

Python Foundation

A programmer's introduction to
Python concepts & style

```
course = {  
    'title':  
        'Python Foundation',  
    'chapters': [  
        'Introduction',  
        'History, Culture & Style',  
        'Multi-Paradigm Programming',  
        'Syntax & Mechanics',  
        'Logic & Flow',  
        'Strings',  
        'Functions',  
        'Built-in Containers',  
        'Iteration',  
        'Classes & Objects',  
        'Outroduction',  
        'Labs & Homework'  
    ],  
    ...  
}
```

```
course = {  
    ...  
    'licence':  
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         'https://creativecommons.org/licenses/by/4.0/'),  
    'contributors': [  
        'Kevlin Henney, kevlin@curbralan.com',  
        'Olve Maudal, olvmauda@cisco.com'  
    ],  
    'date': '2015-03-03'  
}
```

Introduction

Begin at the beginning...

Course goals

- **Introduce the Python 3 language**
 - Some existing experience of Python assumed, but detailed knowledge is not
 - Programming skill in at least one other language is also assumed
- **Explore the structures, mechanics and common idioms of the language**
 - Through slides, discussion and hands-on experiments and labs

Coding experiments

- **Small interactive experiments to try out and explore language features**
 - Use the IDLE environment, the default *python* shell or any available interactive Python environment of your choice!
 - Some experiments are described in the slides, but others may be suggested
- **You can carry out experiments individually or in pairs**

Programming labs

- Labs implemented using Cyber-Dojo
 - *<http://cyber-dojo.org/>*
 - Labs involve writing both code and tests
- Labs are undertaken in pairs
 - But pairing is not marriage — you will move around
- Oh, and there's homework too
 - Individual rather than paired, and not in Cyber-Dojo

Questions, answers & intros

- **The best way to have your questions answered is to ask them**
 - Mindreading is not (yet) supported
- **And now, please introduce yourself!**
 - Briefly...

History, Culture & Style

Versions, PEPs & Zen

Facts at a glance

- Python is a general-purpose, multi-paradigm dynamic OO language
- Python was first publicly released by Guido van Rossum in 1991
- It exists in a number of versions, including CPython 2.7.x and 3.4.x
- Familiarity with *Monty Python's Flying Circus* can help

Versions & implementations

- **CPython is reference implementation**
 - Open source and managed by the Python Software Foundation
 - The Python Enhancement Proposal (PEP) process guides development
- **Alternative and platform-specific implementations and subsets also exist**
 - E.g., PyPy, IronPython for .NET and Jython for JVM

Python 2 versus Python 3

- **Python 3 dates from 2008 and breaks compatibility with Python 2**
 - Based on experience, it simplifies and regularises many aspects of the language
- **Python 2 dates from 2000 and continues to evolve**
 - Large installed base of Python 2 means transition to Python 3 is not always simple
 - Incompatible changes will be marked 🐍

Time travel

- Use forward-compatible styles and features when working with Python 2
 - Unask Python 3 incompatibility questions
- It is also possible to import some features "from the future"
 - Some Python 3 features usable in Python 2

```
from __future__ import print_function  
from __future__ import division
```

Python 2: *print* is a keyword

Python 3: *print* is a function

Python 2: */* is operand dependent

Python 3: */* is true division

// is integer division in both

Python's type system

- **Python is dynamically typed**
 - All values and expressions have a type, but there is no declared type system
 - Polymorphism is based on *duck typing*
- **Python is object oriented**
 - Everything, including functions and built-in primitive values, is an object
 - Encapsulation style is façade-like rather than strict

Objects

Objects are Python's abstraction for data. All data in a Python program is represented by objects or by relations between objects. (In a sense, and in conformance to Von Neumann's model of a "stored program computer," code is also represented by objects.)

Every object has an identity, a type and a value. An object's identity never changes once it has been created; you may think of it as the object's address in memory. The *is* operator compares the identity of two objects; the *id()* function returns an integer representing its identity.

The Python Language Reference: 3.1 Objects, values and types

<https://docs.python.org/3/reference/datamodel.html#objects-values-and-types>

Pythonic style

- **Pythonic style is typically terse and expressive**
 - But not necessarily cryptic
- **Python programming style is multi-paradigm in nature**
 - Encouraged style is idiomatically more functional than procedural
 - Ranges in use from its original role in scripting to application programming

Libraries

- One of Python's greatest strengths is size and scope of its standard library
 - It takes a *batteries included* approach
- Another is the size and scope of other open-source libraries written in Python
 - See PyPI, the Python Package Index:
<https://pypi.python.org>
 - *pip* is the de facto and (as of Python 3.4) the default package manager

PEP 8

- **PEP 8 is a style guide for Python**
 - Offers guidance on accepted convention, and when to follow and when to break with convention
- **Focuses mostly on layout and naming**
 - But there is also programming guidance
- **PEP 8 conformance can be checked automatically**
 - E.g., *<http://pep8online.com/>*, `pep8`, `flake8`

PEP 8 highlights

A style guide is about consistency. Consistency with this style guide is important. Consistency within a project is more important. Consistency within one module or function is most important.

Limit all lines to a maximum of 79 characters.

Use *is not* operator rather than *not ... is*.

Use 4 spaces per indentation level.

Use string methods instead of the *string* module.

Function names should be lowercase, with words separated by underscores as necessary to improve readability.

Class names should normally use the CapWords convention.

The Zen of Python (PEP 20)

```
>>> import this
```

```
The Zen of Python, by Tim Peters
```

```
Beautiful is better than ugly.
```

```
Explicit is better than implicit.
```

```
Simple is better than complex.
```

```
Complex is better than complicated.
```

```
Flat is better than nested.
```

```
Sparse is better than dense.
```

```
Readability counts.
```

```
Special cases aren't special enough to break the rules.
```

```
Although practicality beats purity.
```

```
Errors should never pass silently.
```

```
Unless explicitly silenced.
```

```
In the face of ambiguity, refuse the temptation to guess.
```

```
There should be one-- and preferably only one --obvious way to do it.
```

```
Although that way may not be obvious at first unless you're Dutch.
```

```
Now is better than never.
```

```
Although never is often better than *right* now.
```

```
If the implementation is hard to explain, it's a bad idea.
```

```
If the implementation is easy to explain, it may be a good idea.
```

```
Namespaces are one honking great idea -- let's do more of those!
```

```
>>>
```

Useful Links

Python

[*https://www.python.org/*](https://www.python.org/)

[*https://docs.python.org/3/*](https://docs.python.org/3/)

[*https://docs.python.org/2/*](https://docs.python.org/2/)

[*https://www.python.org/dev/peps/*](https://www.python.org/dev/peps/)

[*http://pep8online.com/*](http://pep8online.com/)

[*https://pypi.python.org/pypi*](https://pypi.python.org/pypi)

Monty Python

[*http://www.montypython.com/*](http://www.montypython.com/)

[*http://en.wikipedia.org/wiki/Monty_Python*](http://en.wikipedia.org/wiki/Monty_Python)

[*https://www.youtube.com/user/MontyPython*](https://www.youtube.com/user/MontyPython)

Multi-Paradigm Programming

Procedural, modular, script,
OO & functional programming

Facts at a glance

- **Although OO at its core, Python supports multiple programming styles**
- **Python has the expected set of control flow structures for most styles**
- **Each file in Python corresponds properly to a module**
- **Pythonic style has many functional programming aspects**

Multi-paradigm programming

- **The Python language is object oriented**
 - Everything is an object
- **Python programming, on the other hand, is multi-paradigm**
 - Supports a straight procedural style, a modular approach, classic shell scripting, functional programming and OOP
 - The same problem can be solved and expressed in different ways

Procedural programming

- **Procedural programming is typically characterised by...**
 - Sequential, conditional and repetitive control flow
 - Local and global variables with assignment
 - Top-down decomposition of named procedures, i.e., functions
 - Data passed as arguments

Basic control flow

Condition-based loop

```
while condition:  
    ...  
else:  
    ...
```

Multiway conditional

```
if condition:  
    ...  
elif condition:  
    ...  
else:  
    ...
```

Exception handling

```
try:  
    ...  
except exception:  
    ...  
else:  
    ...  
finally:  
    ...
```

No-op

```
pass
```

Value-based loop

```
for variable in sequence:  
    ...  
else:  
    ...
```

Functions

- **Functions are the workhorses of Python**
 - Can be called both with positional and with keyword arguments
 - Can be defined with default arguments
 - Can return multiple values

```
def roots(value):  
    from math import sqrt  
    result = sqrt(value)  
    return result, -result
```

```
first, second = roots(4)
```

```
def is_at_origin(x, y):  
    return x == y == 0
```

```
is_at_origin(0, 1)
```

Variables

- **A variable holds an object reference**
 - A variable is a name for an object within a scope
 - *None* is a reference to nothing
- **A variable is created in the current scope on first assignment to its name**
 - It's a runtime error if an unbound variable is referenced
 - Note that assignments are statements

Scope

- Variables are introduced in the smallest enclosing scope
 - Parameter names are local to their corresponding construct (i.e., module, function, lambda or comprehension)
 - To assign to a global from within a function, declare it *global* in the function
 - Note a *for* does not define a scope
 - *del* removes a name from a scope

Assignment

```
parrot = 'Dead'
```

Simple assignment

```
x = y = z = 0
```

Assignment of single value to multiple targets

```
lhs, rhs = rhs, lhs
```

Assignment of multiple values to multiple targets

```
counter += 1
```

Augmented assignment

```
world = 'Hello'  
def farewell():  
    global world  
    world = 'Goodbye'
```

Global assignment from within a function

Modular programming

- **A Python file corresponds to a module**
 - A program is composed of one or more modules
 - A module defines a namespace, e.g., for function and class names
- **A module's name defaults to the file name without the `.py` suffix**
 - Module names should be short and in lower case

Standard modules

- **Python has an extensive library of standard modules**
 - **Much of going beyond the core language is learning to navigate the library**

11. File and Directory Access

- 11.1. `pathlib` — Object-oriented filesystem paths
- 11.2. `os.path` — Common pathname manipulations
- 11.3. `fileinput` — Iterate over lines from multiple input streams
- 11.4. `stat` — Interpreting `stat()` results
- 11.5. `filecmp` — File and Directory Comparisons
- 11.6. `tempfile` — Generate temporary files and directories
- 11.7. `glob` — Unix style pathname pattern expansion
- 11.8. `fnmatch` — Unix filename pattern matching
- 11.9. `linecache` — Random access to text lines
- 11.10. `shutil` — High-level file operations
- 11.11. `macpath` — Mac OS 9 path manipulation functions

import

- **Names in another module are not accessible unless imported**
 - A module is executed on first import
 - Names beginning `_` considered private

Import

```
import sys
import sys as system
from sys import stdin
from sys import stdin, stdout
from sys import stdin as source
from sys import *
```

Discouraged

Imported

```
sys.stdin, ...
system.stdin, ...
stdin
stdin, stdout
source
stdin, ...
```

`__name__` & `dir`

- A module's name is held in a module-level variable called `__name__`
- A module's contents can be listed using the built-in `dir` function
 - Note that `dir` can also be used to list attributes on any object, not just modules


```
import sys  
  
print(sys.__name__, 'contains', dir(sys))  
print(__name__, 'contains', dir())
```

The '*__main__*' module

- A module's name is set to '*__main__*' when it is the root of control
 - I.e., when run as a script
 - A module's name is unchanged on import

```
...  
def main():  
    ...  
if __name__ == '__main__':  
    main()
```

A common idiom is to define a main function to be called when a module is used as '*__main__*'



Shell scripting

- Shell scripting often characterised by...
 - Argument handling
 - Console and file I/O
 - File and directory manipulation
 - String-based operations


```
#!/usr/bin/env python3
import sys
print(' '.join(sys.argv))
```

The appropriate shebang line
for Unix and Unix-like
operating systems

Program arguments available
as list of strings, where
argv[0] is the script name

Basic I/O

- I/O defaults to *stdin* and *stdout*
 - *input* optionally shows a prompt and returns a string result
 - *print* supports output of one or more values (not necessarily strings)



```
what = input('What are you? ')
say = input('What do you say? ')
print('We are the', what, 'who say', say + '!')
```

```
print('We are the {} who say {}!'.format(what, say))
```

File I/O

- **File handling is simple and uniform**
 - Files integrate easily with other constructs
 - Always open files using *with* so that file closing is automatic

```
import sys
if len(sys.argv) > 0:
    for filename in sys.argv[1:]:
        with open(filename) as file:
            print(file.read())
else:
    print(sys.stdin.read())
```

← A slice of *argv* that ignores the zeroth argument (the script name)

Experiment

- Using `os.listdir`, write a simple script that behaves like the Unix `ls` command
 - Lists the contents of the current directory if no arguments are supplied
 - Lists the contents of the given directory if a single argument is supplied
 - Lists the contents of each directory for multiple arguments, prefixing each listing with the directory name

Functional programming

- **Functional programming is based on...**
 - **Functions as principal units of composition**
 - **A declarative rather than imperative style, emphasising data structure relations**
 - **Functions executing without side-effects, i.e., functions are pure functions**
 - **Immutability, so querying state and creating new state rather than updating it**
 - **Lazy rather than eager access to values**

Function application

```
def is_leap_year(year):  
    return year % 4 == 0 and year % 100 != 0 or year % 400 == 0  
years = range(1800, 2100)
```

```
leap_years = []  
for year in years:  
    if is_leap_year(year):  
        leap_years.append(year)
```

Imperative list initialisation

```
leap_years = list(filter(is_leap_year, years))
```

Filtering

Comprehensions

```
squares = []  
for i in range(13):  
    squares.append(i**2)
```

```
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81, 100, 121, 144]
```

Imperative list initialisation

```
squares = [i**2 for i in range(13)]
```

```
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81, 100, 121, 144]
```

List comprehension

OO programming

- **Object orientation is founded on encapsulation and polymorphism**
 - **Encapsulation combines function and data into a behavioural entity with identity**
 - **Polymorphism supports equivalent object use for equivalent object interfaces**
 - **Inheritance factors out common and introduces hooks for polymorphism, but is an auxiliary not essential feature of OO**

Classes

- **Python classes support a full OO programming model**
 - **Class- and instance-level methods**
 - **Class- and instance-level attributes**
 - **Multiple inheritance**

Class statement introduces name and any base classes

`__init__` is automatically invoked after object creation

Convention rather than language dictates that the current object is called *self*

```
class Point:
    def __init__(self, x=0, y=0):
        self.x, self.y = x, y
    def is_at_origin(self):
        return self.x == self.y == 0
```

Class instantiation

- **Objects are instantiated by using a class name as a function**
 - Providing any arguments expected by the special `__init__` function
 - The *self* argument is provided implicitly

```
origin = Point()
print('Is at origin?', origin.is_at_origin())
unit = Point(1, 1)
print(unit.x, unit.y)
```

Ducks, types & polymorphism

When I see a bird that walks like a duck and swims like a duck and quacks like a duck, I call that bird a duck.

James Whitcomb Riley

In other words, don't check whether it IS-a duck: check whether it QUACKS-like-a duck, WALKS-like-a duck, etc, etc, depending on exactly what subset of duck-like behaviour you need to play your language-games with.

Alex Martelli

Substitutable classes

```
class PolarPoint:
    def __init__(self, r=0, theta=0):
        self.__r, self.__theta = r, theta
    def x(self):
        from math import cos
        return self.__r * cos(self.__theta)
    def y(self):
        from math import sin
        return self.__r * sin(self.__theta)
    def r(self):
        return self.__r
    def theta(self):
        return self.__theta
```

Leading `__` in identifier names
keeps them effectively private

Instances of `PolarPoint` and
instances of `CartesianPoint`
support the same method calls,
and are therefore substitutable
for one another — quack, quack

```
class CartesianPoint:
    def __init__(self, x=0, y=0):
        self.__x, self.__y = x, y
    def x(self):
        return self.__x
    def y(self):
        return self.__y
    def r(self):
        return (self.__x**2 + self.__y**2)**0.5
    def theta(self):
        from math import atan
        return atan(self.__y / self.__x)
```

Syntax & Mechanics

Keywords, identifiers, spacing,
built-in types & more

Facts at a glance

- **Python syntax is line oriented and space sensitive rather than free format**
- **Python's built-in types include numeric primitives and container types**
- **Integers hold arbitrary precision values**
- **Both floating-point and complex numbers supported in the language**
- **Python has expected set of operators**

Identifiers

- Identifiers are case-sensitive names for source code entities
 - E.g., functions, classes and variables
- Some identifier classes have reserved meanings

Class

```
_*  
__*__  
__*__
```

Example

```
_load_config  
__init__  
__cached_value
```

Meaning

Not imported by wildcard module imports — a convention to indicate privacy in general

System-defined names, such as special method names and system variables

Class-private names, so typically used to name private attributes

Keywords

False

None

True

and

as

assert

break

class

continue

def

del

elif

else

except

finally

for

from

global

if

import

in

is

lambda

nonlocal

not

or

pass

raise

return

try

while

with

yield

Indentation

- Indentation is significant in Python and is used to define block structure
 - The *suite* is indented from the *header*
 - Multiple statements can occur at same level of indentation

```
response = input('Who are you? ')
if response == '':
    print('Hello, World!')
else:
    print('Hello, ' + response + '!!')
    print('Welcome to the machine...')
```

Spanning multiple lines

- **A single statement can extend over multiple lines**
 - **Implicit continuation across unclosed bracketing (...), [...], {...})**
 - **Forced continuation after \ at end of line**

```
total = amount + \  
tax
```

```
films = [  
    'The Holy Grail',  
    'The Life of Brian',  
    'The Meaning of Life'  
]
```

Compound statements

- It is possible to combine multiple statements on a single line
 - The semi-colon is a statement separator
- This is, however, strongly discouraged

```
if eggs: print('Egg'); print('Spam')
```

Possible

```
if eggs:  
    print('Egg')  
    print('Spam')
```

Preferred

Comments



- **Code comments are introduced with #**
 - **Line-based, i.e., but independent of indentation (but advisable to do so)**
 - **Shell-script friendly, i.e., #! as first line**
- **As in other languages, use sparingly**

```
# This is a comment
if eggs: # This is also a comment
    # This is an aligned comment
    print('Egg')
    # This is a (discouraged) comment
```

Built-in types are classes

- Python's built-in types are all classes, with operators and methods
 - E.g., integers, strings, lists and dictionaries
 - Use *type(value)* to query a value's type and *dir(value)* to query its attributes
- Most built-in types have a literal form
 - E.g., 97 is an *int*, 'swallow' is a *str*, (4, 2) is a *tuple* pair, [] is an empty *list*, {'parrot'} is a *set* with a single value, {} is an empty *dict*

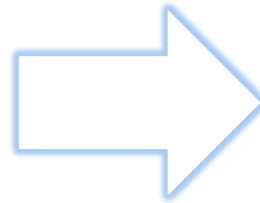
Common built-in types

object	
bool	False True
int	42 -97 0x2a
float	3.14159 3e8
complex	4+2j 9.7+2.3j 1j
str	'Nice' "Isn't it?" r'C:\tmp' '\u0030' 
bytes	b'Its bark is worse than its byte'
bytearray	
list	[] [42, 'Forty two']
tuple	() (42,) ('pair', 'pear')
range 	
dict	{ } {'Norway': 'Oslo', 'UK': 'London'}
set	{15, 30, 40}
frozenset	

Explicit type conversions

- You can use a type name to convert an object of one type to another
 - Assuming that some kind of conversion exists from one type to the other

```
int('314')  
str(314)  
str([3, 1, 4])  
list('314')  
set([3, 1, 4, 1])
```



```
314  
'314'  
'[3, 1, 4]'  
['3', '1', '4']  
{1, 3, 4}
```

Integers

- The *int* type offers arbitrary precision
 - Not limited to machine word size
- It supports the usual operators
 - But */* results in a *float*, so use *//* if integer division is needed

```
42
-273
0b101010
0o1232
0xfffff
```

Floating-point numbers

- Python *float* typically offers better than 32-bit precision
 - Maps to platform double-precision type
- It supports the usual operators
 - But also supports integer division and modulo operator


```
3e8  
-273.15  
.5  
float('NaN')  
float('-Infinity')
```

Further numeric operations

abs (<i>value</i>)	<i>Absolute value</i>
bin (<i>integer</i>)	<i>String of number in binary</i>
divmod (<i>dividend</i> , <i>divisor</i>)	<i>Integer division and remainder</i>
float (<i>string</i>)	<i>Floating-point number from string</i>
hex (<i>integer</i>)	<i>String of number in hexadecimal</i>
int (<i>string</i>)	<i>Integer from decimal number</i>
int (<i>string</i> , <i>base</i>)	<i>Integer from number in base</i>
oct (<i>integer</i>)	<i>String of number in octal</i>
pow (<i>value</i> , <i>exponent</i>)	<i>value ** exponent</i>
round (<i>value</i>)	<i>Round to integer</i>
round (<i>value</i> , <i>places</i>)	<i>Round to places decimal places</i>
str (<i>value</i>)	<i>String form of number (decimal)</i>
sum (<i>values</i>)	<i>Sum sequence (e.g., list) of values</i>
sum (<i>values</i> , <i>initial</i>)	<i>Sum sequence from initial start</i>

Numeric & bitwise operators

Binary arithmetic operators



+	Addition
-	Subtraction
*	Multiplication
**	Power
/	Division
//	Integer division
%	Modulo

Unary arithmetic operators

+	Unary plus
-	Unary minus

Bitwise operators

~	Bitwise complement
<<	Bitwise left shift
>>	Bitwise right shift
&	Bitwise and
	Bitwise or
^	Bitwise xor

Comparison & logic operators

Relational

== *Equality*
!= *Inequality*
< *Less than*
<= *Less than or equal to*
> *Greater than*
>= *Greater than or equal to*

Boolean

and *Logical and*
or *Logical or*
not *Negation*

Identity

is *Identical*
is not *Non-identical*

Membership and containment

in *Membership*
not in *Non-membership*

Conditional

if else *Conditional (ternary) operator*

Augmented assignments

- Augmented assignment forms exist for each binary operator
 - Like regular assignment, augmented assignments are statements not expressions
 - Cannot be chained and can only have a single target
 - There is no ++ or --

+=	/=	<<=
-=	//=	>>=
*=	%=	&=
**=		=
		^=

Logic & Flow

From the conditional to the
exceptional

Facts at a glance

- Logic is not based on a strict Boolean type, but there is a *bool* type
- The *and*, *or* and *if else* operators are partially evaluating
- There is no *switch/case* — use *if*
- Exception handling is similar to that in other languages
- *with* simplifies safe resource usage

What is truth?

- **Boolean logic works with many types**
 - Use *bool* as a function to convert a value to its corresponding canonical Boolean

False

None

0

0.0

' '

b' '

[]

{ }

()

True

Non-null references and not otherwise false

Non-zero numbers

Non-empty strings

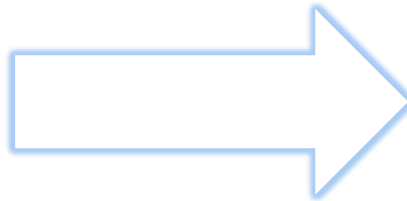
Non-empty containers

← Other empty containers with
non-literal empty forms are also
considered false.

and & or

- The logical operators *and* and *or* are partially evaluating
 - I.e., they do not evaluate their right-hand operand if they do not need to
 - They return the last evaluated operand, without any conversion to *bool*

```
'Hello' and 'World'  
'Hello' or 'World'  
[] and [3, 1, 4]  
{42, 97} or {42}  
{0} and {1} or [2]
```



```
'World'  
'Hello'  
[]  
{42, 97}  
{1}
```

Chained comparisons

- **Comparisons can be combined without using an intermediate *and***
 - **The short-circuiting evaluation is the same, i.e., if the first comparison is false, no further evaluation occurs**

Brief form...

```
minimum < value < maximum  
' ' != selection in options
```

Equivalent to...

```
minimum < value and value < maximum  
' ' != selection and selection in options
```

if else operator

- The conditional operator has a very different syntax to the *if* statement
 - There is no *header–suite* delineation, as for statements
 - The *else* is mandatory
 - There is no *elif*

```
user = input('Who are you? ')\nuser = user.title() if user else 'Guest'
```

Exception handling

- **An exception is a signal (with data) to discontinue a control path**
 - **A raised exception propagates until handled by an *except* in a caller**

```
prompt = ('What is the airspeed velocity '  
          'of an unladen swallow? ')  
try:  
    response = input(prompt)  
except:  
    response = ''
```

Exceptions

- Exceptions are normally used to signal error or other undesirable events
 - But this is not always the case, e.g., *StopIteration* is used by iterators to signal the end of iteration
- Exceptions are objects and their type is defined in a class hierarchy
 - The root of the hierarchy is *BaseException*
 - But yours should derive from *Exception*

Catching exceptions by type

- **Exceptions can be handled by type**
 - *except* statements are tried in turn until there is a base or direct match

The most specific exception
type: *ZeroDivisionError*
derives from *ArithmeticError*

The most general match
handles any remaining
exceptions, but is not
recommended


```
try:
    ...
except ZeroDivisionError:
    ...
except ArithmeticError:
    ...
except:
    ...
```

Accessing an exception

- **A handled exception can be bound to a variable**
 - **The variable is bound only for the duration of the handler, and is not accessible after**

```
try:
    ...
except ZeroDivisionError as byZero:
    ...
except ArithmeticError:
    ...
except Exception as other:
    ...
```

byZero is only
accessible here



One handler, many types

- It is possible to define an *except* handler that matches different types
 - A handler variable can also be assigned

```
try:
    ...
except (ZeroDivisionError, OverflowError):
    ...
except (EOFError, OSError) as external:
    ...
except Exception as other:
    ...
```



Raising exceptions

- A *raise* statement specifies a class or an object as the exception to raise
 - If it's a class name, an object instantiated from that class is created and raised

Re-raise current
handled exception

Raise a new
exception chained
from an existing
exception named
caughtException

```
raise Exception
raise Exception("I don't know that")
raise
raise Exception from caughtException
raise Exception from None
```

Raise a new exception ignoring
any previous exception

try else

- A *try* and *except* can be associated with an *else* statement
 - This is executed after the *try* if and only if no exception was raised

```
try:  
    hal.open(pod_bay.doors())  
except SorryDave:  
    airlock.open()  
else:  
    pod_bay.park(pod)
```

try finally

- A *finally* statement is executed whether an exception is raised or not
 - Useful for factoring out common code from *try* and *except* statements, such as clean-up code

```
log = open('log.txt')
try:
    print(log.read())
finally:
    log.close()
```

Permissible *try* forms

```
try:  
    ...  
except:  
    ...
```

One or more *except* handlers, but no more than a single *finally* or *else*

```
try:  
    ...  
finally:  
    ...
```

```
try:  
    ...  
except:  
    ...  
finally:  
    ...
```

```
try:  
    ...  
except:  
    ...  
else:  
    ...
```

else cannot appear unless it follows an *except*

```
try:  
    ...  
except:  
    ...  
else:  
    ...  
finally:  
    ...
```

with

- The *with* statement makes regular and exception-safe clean-up simple
 - A clean-up action is called automatically whether or not an exception is raised
 - Multiple objects can be specified
 - Relies on `__enter__` and `__exit__` methods

Recommended style
for using *open*



```
with open('log.txt') as log:  
    print(log.read())
```


Exception guidelines

- **Don't catch an exception unless you know what to do with it**
 - And be suspicious if you do nothing with it
- **Always use *with* for resource handling, in particular file handling**
 - And don't bother checking whether a file is open after you open it
- **Use exceptions rather than error codes**

for

- ***for* iterates over a sequence of values**
 - Over containers — e.g., string, list, tuple, set or dictionary — or other iterables
 - Loop values are bound to one or more target variables

```
machete = ['IV', 'V', 'II', 'III', 'VI']  
for episode in machete:  
    print('Star Wars', episode)
```

```
for episode in 'IV', 'V', 'II', 'III', 'VI':  
    print('Star Wars', episode)
```

Iterating over a *range*

- It is common to use *range* to define a number sequence to loop over
 - A range is a first-class, built-in object and doesn't allocate an actual list of numbers

```
for i in range(100):  
    if i % 2 == 0:  
        print(i)
```

← Iterate from 0 up to (but not including) 100

```
for i in range(0, 100, 2):  
    print(i)
```

← Iterate from 0 up to (but not including) 100 in steps of 2

How not to iterate containers

- Do not use a *range*-derived index to index into lists and tuples
 - Traverse the elements directly using *for*
- Only the keys will be iterated over if a dictionary is the object of a *for* loop
 - To iterate over the values or the key–value pairs use a view, i.e., *values* or *items* — do not iterate over the keys and look up the corresponding value each time

Iterating over dictionaries

```
airports = {  
    'AMS': 'Schiphol',  
    'LHR': 'Heathrow',  
    'OSL': 'Oslo',  
}
```

```
for code in airports:  
    print(code)
```

← Iterate over the keys

```
for code in airports.keys():  
    print(code)
```

← Iterate over the keys

```
for name in airports.values():  
    print(name)
```

← Iterate over the values

```
for code, name in airports.items():  
    print(code, name)
```

← Iterate over key–value pairs as tuples

Loop *else* statements

- Both *while* and *for* support optional *else* statements
 - It is executed if when the loop completes, i.e., (mostly) equivalent to a statement following the loop

```
with open('log.txt') as log:
    for line in log:
        if line.startswith('DEBUG'):
            print(line, end='')
    else:
        print('*** End of log ***')
```

break & continue

- Both *while* and *for* support...
 - Early loop exit using *break*, which bypasses any loop *else* statement
 - Early loop repeat using *continue*, which execute *else* if nothing further to loop

```
with open('log.txt') as log:
    for line in log:
        if line.startswith('FATAL'):
            print(line, end='')
            break
```

assert

- The *assert* statement can be used to check invariants in program code
 - Can also be used for ad hoc testing

```
assert value is not None
```

Equivalent to...

```
if __debug__ and not (value is not None):  
    raise AssertionError
```

```
assert value is not None, 'Value missing'
```

Equivalent to...

```
if __debug__ and not (value is not None):  
    raise AssertionError('Value missing')
```


Strings

From string theory to string
practice

Facts at a glance

- **Strings are immutable sequences**
- **There are many string literal forms**
- **Operations include comprehensive support for indexing and slicing**
- **There are two supported approaches to string formatting**
- **Strings are used for function, class and module documentation**

Of strings & bytes

- **Strings are immutable**
 - Cannot be modified in place; if you want a different string, use a different string
- **The *str* type holds Unicode characters**
 - There is no type for single characters
- **The *bytes* type is used for strings of bytes, i.e., ASCII or Latin-1**
 - The *bytearray* type is used for modifiable byte sequences

String literal forms

print(...)

```
'Single-quoted string'  
"Double-quoted string"  
'String with\nnewline'  
  
'Unbroken\  
string'  
r'\n is an escape code'  
'Pasted' ' ' 'string'  
('Pasted'  
 ' '  
 'string')  
"""String with  
newline"""
```

gives...

```
Single-quoted string  
Double-quoted string  
String with  
newline  
Unbroken string  
  
\n is an escape code  
Pasted string  
Pasted string  
  
String with  
newline
```

String operations

Built-in query functions

```
chr(codepoint)  
len(string)  
ord(character)  
str(value)
```

Substring containment

```
substring in string  
substring not in string
```

String concatenation

```
first + second  
string * repeat  
repeat * string
```

String comparison (lexicographical ordering)

```
lhs == rhs  
lhs != rhs  
lhs < rhs  
lhs <= rhs  
lhs > rhs  
lhs >= rhs
```

String indexing

- **Strings can be indexed, which results in a string of length 1**
 - **As strings are immutable, a character can be subscripted but assigned to**
- **Index 0 is the initial character**
 - **Indexing past the end raises an exception**
- **Negative indexing goes through the string in reverse**
 - **I.e., -1 indexes the last character**

String slicing

- It is possible to take a slice of a string by specifying one or more of...
 - A start position, which defaults to *0*
 - A non-inclusive end position (which may be past the end, in which case the slice is up to the end), which defaults to *len*
 - A step, which defaults to *1*
- With a step of *1*, a slice is equivalent to a simple substring

String indexing & slicing

<i>string[index]</i>	<i>General form of subscript operation</i>
<i>string[0]</i>	<i>First character</i>
<i>string[len(string) - 1]</i>	<i>Last character</i>
<i>string[-1]</i>	<i>Last character</i>
<i>string[-len(string)]</i>	<i>First character</i>
<i>string[first:last]</i>	<i>Substring from first up to last</i>
<i>string[index:]</i>	<i>Substring from index to end</i>
<i>string[:index]</i>	<i>Substring from start up to index</i>
<i>string[:]</i>	<i>Whole string</i>
<i>string[first:last:step]</i>	<i>Slice from first to last in steps of step</i>
<i>string[::-step]</i>	<i>Slice of whole string in steps of step</i>

Selection of string methods

string.join(strings)

Join each element of strings with string

string.split()

Split into a list based on spacing

string.split(separator)

Split into a list based on separator

string.replace(old, new)

Replace all occurrences of old with new

string.strip()

Strip leading and trailing spaces

string.lower()

All to lower case

string.upper()

All to upper case

string.startswith(text)

Whether starts with text substring

string.endswith(text)

Whether ends with text substring

string.count(text)

Number of occurrences of text

string.find(text)

Index of first occurrence of text, or -1

string.index(text)

Like find, but ValueError raised on fail

string.isalpha()

True if all characters are alphabetic

string.isdecimal()

True if all characters are decimal digits

string.islower()

True if all characters are lower case

string.isupper()

True if all characters are lower case

String formatting with *format*

- **Strings support *format*, a method for formatting multiple arguments**
 - **Default-ordered, positional and named parameter substitution are supported**

```
'First {}, now {}!'.format('that', 'this')  
'First {0}, now {1}!'.format('that', 'this')  
'First {1}, now {0}!'.format('that', 'this')  
'First {0}, now {0}!'.format('that', 'this')  
'First {x}, now {y}!'.format(x='that', y='this')
```

Use `{{` and `}}` to embed `{` and `}` in a string without format substitution

String formatting with %

- **Strings also support a *printf*-like approach to formatting**
 - **The mini-language is based on C's *printf*, plus some additional features**
 - **Its use is often discouraged as it is error prone for large formatting tasks**

```
'First %s, now %s!' % ('that', 'this')
```

```
'First %(x)s, now %(y)s!' % {'x': 'that', 'y': 'this'}
```

```
'First %d, now %d!' % (1, 2)
```

Documentation strings

- The first line of a function, class or module can optionally be a string
 - This docstring can be accessed via `__doc__` on the function or class
 - Conventionally a complete sentence enclosed in triple quotes

```
def echo(strings):  
    """Prints space-adjoined sequence of strings."""  
    print(' '.join(strings))
```

Functions

Defining, calling & passing

Facts at a glance

- **Functions are first-class objects**
- **Python supports lambda expressions and nested function definitions**
- **Argument values can be defaulted**
- **Functions can take both positional arguments and keyword arguments**
- **Functions can be defined to take an arbitrary number of arguments**

Functions as objects

- **Functions can be passed as arguments and can be used in assignment**
 - This supports many callback techniques and functional programming idioms
- **Conversely, any object that is callable can be treated as a function**
 - *callable* is a built-in predicate function
- **Functions always return a value**
 - *None* if nothing is returned explicitly

Passing & calling functions

```
def does_nothing():  
    pass  
  
assert callable(does_nothing)  
assert does_nothing() is None
```

```
unsorted = ['Python', 'parrot']  
print(sorted(unsorted, key=str.lower))
```

← Keyword argument

```
def is_even(number):  
    return number % 2 == 0  
  
def print_if(values, predicate):  
    for value in values:  
        if predicate(value):  
            print(value)  
  
print_if([2, 9, 9, 7, 9, 2, 4, 5, 8], is_even)
```



Lambda expressions

- **A *lambda* is simply an expression that can be passed around for execution**
 - It can take zero or more arguments
 - As it is an expression not a statement, this can limit the applicability
- **Lambdas are anonymous, but can be assigned to variables**
 - But defining a one-line named function is preferred over global lambda assignment

Lambdas expressed

```
def print_if(values, predicate):  
    for value in values:  
        if predicate(value):  
            print(value)
```

```
print_if(  
    [2, 9, 9, 7, 9, 2, 4, 5, 8],  
    lambda number: number % 2 == 0)
```



An ad hoc function that takes a single argument — in this case, *number* — and evaluates to a single expression — in this case, *number % 2 == 0*, i.e., whether the argument is even or not.

Experiment

- Create a *dict* mapping airport codes to airport names
 - Select 3 to 6 airports
- Use *sorted* to sort by...
 - Airport code
 - Airport name
 - Longitude and/or latitude — either extend the mapping from just names or introduce an additional *dict* with positions

Nested functions

- **Function definitions can be nested**
 - **Each invocation is bound to its surrounding scope, i.e., it's a closure**

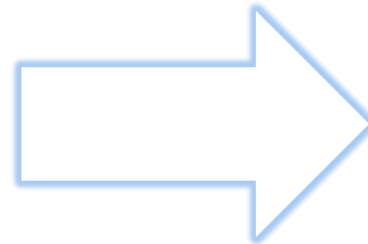
```
def logged_execution(action, output):  
    def log(message):  
        print(message, action.__name__, file=output)  
    log('About to execute')  
    try:  
        action()  
        log('Successfully executed')  
    except:  
        log('Failed to execute')  
        raise
```

Name access

```
world = 'Hello'
def outer_function():
    def nested_function():
        nonlocal world
        world = 'Ho'
    world = 'Hi'
    print(world)
    nested_function()
    print(world)
```

Refers to any *world* that will be assigned in within *outer_function*, but not the global *world*

```
outer_function()
print(world)
```



```
Hi
Ho
Hello
```

Default arguments

- **The defaults will be substituted for corresponding missing arguments**
 - **Non-defaulted arguments cannot follow defaulted arguments in the definition**

```
def line_length(x=0, y=0, z=0):  
    return (x**2 + y**2 + z**2)**0.5  
  
line_length()  
line_length(42)  
line_length(3, 4)  
line_length(1, 4, 8)
```

Defaults & evaluation

- **Defaults evaluated once, on definition, and held within the function object**
 - **Avoid using mutable objects as defaults, because any changes will persist between function calls**
 - **Avoid referring to other parameters in the parameter list — this will either not work at all or will appear to work, but using a name from an outer scope**

Arbitrary argument lists

- **A function can be defined to take a variable argument list**
 - Variadic arguments passed in as a tuple
 - Variadic parameter declared using ***** after any mandatory positional arguments
 - This syntax also works in assignments

```
def mean(value, *values):  
    return sum(values, value) / (1 + len(values))
```


Unpacking argument lists

- **To apply values from an iterable, e.g., a tuple, as arguments, unpack using ***
 - **The iterable is expanded to become the argument list at the point of call**

```
def line_length(x, y, z):  
    return (x**2 + y**2 + z**2)**0.5
```

```
point = (2, 3, 6)  
length = line_length(*point)
```

Keyword arguments

- **Reduce the need for chained builder calls and parameter objects**
 - Keep in mind that the argument names form part of the function's public interface
 - Arguments following a variadic parameter are necessarily keyword arguments

```
def date(year, month, day):  
    return year, month, day  
  
sputnik_1 = date(1957, 10, 4)  
sputnik_1 = date(day=4, month=10, year=1957)
```

Arbitrary keyword arguments

- A function can be defined to receive arbitrary keyword arguments
 - These follow the specification of any other parameters, including variadic
 - Use `**` to both specify and unpack
- Keyword arguments are passed in a *dict* — a keyword becomes a key
 - Except any keyword arguments that already correspond to formal parameters

Positionals and keywords

```
def present(*listing, **header):  
    for tag, info in header.items():  
        print(tag + ': ' + info)  
    for item in listing:  
        print(item)
```

```
present(  
    'Mercury', 'Venus', 'Earth', 'Mars',  
    type='Terrestrial', star='Sol')
```

```
type: Terrestrial  
star: Sol  
Mercury  
Venus  
Earth  
Mars
```

Annotations

- **A function's parameters and its result can be annotated with expressions**
 - **No semantic effect, but are associated with the function object as metadata, typically for documentation purposes**

```
def is_leap_year(year : 'Gregorian') -> bool:  
    return year % 4 == 0 and year % 100 != 0 or year % 400 == 0
```

```
is_leap_year.__annotations__  
{'return': <class 'bool'>, 'year': 'Gregorian'}
```

Decorators

- A function definition may be wrapped in decorator expressions
 - A decorator is a function that transforms the function it decorates

```
class List:
    @staticmethod
    def nil():
        return []
    @staticmethod
    def cons(head, tail):
        return [head] + tail
```

```
nil = List.nil()
one = List.cons(1, nil)
two = List.cons(2, one)
```

[
[1]
[2, 1]

Built-in Containers

Sequences, sets & dictionaries

Facts at a glance

- *range*, *tuple* and *list* are sequence types
- Sequence types hold values in an indexable and sliceable order
- *range*, *tuple* and *frozenset* are immutable containers
- *set* and *frozenset* hold unique values
- *dict* is a mutable mapping type

Iterable objects

- All container types — including *range* and *str* — are iterable
 - Can appear on right-hand side of *in* (*for* or membership) or of a multiple assignment
- Except for text and *range* types, containers are heterogeneous

```
first, second, third = [1, 2, 3]  
head, *tail = range(10)  
*most, last = 'Hello'
```

Container operations

Built-in queries and predicates

Equality comparison

```
lhs == rhs  
lhs != rhs
```

Returns sorted list of *container*'s values
(also takes keyword arguments for key
comparison — *key* — and reverse
sorting — *reverse*)

```
len(container)  
min(container)  
max(container)  
any(container)  
all(container)  
sorted(container)
```

Membership (key membership for mapping types)

```
value in container  
value not in container
```

Sequences

- **A *tuple* is an immutable sequence**
 - Supports (negative) indexing, slicing, concatenation and other operations
- **A *list* is a mutable sequence**
 - It supports similar operations to a *tuple*, but in addition it can be modified
- **A *range* is an immutable sequence**
 - It supports indexing, slicing and other operations

Immutable sequences

Raises exception if *value* not found

Search methods

sequence.index(value)
sequence.count(value)

Lexicographical ordering
(not for range)

lhs < rhs
lhs <= rhs
lhs > rhs
lhs >= rhs

Indexing and slicing

sequence[index]
sequence[first:last]
sequence[index:]
sequence[:index]
sequence[:]
sequence[first:last:step]
sequence[::step]

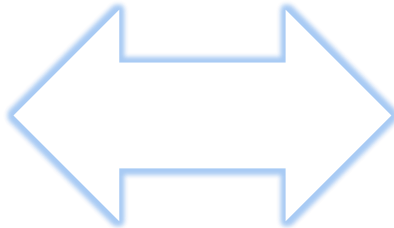
Concatenation (not for *range*)

first + second
*sequence * repeat*
*repeat * sequence*

Tuples

- Tuples are the default structure for unpacking in multiple assignment
- The display form of *tuple* relies on parentheses
 - Thus it requires a special syntax case to express a tuple of one item

```
x = 1,  
x = 1, 2  
x, y = 1, 2  
x = 1, (2, 3)
```



```
x = (1,)  
x = (1, 2)  
(x, y) = (1, 2)  
x = (1, (2, 3))
```

Lists

- **As lists are mutable, assignment is supported for their elements**
 - **Augmented assignment on subscripted elements**
 - **Assignment to subscripted elements and assignment through slices**
- **List slices and elements support *del***
 - **Removes them from the list**

list extras

Index- and slice-based operations

```
list[index]  
list[index] = value  
del list[index]  
list[first:last:step]  
list[first:last:step] = other  
del list[first:last:step]
```

Whole-list operations

```
list.clear()  
list.reverse()  
list.sort()
```

Element modification methods

```
list.append(value)  
list.insert(index, value)  
list.pop()  
list.pop(index)  
list.remove(value)
```

Dictionaries

- ***dict* is a mapping type**
 - I.e., it maps a key to a correspond value
 - Keys, values and mappings are viewable via *keys*, *values* and *items* methods
- **Keys must be of immutable types**
 - This includes *int*, *float*, *str*, *tuple*, *range* and *frozenset*, but excludes *list*, *set* and *dict*
 - Immutable types are hashable (*hash* can be called on them)

dict operations

Key-based operations

```
key in dict  
key not in dict  
dict.get(key, default)  
dict.get(key)  
dict[key]  
dict[key] = value  
del dict[key]
```

Equivalent to calling *get* with a *default* of *None*

Automagically creates entry if *key* not already in *dict*

Views

```
dict.keys()  
dict.values()  
dict.items()
```

Manipulation methods

```
dict.clear()  
dict.pop(key)  
dict.pop(key, default)  
dict.get(key)  
dict.get(key, default)  
dict.update(other)
```

Sets

- ***set* and *frozenset* both define containers of unique hashable values**
 - ***set* is mutable and has a display form — note that *set()* is the empty set, not *{}***
 - ***frozenset* is immutable and can be constructed from a *set* or other iterable**

```
text = 'the cat sat on the mat'  
words = frozenset(text.split())  
print('different words used:', len(words))
```

set & frozenset operations

Set relations (in addition to equality and set membership)

$lhs < rhs$

$lhs \leq rhs$ `lhs.issubset(rhs)`

$lhs > rhs$

$lhs \geq rhs$ `lhs.issuperset(rhs)`

`lhs.isdisjoint(rhs)`

Set combinations

$lhs \mid rhs$ `lhs.union(rhs)`

$lhs \& rhs$ `lhs.intersection(rhs)`

$lhs - rhs$ `lhs.difference(rhs)`

$lhs \wedge rhs$ `lhs.symmetric_difference(rhs)`

set extras

Manipulation methods

```
set.add(element)  
set.remove(element)  
set.discard(element)  
set.clear()  
set.pop()
```

Removes and returns
arbitrary element



Augmented assignment and updates

```
lhs |= rhs    lhs.update(rhs)  
lhs &= rhs    lhs.intersection_update(rhs)  
lhs -= rhs    lhs.difference_update(rhs)  
lhs ^= rhs    lhs.symmetric_difference_update(rhs)
```

Iteration

Iterables, comprehensions,
iterators & generators

Facts at a Glance

- **A number of functions eliminate the need to many common loop patterns**
- **Functional programming tools reduce many loops to simple expressions**
- **A comprehension creates a list, set or dictionary without explicit looping**
- **Iterators and generators support a lazy approach to handling series of values**

Iteration

- The conventional approach to iterating a series of values is to use *for*
 - Iterating over one or more iterables directly, as opposed to index-based loops
- However, part of the secret to good iteration is... don't iterate explicitly
 - Think more functionally — use functions and other objects that set up or perform the iteration for you

Being lazy (part 1)

- Be lazy by taking advantage of functionality already available
 - E.g., the *min*, *max*, *sum*, *all*, *any* and *sorted* built-ins all apply to iterables
 - Many common container-based looping patterns are captured in the form of container comprehensions
 - Look at *itertools* and *functools* modules for more possibilities

Being lazy (part 2)

- **Be lazy by using abstractions that evaluate their values on demand**
 - You don't need to resolve everything into a list in order to use a series of values
- **Iterators and generators let you create objects that yield values in sequence**
 - An iterator is an object that iterates
 - For some cases you can adapt existing iteration functionality using the *iter* built-in

Enumerating iterable items

- Iterating a list without an index is easy... but what if you need the index?
 - Use *enumerate* to generate indexed pairs from any iterable

```
codes = ['AMS', 'LHR', 'OSL']  
  
for index, code in enumerate(codes, 1):  
    print(index, code)
```

```
1 AMS  
2 LHR  
3 OSL
```

Zippping iterables together

- Elements from multiple iterables can be zipped into a single sequence
 - Resulting iterator *tuple*-ises corresponding values together

```
codes = ['AMS', 'LHR', 'OSL']  
names = ['Schiphol', 'Heathrow', 'Oslo']  
  
for airport in zip(codes, names):  
    print(airport)  
  
airports = dict(zip(codes, names))
```

Mapping over iterables

- ***map* applies a function to iterable elements to produce a new iterable**
 - The given callable object needs to take as many arguments as there are iterables

```
def histogram(data):  
    return map(lambda size: size * '#',  
               map(lambda value: len(value), data))  
  
text = "I'm sorry Dave, I'm afraid I can't do that."  
print('\n'.join(histogram(text.split())))
```

Filtering iterable values

- ***filter*** includes only values that satisfy a given predicate in its generated result
 - If no predicate is provided — i.e., *None* — the Boolean of each value is assumed

```
numbers = [42, 0, -273.15, 0.0, 97, 23, -1]
positive = filter(lambda value: value > 0, numbers)
non_zero = filter(None, numbers)
```

```
list(positive)           [42, 97, 23]
list(non_zero)           [42, -273.15, 97, 23, -1]
```

Comprehensions

- **Comprehensions are expressions that define value sequences declaratively**
 - Defined by intension as an expression, rather than procedurally
 - Comprehension syntax is used to create lists, sets, dictionaries and generators
- **Although the *for* and *if* keywords are used, they have different implications**
 - Can read *for* as *from* and *if* as *where*

Container comprehensions

```
[i**2 for i in range(13)]
```

```
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81, 100, 121, 144]
```

List comprehension

```
{abs(i) for i in range(-10, 10)}
```

```
{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10}
```

Set comprehension

```
{i: i**2 for i in range(8)}
```

```
{0: 0, 1: 1, 2: 4, 3: 9, 4: 16, 5: 25, 6: 36, 7: 49}
```

Dictionary comprehension

One way to do it?

```
list(range(0, 100, 2))
```

```
list(range(100))[::2]
```

```
list(range(100)[::2])
```

```
list(map(lambda i: i * 2, range(50)))
```

```
list(filter(lambda i: i % 2 == 0, range(100)))
```

```
[i * 2 for i in range(50)]
```

```
[i for i in range(100) if i % 2 == 0]
```

```
[i for i in range(100)][::2]
```

Experiment

```
values = ['A'] + list(range(2, 11)) + ['J', 'Q', 'K']  
suits = ['spades', 'hearts', 'diamonds', 'clubs']  
[(value, suit) for suit in suits for value in values]
```



In what order do you expect the elements
in the comprehension to appear?

Experiment

- A Pythagorean triple is three integers — a , b and c — such that $a^2 + b^2 = c^2$
 - E.g., $(3, 4, 5)$ and $(5, 12, 13)$ are Pythagorean triples
- Write a comprehension to find Pythagorean triples (up to some value)
 - Try to ensure that triples occur once, i.e., $(3, 4, 5)$ but not also $(4, 3, 5)$, $(5, 4, 3)$, etc.

Iterables & iterators

- An iterator is an object that supports the `__next__` method for traversal
 - Invoked via the `next` built-in function
- An iterable is an object that returns an iterator in support of `__iter__` method
 - Invoked via the `iter` built-in function
 - Iterators are iterable, so the `__iter__` method is an identity operation

Generators

- **A generator is a comprehension that results in an iterator object**
 - It does not result in a container of values
 - Must be surrounded by parentheses unless it is the sole argument of a function

```
(i * 2 for i in range(50))  
(i for i in range(100) if i % 2 == 0)
```

```
sum(i * i for i in range(10))
```

Generator functions & *yield*

- You can write your own iterator classes or, in many cases, just use a function
 - On calling, a generator function returns an iterator and behaves like a coroutine

```
def evens_up_to(limit):  
    for i in range(0, limit, 2):  
        yield i  
  
for i in evens_up_to(100):  
    print(i)
```

Classes & Objects

Definition, instantiation & usage

Facts at a glance

- Object types are defined by classes
- Attributes are not strictly private
- Methods can be bound to instance or class or be static
- Classes derive from one or more other classes, with *object* as default base
- Classes and methods may be abstract by convention or by decoration

Classes

- A class's suite is executed on definition
 - Instance methods in a class must allow for a *self* parameter, otherwise they cannot be called on object instances
 - Attributes are held internally within a *dict*



By default all classes
inherit from *object*

```
class Point:
    def __init__(self, x=0, y=0):
        self.x, self.y = x, y
    def is_at_origin(self):
        return self.x == self.y == 0
```

Object initialisation

- The special `__init__` method is used to initialise an object instance
 - It is called automatically, if present
 - A class name is *callable*, and its call signature is based on `__init__`
- Introduce instance attributes by assigning to them in `__init__`
 - Can be problematic in practice to introduce instance attributes elsewhere

Publicity & privacy

- Attribute and method names that begin `__` are considered private
 - They are mangled with the class name, e.g., `__x` in `Point` becomes `_Point__x`
 - Other names publicly available as written

`__x` and `__y` are mangled to
`_Point__x` and `_Point__y`

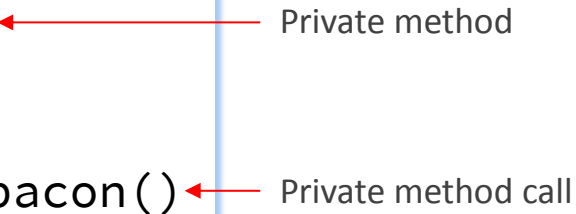
Within *Point*'s methods
`__x` and `__y` are available
by their unmangled names

```
class Point:
    def __init__(self, x=0, y=0):
        self.__x, self.__y = x, y
    def is_at_origin(self):
        return self.__x == self.__y == 0
```

Attribute & method access

- **Attributes and methods of an object can be accessed using dot notation**
 - Access from outside is subject to name mangling if the features are private
 - Access within a method is unmangled

```
class Spam:
    def __bacon(self):
        return Spam()
    def egg(self):
        return self.__bacon()
```



Private method

Private method call

Class attributes

- **A class attribute is defined as a variable within the class statement**
 - Can be accessed as a variable of the class using dot notation
 - Can be accessed by methods via self
 - Single occurrence shared by all instances

```
class Menu:  
    options = {'spam', 'egg', 'bacon', 'sausage'}  
    def order(self, *choice):  
        return set(choice) <= self.options
```

Class methods

- **Class methods are bound to the class, not just its instances**
 - They are decorated with **`@classmethod`**
 - They take a class object, conventionally named **`cls`**, as their first argument
 - They can be overridden in derived classes
 - They are also accessible, via **`self`**, within instance methods

Derived breakfast

```
class Menu:
    @classmethod
    def options(cls):
        return {'spam', 'egg', 'bacon', 'sausage'}
    def order(self, *choice):
        return set(choice) <= self.options()

class NonSpammyMenu(Menu):
    @classmethod
    def options(cls):
        return {'beans', 'egg', 'bacon', 'sausage'}
```

Static methods

- **Static methods are scoped within a class but have no context argument**
 - I.e., neither a *cls* nor a *self* argument
- **They are effectively global functions in a class scope**

```
class Menu:
    @staticmethod
    def options():
        return {'spam', 'egg', 'bacon', 'sausage'}
    def order(self, *choice):
        return set(choice) <= self.options()
```


Methods versus functions

- **Instance and class methods are functions bound to their first argument**
 - A bound function is an object
- **Method definitions are ordinary function definitions**
 - Can be used as functions, accessed with dot notation from the class

```
class Spam:
    def egg(self):
        pass

spam = Spam()
spam.egg()
Spam.egg(spam)
```

Inheritance

- A class can be derived from one or more other classes
 - By default, all classes inherit from *object*
 - Method names are searched depth first from left to right in the base class list

```
class Base:  
    pass  
class Derived(Base):  
    pass
```



```
class Base(object):  
    pass  
class Derived(Base):  
    pass
```

Inheritance & overriding

- **Methods from the base classes are inherited into the derived class**
 - No difference in how they are called
 - They can be overridden simply by defining a new method of the same name
 - Inheritance is queryable feature of objects

```
isinstance(value, Class)  
issubclass(Class1, Class2)
```

Abstract classes

- **Abstract classes are more a matter of convention than of language**
 - Python lacks the direct support found found in statically typed languages
- **There are two approaches...**
 - In place of declaring a method abstract, define it to raise *NotImplementedError*
 - Use the `@abstractmethod` decorator from the *abc* module

Two abstract

Instances of *Command* can be instantiated, but calls to *execute* will fail

```
class Command:
    def execute(self):
        raise NotImplementedError
```

Instances of *Command* cannot be instantiated — but *ABCMeta* must be the metaclass for *@abstractmethod* to be used

```
from abc import ABCMeta
from abc import abstractmethod

class Command(metaclass=ABCMeta):
    @abstractmethod
    def execute(self):
        pass
```

Outroduction

What's done is done

The end?

- **No, only a beginning**
 - There is more to the language and how to use it effectively
 - There is more to the library and how to use it effectively
 - There is more to the Python ecosystem and how to use it effectively
- **But it is a beginning**
 - Well done!

What next?

- **Language...**
 - Namespaces, decorators, special methods, generators, etc.
- **Libraries...**
 - Both the extensive standard one and the even more extensive non-standard ones
- **Styles...**
 - Master Python's OO approach and its support for functional programming

Labs & Homework

To do...

Guidance

- **Labs should be undertaken in pairs using Cyber-Dojo**
 - **Swap between driving and navigator roles within the same pair**
- **Homework is carried out individually in your own environment**
 - **Do not spend too much time on this — an hour or so — and try not to overengineer the solution!**

Lab: Day 1

Yatzy

The game of Yatzy is a simple dice game. Each player rolls five six-sided dice. The player places the roll in a category, such as Ones, Twos, Fives, Pair, Two Pairs, etc.

If the roll is compatible with the category, the player gets a score for the roll according to the rules. If the roll is not compatible with the category, the player scores zero for the roll.

For example, if a player rolls 5, 6, 5, 5, 2 and scores the dice in the Fives category they would score 15 (three fives).

Your task is to score a *given* roll in a *given* category.

You do *not* have to program the random dice rolling.

You do *not* have to program re-rolls (as in the real game).

You do *not* play by letting the computer choose the highest scoring category for a given roll.

Lab: Day 1

Yatzy categories and scoring rules

Chance: The player scores the sum of all dice, no matter what they read. E.g., 1, 1, 3, 3, 6 placed on Chance scores 14 ($1+1+3+3+6$); 4, 5, 5, 6, 1 placed on Chance scores 21 ($4+5+5+6+1$).

Yatzy: If all dice have the same number, the player scores 50 points. E.g., 1, 1, 1, 1, 1 placed on Yatzy scores 50; 5, 5, 5, 5, 5 placed on Yatzy scores 50; 1, 1, 1, 2, 1 placed on Yatzy scores 0.

Ones, Twos, Threes, Fours, Fives, Sixes: The player scores the sum of the dice that reads 1, 2, 3, 4, 5 or 6, respectively. E.g., 1, 1, 2, 4, 4 placed on Fours scores 8 ($4+4$); 2, 3, 2, 5, 1 placed on Twos scores 4 ($2+2$); 3, 3, 3, 4, 5 placed on Ones scores 0.

Pair: If exactly two dice have the same value, the player scores the sum of the two highest matching dice. E.g., when placed on Pair: 3, 3, 3, 4, 4 scores 8 ($4+4$); 1, 1, 6, 2, 6 scores 12 ($6+6$); 3, 3, 3, 4, 1 scores 0; 3, 3, 3, 3, 1 scores 0.

Lab: Day 1

Yatzy categories and scoring rules (continued)

Two Pairs: If exactly two dice have the same value and exactly two dice have a different value, the player scores the sum of these four dice. E.g., when placed on Two Pairs: 1, 1, 2, 3, 3 scores 8 ($1+1+3+3$); 1, 1, 2, 3, 4 scores 0; 1, 1, 2, 2, 2 scores 0.

Three of a Kind: If there are exactly three dice with the same number, the player scores the sum of these dice. E.g., when placed on Three of a Kind: 3, 3, 3, 4, 5 scores 9 ($3+3+3$); 3, 3, 4, 5, 6 scores 0; 3, 3, 3, 3, 1 scores 0.

Four of a Kind: If there are exactly four dice with the same number the player scores the sum of these dice. E.g., when placed on Four of a Kind: 2, 2, 2, 2, 5 scores 8 ($2+2+2+2$); 2, 2, 2, 5, 5 scores 0; 2, 2, 2, 2, 2 scores 0.

Small Straight: When placed on Small Straight, if the dice read 1, 2, 3, 4, 5, the player scores 15 (the sum of all the dice).

Large Straight: When placed on Large Straight, if the dice read 2, 3, 4, 5, 6, the player scores 20 (the sum of all the dice).

Full House: If the dice are two of a kind and three of a different kind, the player scores the sum of all five dice. E.g., when placed on Full House: 1, 1, 2, 2, 2 scores 8 ($1+1+2+2+2$); 2, 2, 3, 3, 4 scores 0; 4, 4, 4, 4, 4 scores 0.

Homework

***numgen* — Phone number generator**

Write a small command line tool that reads a data file (*numgen.dat*) containing existing numbers, generate a new unique random 8-digit number and add it to the data file. Consider also printing it out to the console. If you give the program a numeric argument, it should append that many new numbers to the data file.

It is important that the new numbers generated are unique, but also that they are reachable: a number is unreachable if there exists another number in the database that is a leading substring of the number. E.g., if *911* exists in the database, *91134345* would not be valid number to add because when someone tries to dial the 8-digit number you will reach *911* first. You should assume that the order of numbers in the data file is significant, so you should only append new numbers to it. A naïve, but completely acceptable approach, is to iterate over every existing number and make sure it is neither the same nor a leading substring of a candidate number you have generated.

When you are done with the initial version, consider one of the options.

NB: You should find relevant info and code snippets in the *Python Codebook* and <https://docs.python.org/3/index.html>.

Homework

Usage example

```
$ cat numgen.dat
911
112
999
45783349
56778856
$ python numgen.py
88533934
$ python numgen.py 4
65899323
89798871
01334908
73344345
$ cat numgen.dat
911
112
999
88533934
65899323
89798871
01334908
73344345
```

Homework

Option 1: Make *numgen* more like a command-line utility

The next step is to use *module argparse* to parse the command line (see documentation) and try to make it look like a professional and solid tool that others might want to use. E.g., something like this:

```
$ python numgen.py
```

```
usage: numgen.py [-h] [-n] [n]
```

Create random, unique and reachable 8-digit phone numbers.

positional arguments:

n how many numbers to generate (default is 1)

optional arguments:

-h, --help show this help message and exit

-n, --dry-run do not actually update the database

--db file specify data file (default is numgen.dat)

If on a Unix-like environment, make it look and behave like a Unix command: add `#!/usr/bin/env python3` as first line in your script, then make the file executable (`chmod 0755 numgen.py`) and remove the `.py` suffix (`mv numgen.py numgen`).

Homework

Option 2: Improve performance

How long does it take to execute `numgen` for 1000, 10000 and 100000 new numbers?

How far can you improve the code so it runs faster? Experiment with different techniques.

Option 3: Guarantee termination

What happens when the database fills up? If you ask to generate more numbers than are available, what does *numgen* do?

Ensure that it does something sensible, such as stopping once it reaches a limit — either database full or after too many failed attempts to generate a new number — or refusing a request to create more numbers than are available.

Option 4: Alternative implementations under different constraints

If you changed one of the basic constraints of the problem, such as using 5- or 6-digit rather than 8-digit numbers, what alternative implementations would be practical? Experiment with different techniques.

Lab: Day 2

ISBNs – International Standard Book Numbers

There are two ISBN standards: ISBN-10 and ISBN-13. In this exercise, support for ISBN-13 is essential, whereas support for ISBN-10 is optional.

Here are some valid examples of each:

ISBN-10: 0471958697, 0 471 60695 2, 0-470-84525-2, 0-321-14653-0.

ISBN-13: 9780470059029, 978 0 471 48648 0, 978-0596809485,
978-0-13-149505-0, 978-0-262-13472-9.

Main task

Create a function that takes a string and returns true if that is a valid ISBN-13 and false otherwise.

Optional task

Also return true if the string is a valid ISBN-10.

Lab: Day 2

ISBN-10 and ISBN-13 definitions

ISBN-10 is made up of 9 digits plus a check digit (which may be X) and ISBN-13 is made up of 12 digits plus a check digit. Spaces and hyphens may be included in a code, but are not significant. This means 9780471486480 is equivalent to 978-0-471-48648-0 and 978 0 471 48648 0.

The check digit for ISBN-10 is calculated by multiplying each digit by its position (i.e., 1 x 1st digit, 2 x 2nd digit, etc.), summing these products together and taking modulo 11 of the result (with X used if the result is 10).

The check digit for ISBN-13 is calculated by multiplying each digit alternately by 1 or 3 (i.e., 1 x 1st digit, 3 x 2nd digit, 1 x 3rd digit, 3 x 4th digit, etc.), summing these products together, taking modulo 10 of the result and subtracting this value from 10, and then taking the modulo 10 of the result again to produce a single digit.