s

OK
```

Look closer at the class TestCase!

Topic 9a: Object Oriented Concepts

Introduction

We will learn about the four major principles of object-orientation and the way Python deals with them.

- **Encapsulation**
- **Data Abstraction**
- **Polymorphism**
- **Inheritance**

Everything is a class in Python. Guido van Rossum has designed the language according to the principle "first-class everything". He wrote: "One of my goals for Python was to make it so that all objects were "first class." By this he meant that he wanted all objects that could be named in the language (e.g., integers, strings, functions, classes, modules, methods, and so on) to have equal status.

```
>>> x = 42
>>> type(x)
<class 'int'>
>>> y = 4.34
>>> type(y)
<class 'float'>
>>> def f(x):
...     return x + 1
...
>>> type(f)
<class 'function'>
>>> import math
>>> type(math)
<class 'module'>
```

```
>>> x = [3,6,9]
>>> y = [45, "abc"]
>>> print(x[1])
6
>>> x[1] = 99
>>> x.append(42)
>>> last = y.pop()
>>> print(last)
abc
```

Minimal Class in Python

```
class Robot:
    pass
```

A class consists of two parts: the header and the body.

```
class Robot:
    pass

if __name__ == "__main__":
    x = Robot()
    y = Robot()
    y2 = y
    print(y == y2)
    print(y == x)
```

```
>>> class Robot:
...     pass
...
>>> x = Robot()
>>> y = Robot()
>>>
>>> x.name = "Marvin"
>>> x.build_year = "1979"
>>>
>>> y.name = "Caliban"
>>> y.build_year = "1993"
>>>
>>> print(x.name)
Marvin
>>> print(y.build_year)
1993
```

```
>>> x.__dict__
{'name': 'Marvin', 'build_year': '1979'}
>>> y.__dict__
{'name': 'Caliban', 'build_year': '1993'}
```

```
>>> class Robot(object):
...     pass
...
>>> x = Robot()
>>> Robot.brand = "Kuka"
>>> x.brand
'Kuka'
>>> x.brand = "Thales"
>>> Robot.brand
'Kuka'
>>> y = Robot()
>>> y.brand
'Kuka'
>>> Robot.brand = "Thales"
>>> y.brand
'Thales'
>>> x.brand
'Thales'
```

```
>>> x.__dict__
{'brand': 'Thales'}
>>> y.__dict__
{}
>>>
>>> Robot.__dict__
mappingproxy({'__module__': '__main__',
'__weakref__': , '__doc__': None, '__dict__':
, 'brand': 'Thales'})
```

If an attribute name is not in included in either of the dictionary, the attribute name is not defined. If you try to access a non-existing attribute, you will raise an AttributeError.

```
>>> x.energy
Traceback (most recent call last):
  File "<stdin>", line 1, in
AttributeError: 'Robot' object has no
attribute 'energy'
```

By using the function getattr, we can prevent this exception, by providing default value as third argument:

```
>>> getattr(x, 'energy', 100)
100
```

Methods & __init__ Method

Function which is member of a class is called a Method.

__init__ is a magic method which is immediately and automatically called after an instance has been created. This name is fixed and it is not possible to chose another name. This method is used to initialize an instance.

```
class Robot:

    def __init__(self, name=None):
        self.name = name

    def say_hi(self):
        if self.name:
            print("Hi, I am " + self.name)
        else:
            print("Hi, I am a robot without a
name")


x = Robot()
x.say_hi()
y = Robot("Marvin")
y.say_hi()
```

More OOPS features

Data Abstraction = Data Encapsulation + Data Hiding

```
class Robot:

    def __init__(self, name=None):
        self.name = name

    def say_hi(self):
        if self.name:
            print("Hi, I am " + self.name)
        else:
            print("Hi, I am a robot without a name")

    def set_name(self, name):
        self.name = name

    def get_name(self):
        return self.name


x = Robot()
x.set_name("Henry")
x.say_hi()
y = Robot()
y.set_name(x.get_name())
print(y.get_name())
```

__str__ & __repr__ Methods

We had seen that we can depict various data as string by using the str function, which uses "magically" the internal __str__ method of the corresponding data type. __repr__is similar. It produces a string representation.

```
>>> l = ["Python", "Java", "C++", "Perl"]
>>> print(l)
['Python', 'Java', 'C++', 'Perl']
>>> str(l)
"['Python', 'Java', 'C++', 'Perl']"
>>> repr(l)
"['Python', 'Java', 'C++', 'Perl']"
>>> d = {"a":3497, "b":8011, "c":8300}
>>> print(d)
{'a': 3497, 'c': 8300, 'b': 8011}
>>> str(d)
"{'a': 3497, 'c': 8300, 'b': 8011}"
>>> repr(d)
"{'a': 3497, 'c': 8300, 'b': 8011}"
>>> x = 587.78
>>> str(x)
'587.78'
>>> repr(x)
'587.78'
```

```
>>> class A:
...     pass
...
>>> a = A()
>>> print(a)
<__main__.A object at 0xb720a64c>
>>> print(repr(a))
<__main__.A object at 0xb720a64c>
>>> print(str(a))
<__main__.A object at 0xb720a64c>
>>> a
<__main__.A object at 0xb720a64c>
```

```
>>> class A:
...     def __str__(self):
...         return "42"
...
>>> a = A()

>>> print(repr(a))
<__main__.A object at 0xb720a4cc>
>>> print(str(a))
42
>>> a
<__main__.A object at 0xb720a4cc>
```

A frequently asked question is when to use __repr__ annd when __str__. __str__ is always the right choice, if the output should be for the end user or in other words, if it should be nicely printed. __repr__ on the other hand is used for the internal representation of an object.

```
>>> import datetime
>>> today = datetime.datetime.now()
>>> str_s = str(today)
>>> eval(str_s)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<string>", line 1
    2014-01-26 17:35:39.215144
             ^
SyntaxError: invalid token
>>> repr_s = repr(today)
>>> t = eval(repr_s)
>>> type(t)
<class 'datetime.datetime'>
```

```
class Robot:

    def __init__(self, name, build_year):
        self.name = name
        self.build_year = build_year

    def __repr__(self):
        return "Robot(\"" + self.name + "\","
+  str(self.build_year) +  ")"

    def __str__(self):
        return "Name: " + self.name + ", Build
Year: " +  str(self.build_year)

if __name__ == "__main__":
    x = Robot("Marvin", 1979)

    x_repr = repr(x)
    print(x_repr, type(x_repr))
    new = eval(x_repr)
    print(new)
    print("Type of new:", type(new))
```

Public/Private/Protected Attributes

Naming	Type	Meaning
name	Public	These attributes can be freely used inside or outside of a class definition.
_name	Protected	Protected attributes should not be used outside of the class definition, unless inside of a subclass definition.
__name	Private	This kind of attribute is inaccessible and invisible. It's neither possible to read nor write to those attributes, except inside of the class definition itself.

```
class A():

    def __init__(self):
        self.__priv = "I am private"
        self._prot = "I am protected"
        self.pub = "I am public"
```

```
>>> from attribute_tests import A
>>> x = A()
>>> x.pub
'I am public'
>>> x.pub = x.pub + " and my value can be
changed"
>>> x.pub
'I am public and my value can be changed'
>>> x._prot
'I am protected'
>>> x.__priv
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: 'A' object has no attribute
'__priv'
```

```
class Robot:
    def __init__(self, name=None, build_year=2000):
        self.__name = name
        self.__build_year = build_year
    def say_hi(self):
        if self.__name:
            print("Hi, I am " + self.__name)
        else:
            print("Hi, I am a robot without a name")
    def set_name(self, name):
        self.__name = name
    def get_name(self):
        return self.__name
    def set_build_year(self, by):
        self.__build_year = by
    def get_build_year(self):
        return self.__build_year
    def __repr__(self):
        return "Robot('" + self.__name + "', " +  str(self.__build_year) +  ")"
    def __str__(self):
        return "Name: " + self.__name + ", Build Year: " +  str(self.__build_year)


if __name__ == "__main__":
    x = Robot("Marvin", 1979)
    y = Robot("Caliban", 1943)
    for rob in [x, y]:
        rob.say_hi()
        if rob.get_name() == "Caliban":
            rob.set_build_year(1993)
        print("I was built in the year " + str(rob.get_build_year()) + "!")
```

Every private attribute of our class has a getter and a setter. There are IDEs to provide them automatically also.

Destructor

Python destructor is the method __del__. It is called when the instance is about to be destroyed and if there is no other reference to this instance.

```
class Robot():

    def __init__(self, name):
        print(name + " has been created!")

    def __del__(self):
        print ("Robot has been destroyed")


if __name__ == "__main__":
    x = Robot("Tik-Tok")
    y = Robot("Jenkins")
    z = x
    print("Deleting x")
    del x
    print("Deleting z")
    del z
    del y
```

```
class Robot():

    def __init__(self, name):
        print(name + " has been created!")

    def __del__(self):
        print (self.name + " says bye-bye!")


if __name__ == "__main__":
    x = Robot("Tik-Tok")
    y = Robot("Jenkins")
    z = x
    print("Deleting x")
    del x
    print("Deleting z")
    del z
    del y
```

Topic 9b: Class & Instance Attributes

Introduction

Instance attributes are owned by the specific instances of a class. This means for two different instances the instance attributes are usually different.

```
>>> class A:
...     a = "I am a class attribute!"
...
>>> x = A()
>>> y = A()
>>> x.a
'I am a class attribute!'
>>> y.a
'I am a class attribute!'
>>> A.a
'I am a class attribute!'
```

```
>>> class A:
...     a = "I am a class attribute!"
...
>>> x = A()
>>> y = A()
>>> x.a = "This creates a new instance
attribute for x!"
>>> y.a
'I am a class attribute!'
>>> A.a
'I am a class attribute!'
>>> A.a = "This is changing the class
attribute 'a'!"
>>> A.a
"This is changing the class attribute 'a'!"
>>> y.a
"This is changing the class attribute 'a'!"
>>> # but x.a is still the previously created
instance variable:
...
>>> x.a
'This creates a new instance attribute for x!'
```

Python's class attributes and object attributes are stored in separate dictionaries.

```
>>> x.__dict__
{'a': 'This creates a new instance attribute
for x!'}
>>> y.__dict__
{}
>>> A.__dict__
dict_proxy({'a': "This is changing the class
attribute 'a'!", '__dict__': <attribute
'__dict__' of 'A' objects>, '__module__':
'__main__', '__weakref__': <attribute
'__weakref__' of 'A' objects>, '__doc__':
None})
>>> x.__class__.__dict__
dict_proxy({'a': "This is changing the class
attribute 'a'!", '__dict__': <attribute
'__dict__' of 'A' objects>, '__module__':
'__main__', '__weakref__': <attribute
'__weakref__' of 'A' objects>, '__doc__':
None})
```

Example to count instance with class attributes.

```
class C:

    counter = 0

    def __init__(self):
        type(self).counter += 1

    def __del__(self):
        type(self).counter -= 1

if __name__ == "__main__":
    x = C()
    print("Number of instances: : " + str(C.counter))
    y = C()
    print("Number of instances: : " + str(C.counter))
    del x
    print("Number of instances: : " + str(C.counter))
    del y
    print("Number of instances: : " + str(C.counter))
```

Static Methods

It is a method which we can call via the class name or via the instance name without the necessity of passing a reference to an instance to it. It's the decorator syntax.

```
class Robot:
    __counter = 0

    def __init__(self):
        type(self).__counter += 1

    @staticmethod
    def RobotInstances():
        return Robot.__counter


if __name__ == "__main__":
    print(Robot.RobotInstances())
    x = Robot()
    print(x.RobotInstances())
    y = Robot()
    print(x.RobotInstances())
    print(Robot.RobotInstances())
```