Lecture 12 – Testing

https://cw.fel.cvut.cz/wiki/courses/be5b33prg/start

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ADMIN – FINAL EXAMS

- Multiple choice test, **no materials as well as no devices allowed** (papers will be provided, only own pen is necessary). Any use of materials, devices or cooperation during the exam will be awarded with 0 points (fail).

- The **content of the final exam** will be based on the content of:
  1. **Lectures** (not limited but including the slides released after each lecture)
  2. **Exercises** during the labs
  3. **Relevant chapters** of the [Wentworth2012] book (links to relevant chapters can be found at the bottom of lecture slides)

- **Dates**: 19.1. 2018, 26.1. 2018, 2.2. 2018, 9.2. 2018.
  The exam starts sharp at 8:00. Use the Faculty information system to enroll

- **Python multiple-choice tests to study (only relevant sections)**
  http://www.sanfoundry.com/1000-python-questions-answers/

TESTING

- Including **automated tests** proves invaluable if the project becomes larger or if we have to return to it to make a small change after a long absence
- Tests serve as a form of **documentation** – by reading through test cases we can get an idea of expected behavior
- Test driven approach – **writing tests first**, thereby creating a **specification** for what the program is supposed to do, and filling in the actual program code **afterwards**

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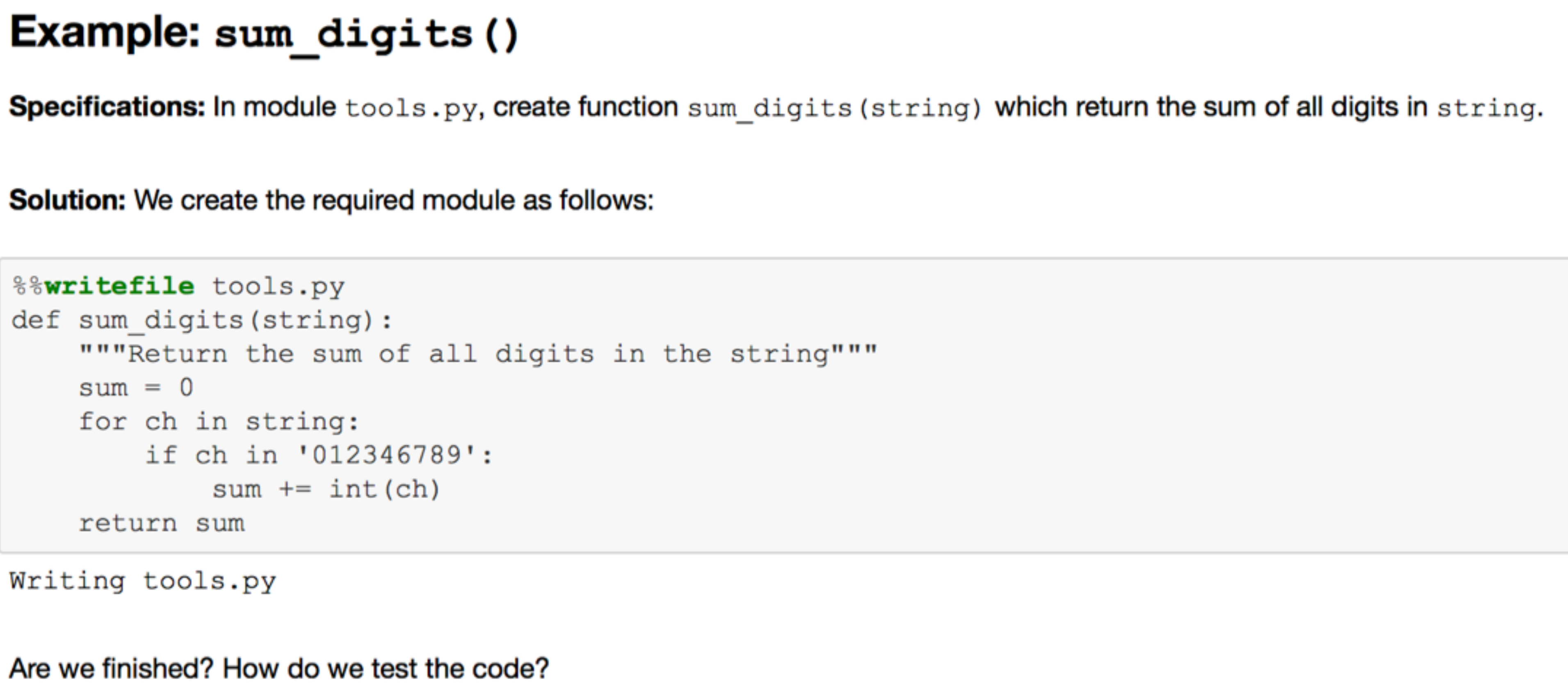
SELECTING TEST CASES

- Two major approaches: **black-box** or **glass-box** testing
- In **black-box** testing treat tested function like an opaque "black box" – only think about what the function is supposed to do (*strategies*: **equivalence testing**, **boundary value analysis**)
- In **glass-box** testing pick test cases by analyzing the code inside our function (*strategies*: **path coverage**, **statement coverage**)

SOURCE http://python-textbok.readthedocs.io/en/1.0/Packaging_and_Testing.html#testing

TESTING



Example: `sum_digits()`

Specifications: In module `tools.py`, create function `sum_digits(string)` which return the sum of all digits in `string`.

Solution: We create the required module as follows:

```
%%writefile tools.py
def sum_digits(string):
    """Return the sum of all digits in the string"""
    sum = 0
    for ch in string:
        if ch in '012346789':
            sum += int(ch)
    return sum
```

```
Writing tools.py
```

Are we finished? How do we test the code?

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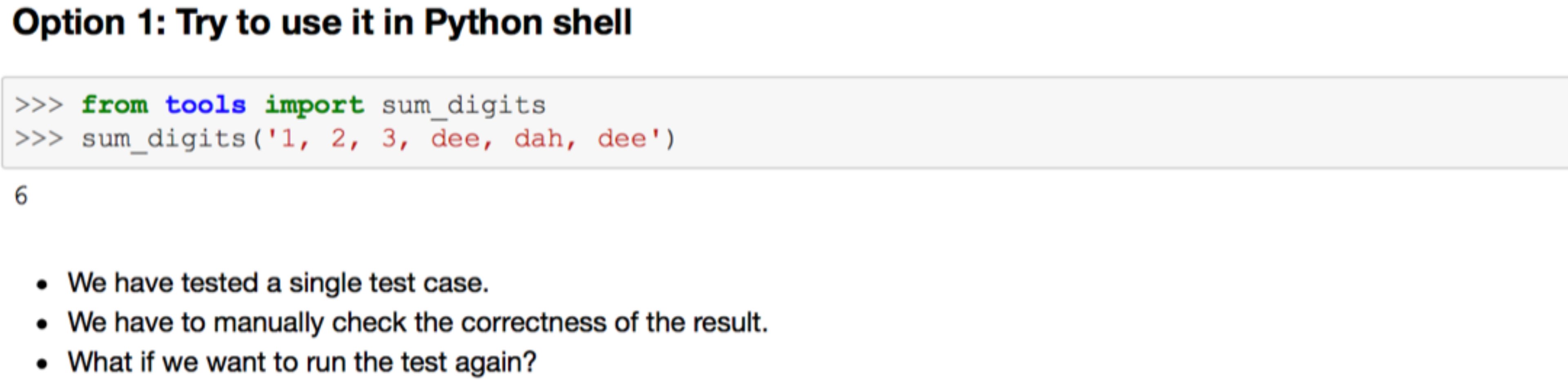
TESTING



Option 1: Try to use it in Python shell

```
>>> from tools import sum_digits
>>> sum_digits('1, 2, 3, dee, dah, dee')
```

```
6
```

- We have tested a single test case.
- We have to manually check the correctness of the result.
- What if we want to run the test again?

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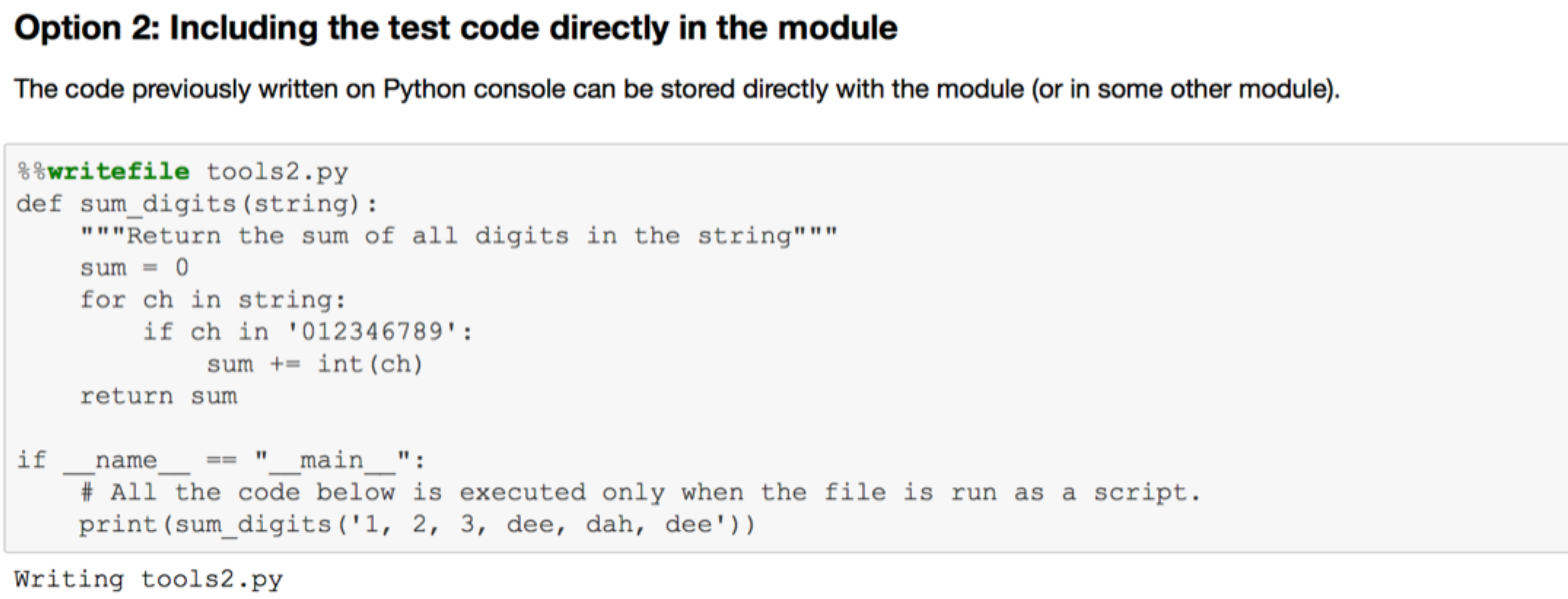
TESTING



Option 2: Including the test code directly in the module

The code previously written on Python console can be stored directly with the module (or in some other module).

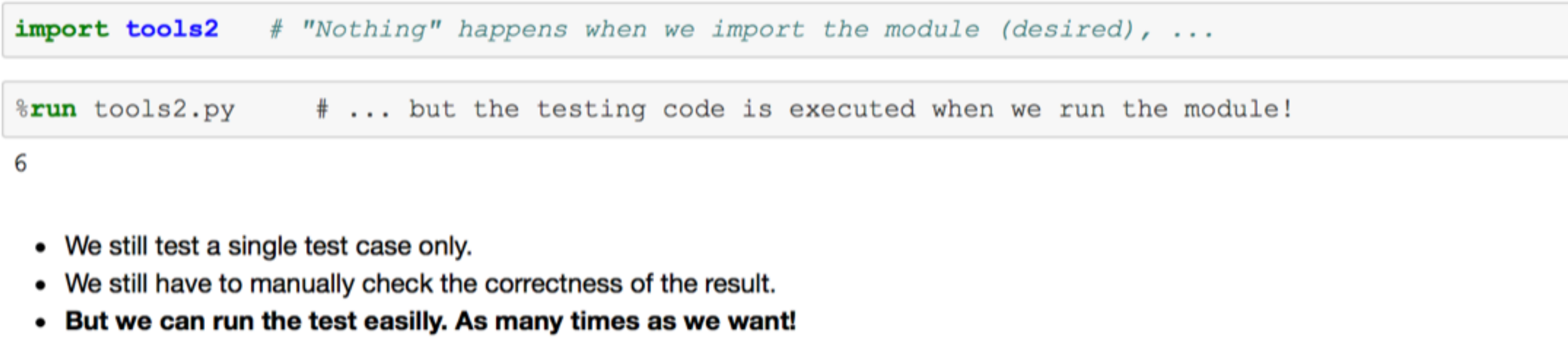
```
%%writefile tools2.py
def sum_digits(string):
    """Return the sum of all digits in the string"""
    sum = 0
    for ch in string:
        if ch in '012346789':
            sum += int(ch)
    return sum

if __name__ == "__main__":
    # All the code below is executed only when the file is run as a script.
    print(sum_digits('1, 2, 3, dee, dah, dee'))
```

```
Writing tools2.py
```

SOURCE: courtesy of Petr Posik BE5b33PR 2016/2017

TESTING



```
import tools2    # "Nothing" happens when we import the module (desired), ...
```

```
%run tools2.py      # ... but the testing code is executed when we run the module!
```

```
6
```

- We still test a single test case only.
- We still have to manually check the correctness of the result.
- **But we can run the test easilly. As many times as we want!**

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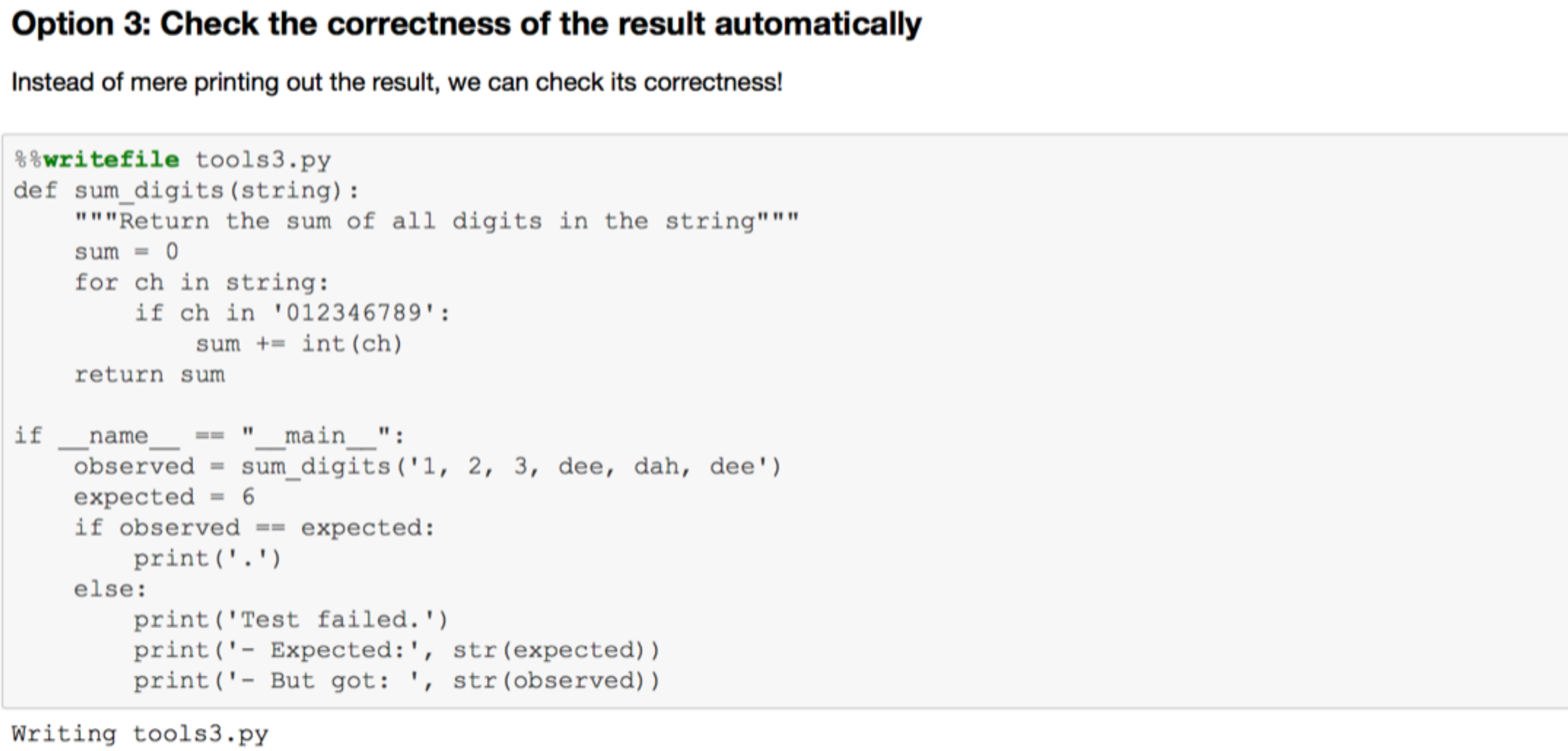
TESTING



Option 3: Check the correctness of the result automatically

Instead of mere printing out the result, we can check its correctness!

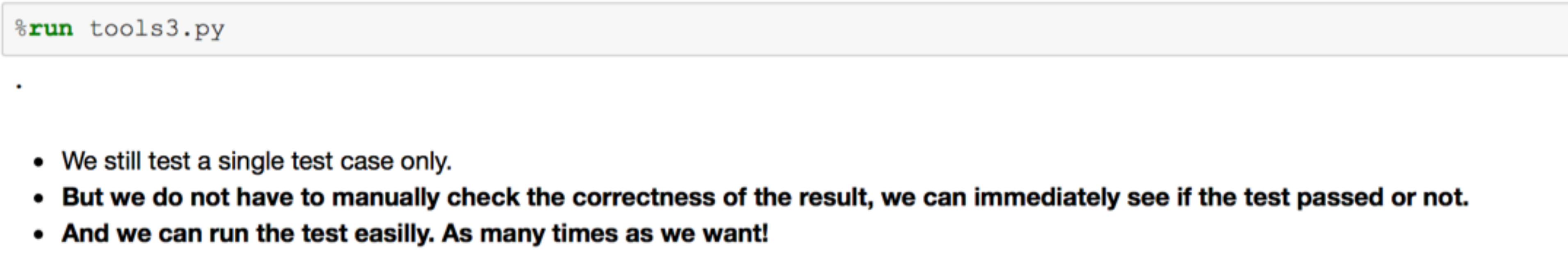
```
%%writefile tools3.py
def sum_digits(string):
    """Return the sum of all digits in the string"""
    sum = 0
    for ch in string:
        if ch in '012346789':
            sum += int(ch)
    return sum

if __name__ == "__main__":
    observed = sum_digits('1, 2, 3, dee, dah, dee')
    expected = 6
    if observed == expected:
        print('.')
    else:
        print('Test failed.')
        print('- Expected:', str(expected))
        print('- But got: ', str(observed))
```

```
Writing tools3.py
```

SOURCE: courtesy of Petr Posik BE5b33PR 2016/2017

TESTING



```
%run tools3.py
```

```
.
```

- We still test a single test case only.
- **But we do not have to manually check the correctness of the result, we can immediately see if the test passed or not.**
- **And we can run the test easilly. As many times as we want!**

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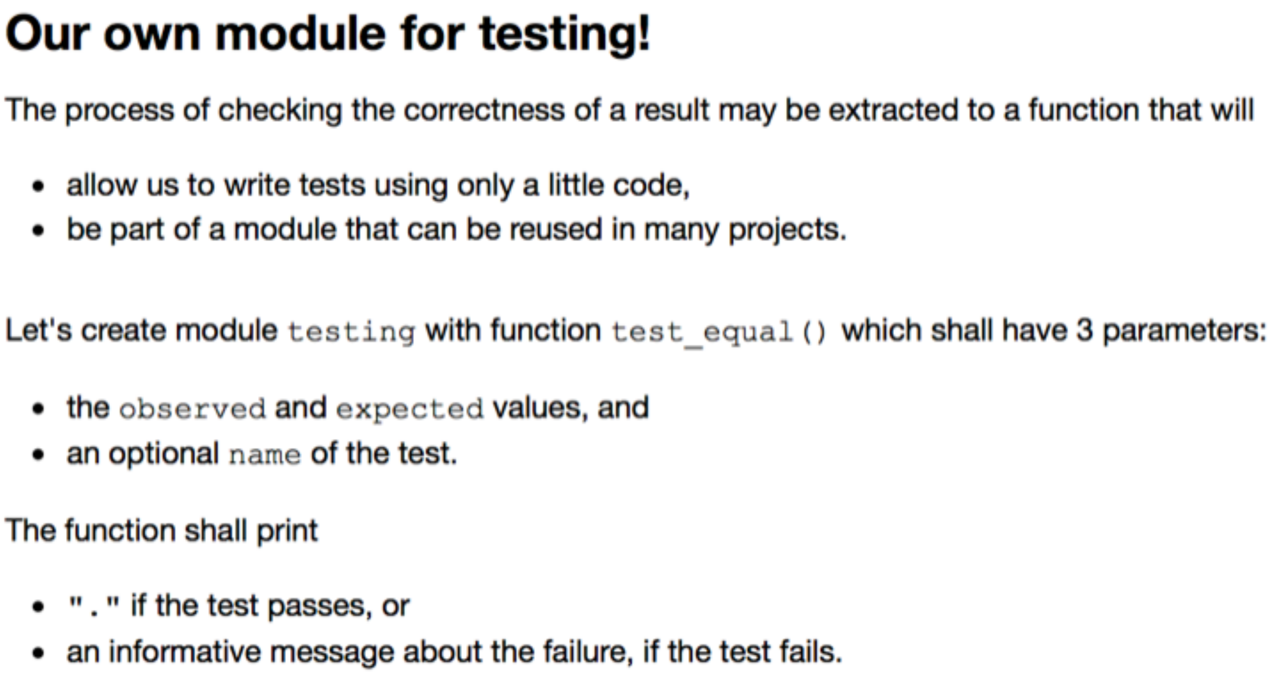
TESTING



Our own module for testing!

The process of checking the correctness of a result may be extracted to a function that will

- allow us to write tests using only a little code,
- be part of a module that can be reused in many projects.

Let's create module `testing` with function `test_equal()` which shall have 3 parameters:

- the `observed` and `expected` values, and
- an optional `name` of the test.

The function shall print

- `"."` if the test passes, or
- an informative message about the failure, if the test fails.

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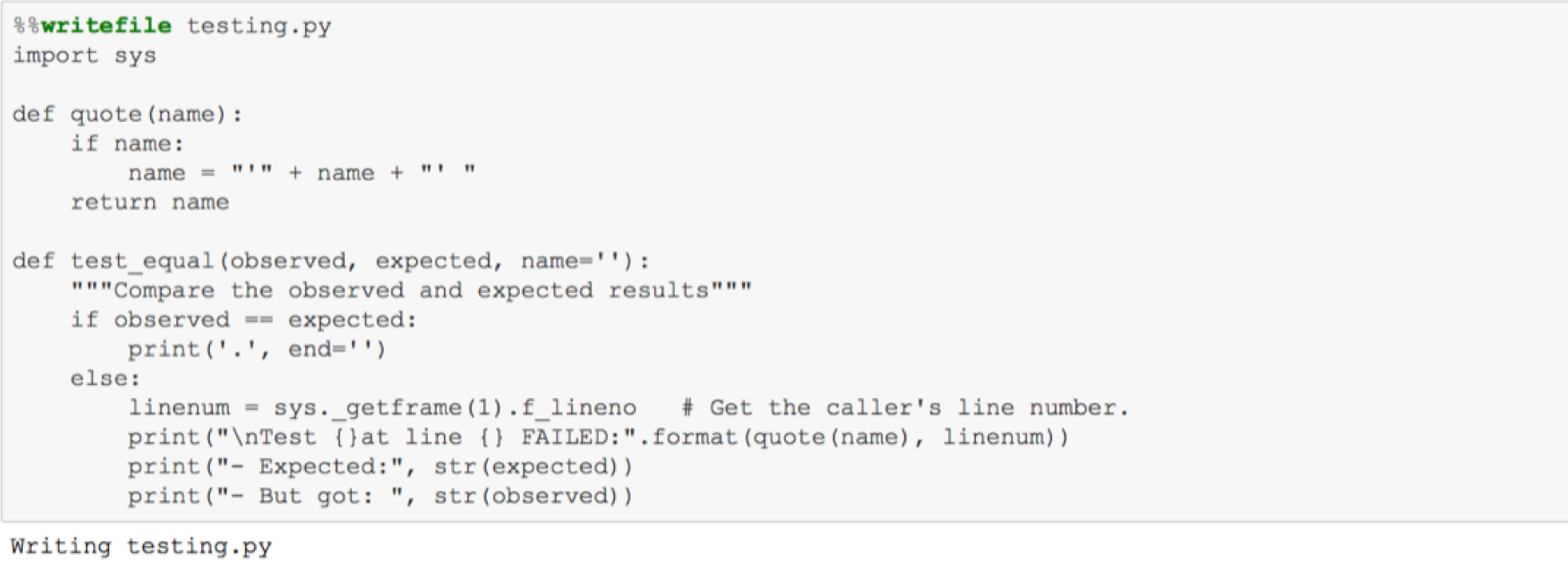
TESTING

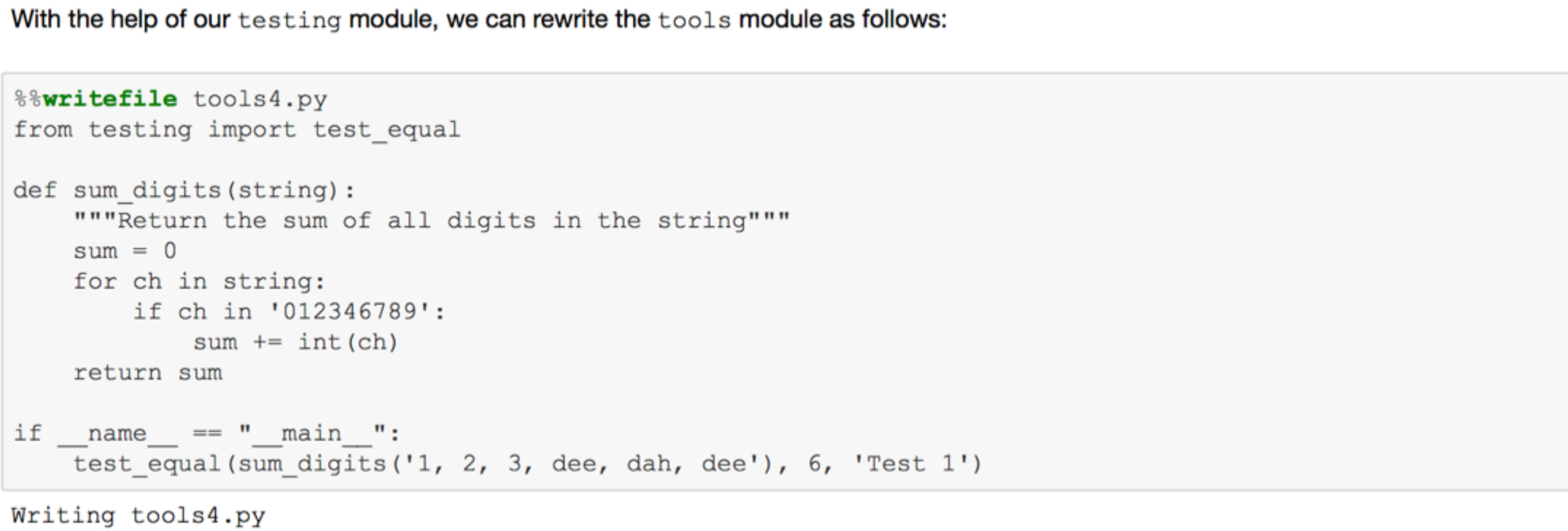


```
%%writefile testing.py
import sys

def quote(name):
    if name:
        name = "'" + name + "' "
    return name

def test_equal(observed, expected, name=''):
    """Compare the observed and expected results"""
    if observed == expected:
        print('.', end='')
    else:
        linenum = sys._getframe(1).f_lineno   # Get the caller's line number.
        print("\nTest {}at line {} FAILED:".format(quote(name), linenum))
        print("- Expected:", str(expected))
        print("- But got: ", str(observed))
```

```
Writing testing.py
```

SOURCE: courtesy of Petr Posik BE5b33PR 2016/2017

TESTING



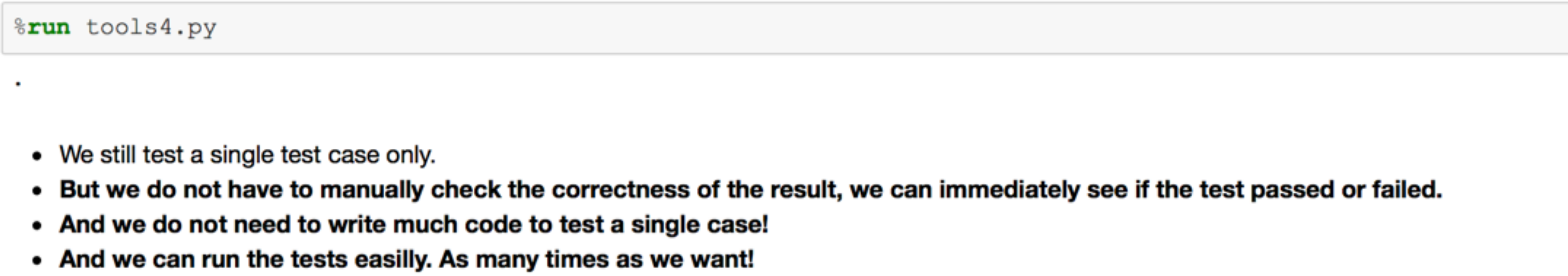
With the help of our `testing` module, we can rewrite the `tools` module as follows:

```
%%writefile tools4.py
from testing import test_equal

def sum_digits(string):
    """Return the sum of all digits in the string"""
    sum = 0
    for ch in string:
        if ch in '012346789':
            sum += int(ch)
    return sum

if __name__ == "__main__":
    test_equal(sum_digits('1, 2, 3, dee, dah, dee'), 6, 'Test 1')
```

```
Writing tools4.py
```

SOURCE: courtesy of Petr Posik BE5b33PR 2016/2017

TESTING

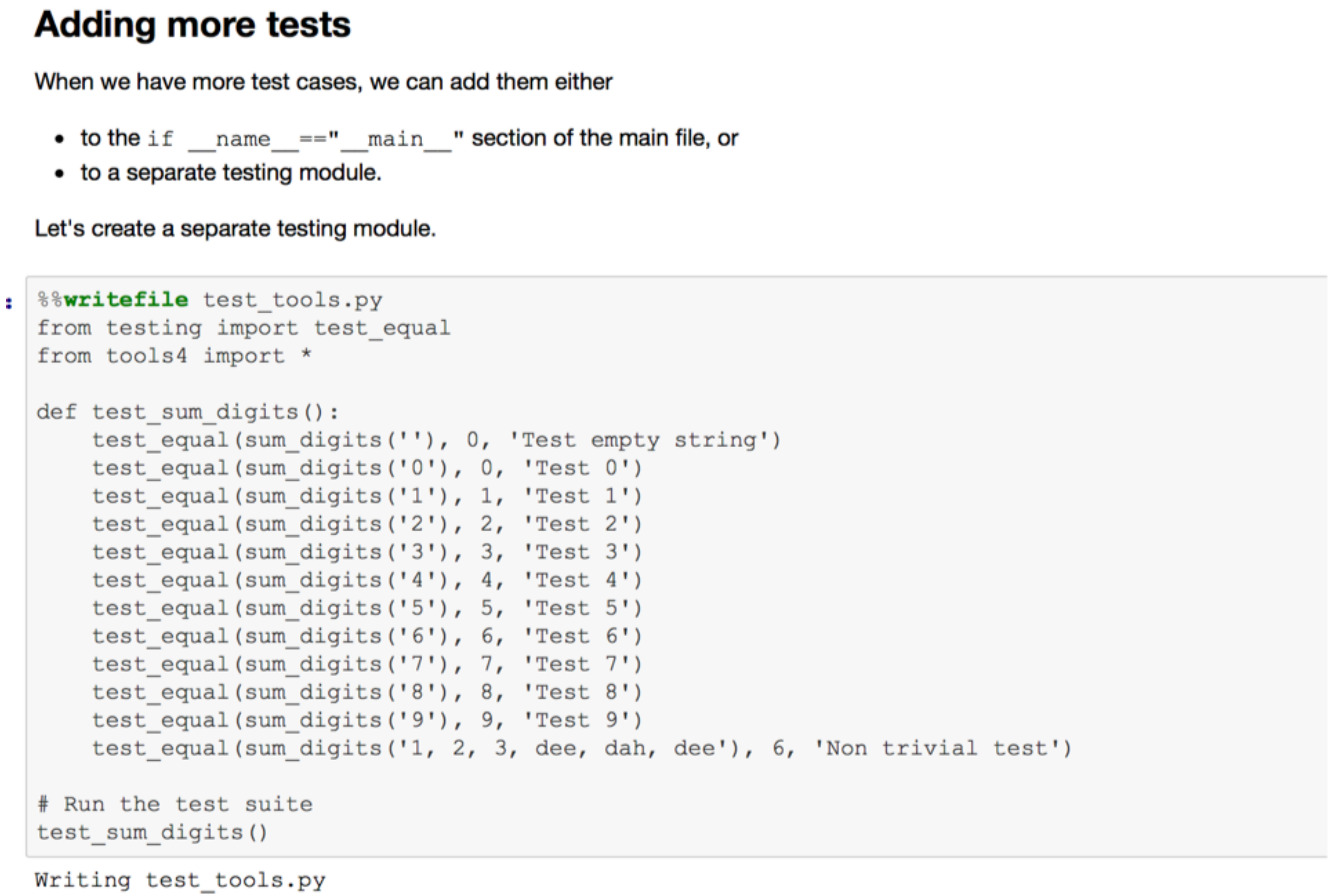


```
%run tools4.py
```

```
.
```

- We still test a single test case only.
- **But we do not have to manually check the correctness of the result, we can immediately see if the test passed or failed.**
- **And we do not need to write much code to test a single case!**
- **And we can run the tests easilly. As many times as we want!**

SOURCE: courtesy of Petr Posik BE5b33PR 2016/2017



Adding more tests

When we have more test cases, we can add them either

- to the `if __name__=="__main__"` section of the main file, or
- to a separate testing module.

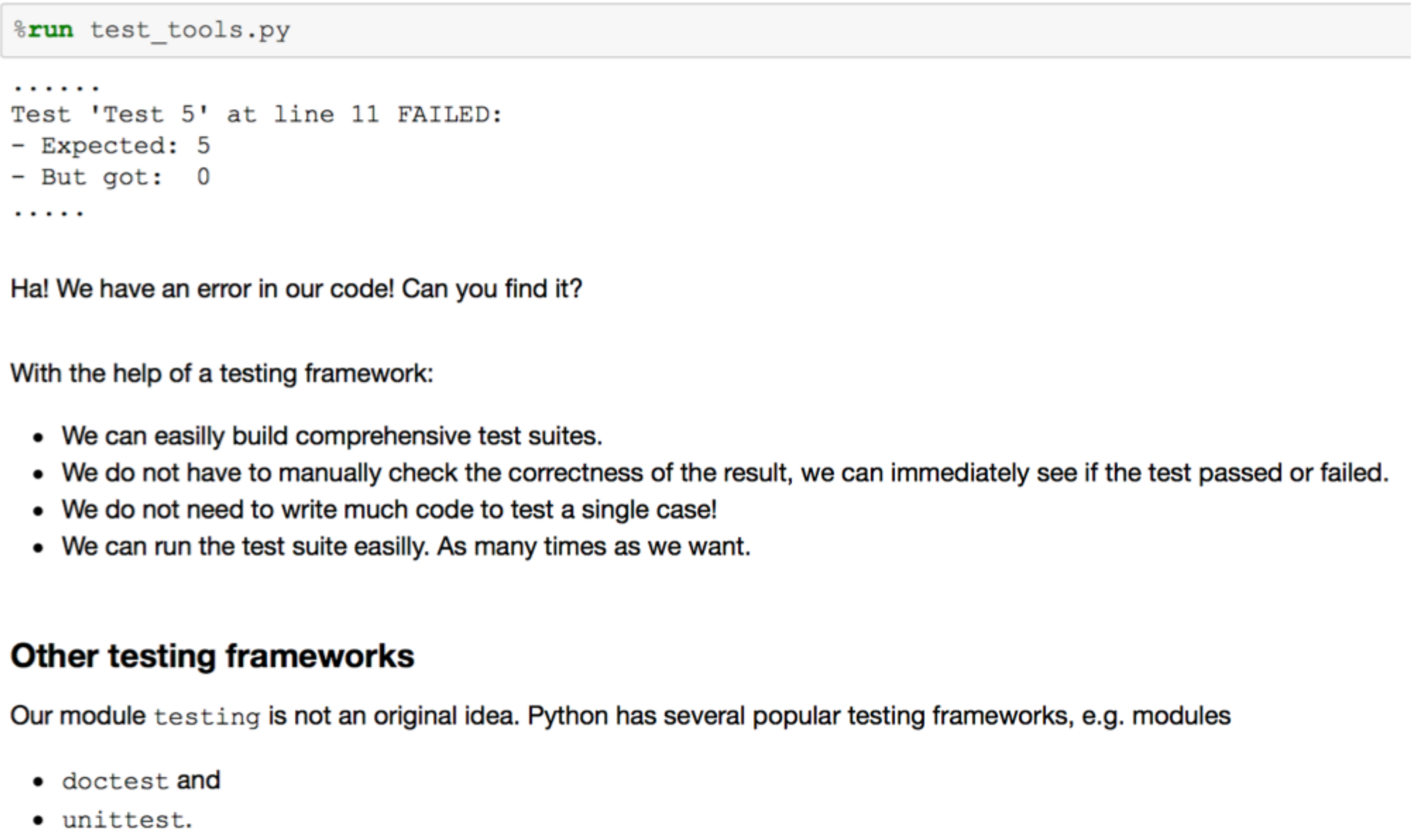
Let's create a separate testing module.

```
%%writefile test_tools.py
from testing import test_equal
from tools4 import *

def test_sum_digits():
    test_equal(sum_digits(''), 0, 'Test empty string')
    test_equal(sum_digits('0'), 0, 'Test 0')
    test_equal(sum_digits('1'), 1, 'Test 1')
    test_equal(sum_digits('2'), 2, 'Test 2')
    test_equal(sum_digits('3'), 3, 'Test 3')
    test_equal(sum_digits('4'), 4, 'Test 4')
    test_equal(sum_digits('5'), 5, 'Test 5')
    test_equal(sum_digits('6'), 6, 'Test 6')
    test_equal(sum_digits('7'), 7, 'Test 7')
    test_equal(sum_digits('8'), 8, 'Test 8')
    test_equal(sum_digits('9'), 9, 'Test 9')
    test_equal(sum_digits('1, 2, 3, dee, dah, dee'), 6, 'Non trivial test')

# Run the test suite
test_sum_digits()
```

```
Writing test_tools.py
```

SOURCE: courtesy of Petr Posik BE5b33PR 2016/2017

TESTING



```
%run test_tools.py
```

```
......
Test 'Test 5' at line 11 FAILED:
- Expected: 5
- But got:  0
.....
```

Ha! We have an error in our code! Can you find it?

With the help of a testing framework:

- We can easilly build comprehensive test suites.
- We do not have to manually check the correctness of the result, we can immediately see if the test passed or failed.
- We do not need to write much code to test a single case!
- We can run the test suite easilly. As many times as we want.

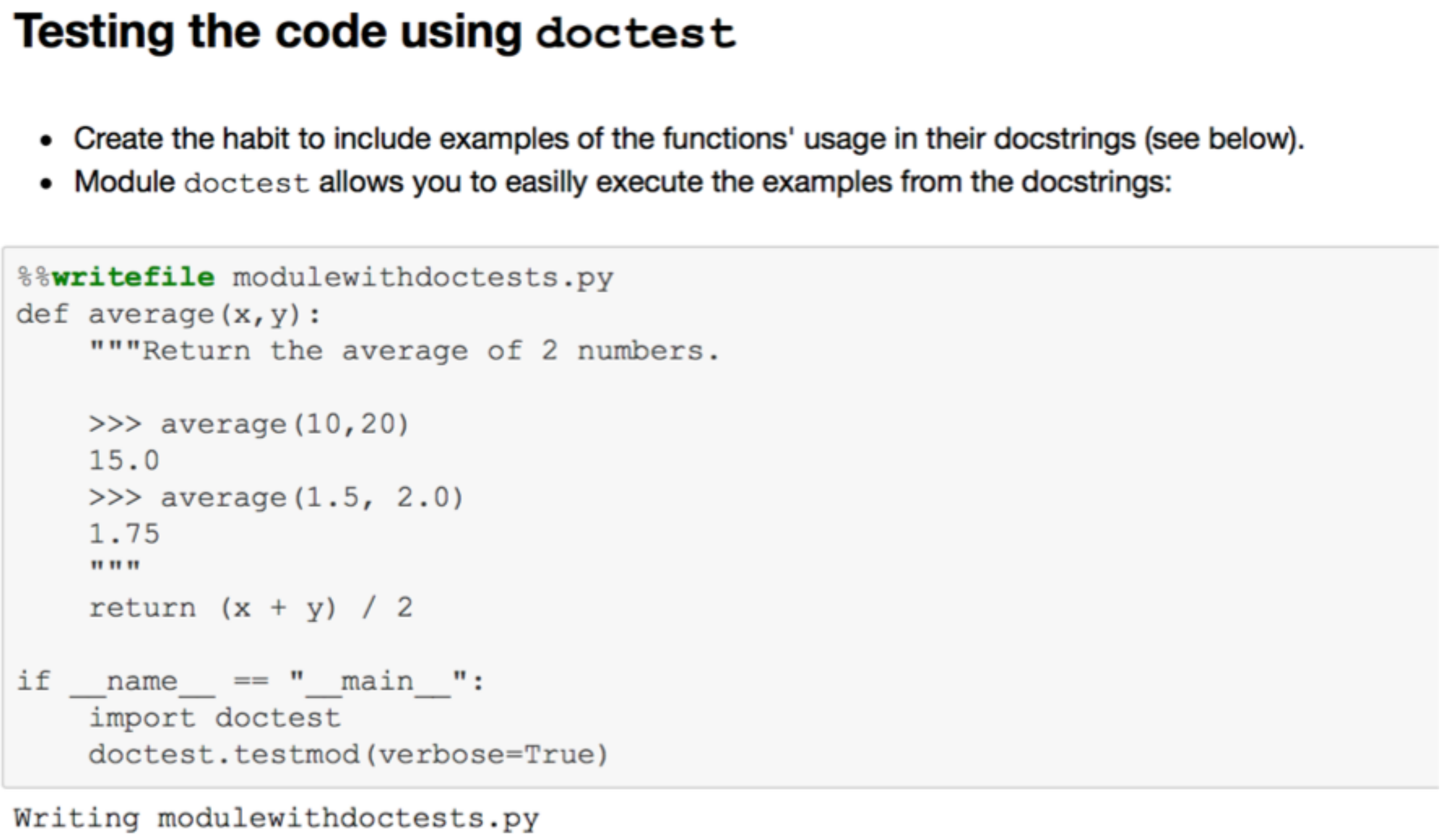
Other testing frameworks

Our module `testing` is not an original idea. Python has several popular testing frameworks, e.g. modules

- `doctest` and
- `unittest`.

SOURCE: courtesy of Petr Posik BE5b33PR 2016/2017

TESTING



Testing the code using doctest

- Create the habit to include examples of the functions' usage in their docstrings (see below).
- Module `doctest` allows you to easily execute the examples from the docstrings:

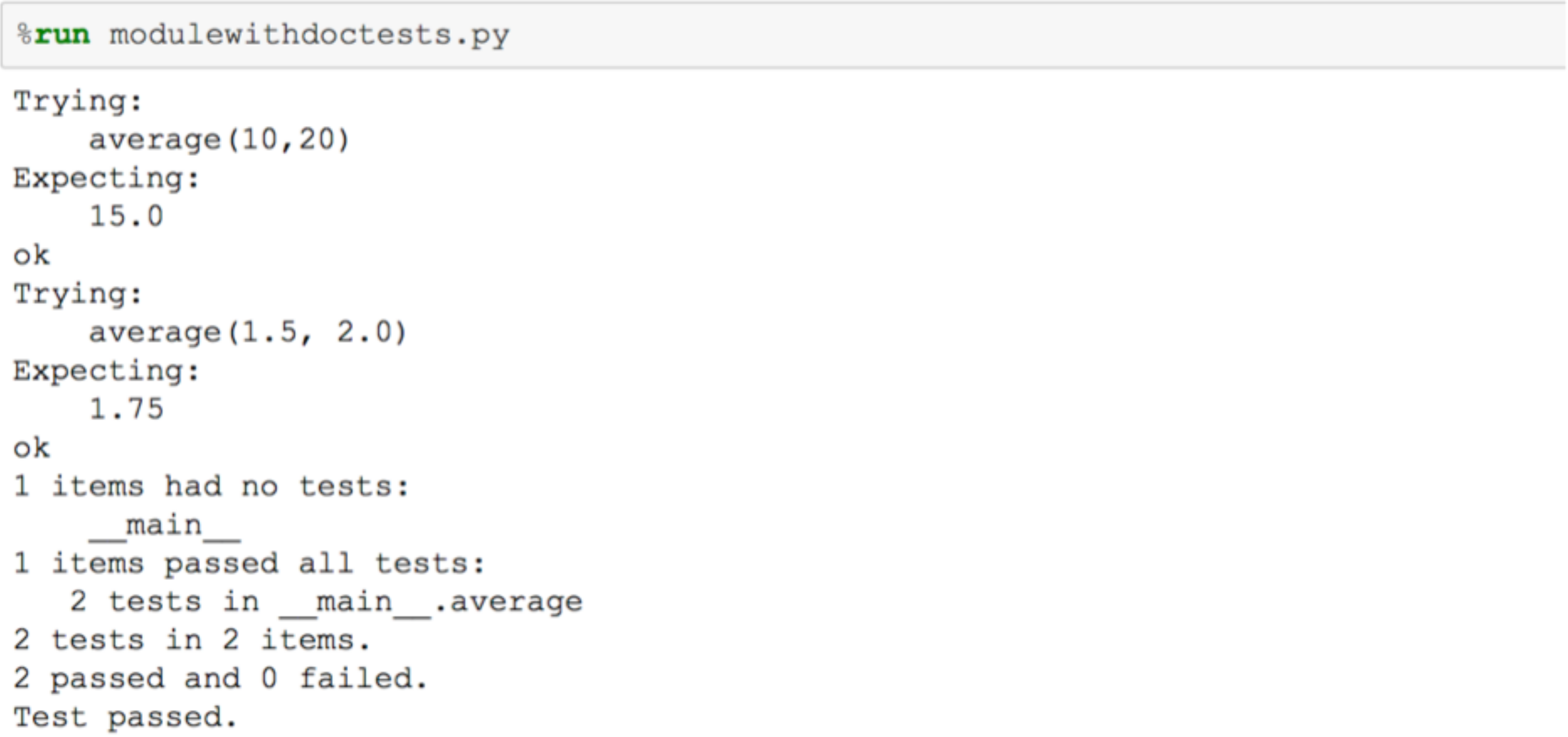
```
%%writefile modulewithdoctests.py
def average(x,y):
    """Return the average of 2 numbers.

    >>> average(10,20)
    15.0
    >>> average(1.5, 2.0)
    1.75
    """
    return (x + y) / 2

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

```
Writing modulewithdoctests.py
```

SOURCE: courtesy of Petr Posik BE5b33PR 2016/2017

TESTING

Then, if you run the module, the tests are executed automatically and compared with their expected results:

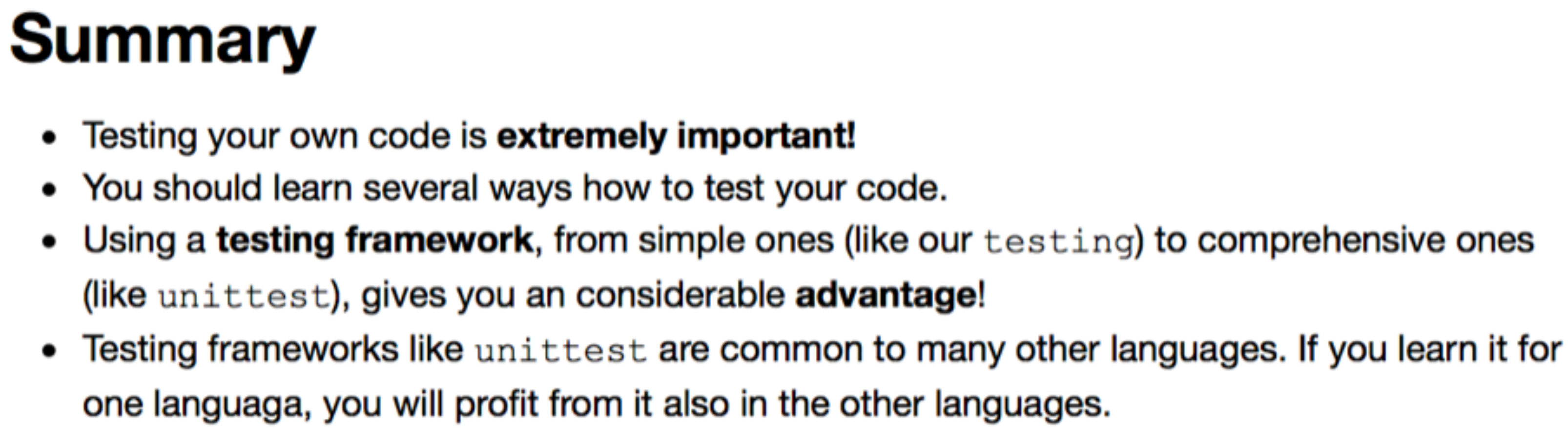


```
%run modulewithdoctests.py
```

```
Trying:
    average(10,20)
Expecting:
    15.0
ok
Trying:
    average(1.5, 2.0)
Expecting:
    1.75
ok
1 items had no tests:
    __main__
1 items passed all tests:
   2 tests in __main__.average
2 tests in 2 items.
2 passed and 0 failed.
Test passed.
```

SOURCE: courtesy of Petr Posik BE5b33PR 2016/2017

TESTING



Summary

- Testing your own code is **extremely important!**
- You should learn several ways how to test your code.
- Using a **testing framework**, from simple ones (like our `testing`) to comprehensive ones (like `unittest`), gives you an considerable **advantage**!
- Testing frameworks like `unittest` are common to many other languages. If you learn it for one languaga, you will profit from it also in the other languages.

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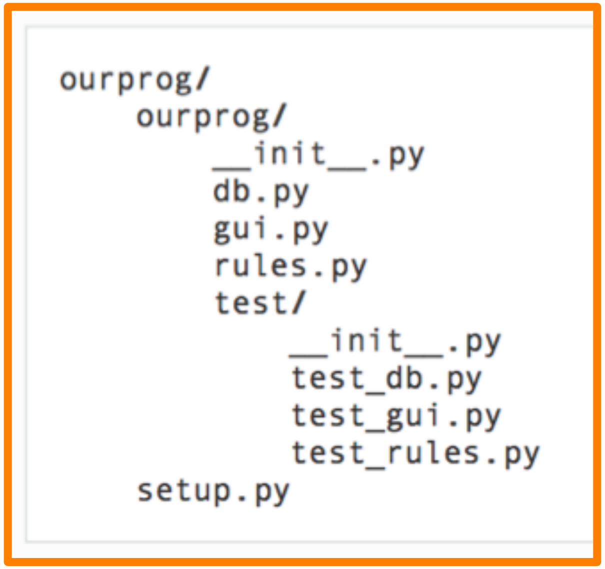
UNITTESTS

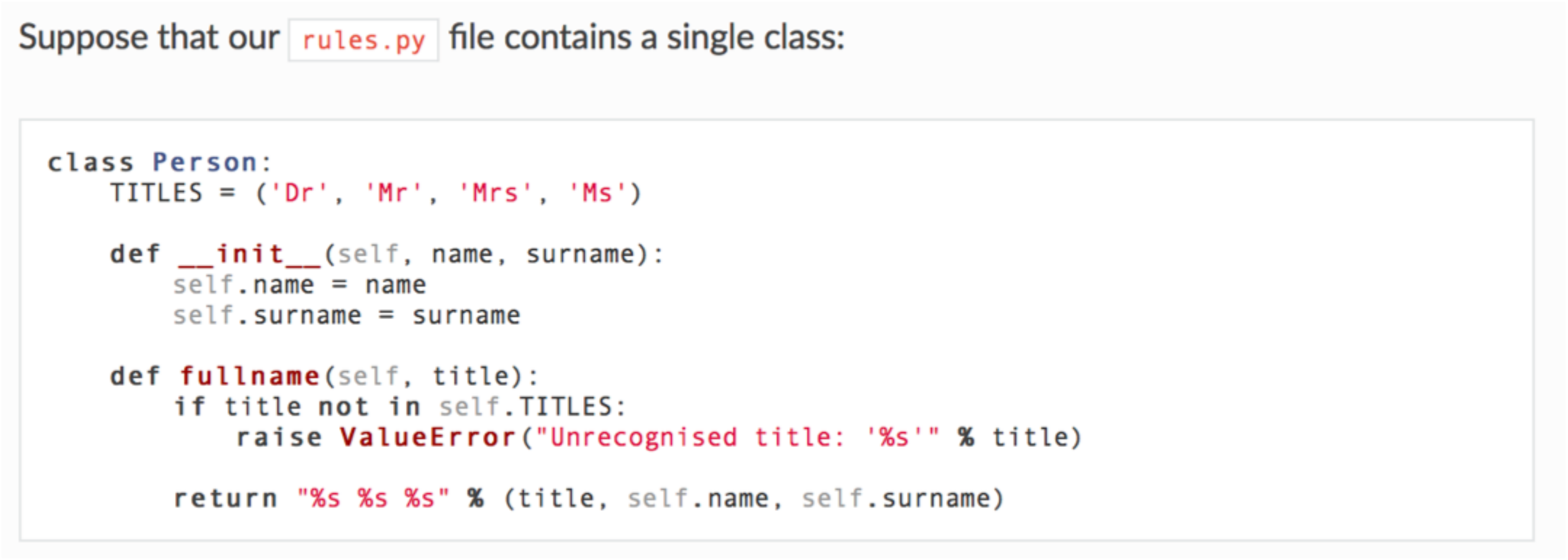


```
ourprog/
    ourprog/
        __init__.py
        db.py
        gui.py
        rules.py
        test/
            __init__.py
            test_db.py
            test_gui.py
            test_rules.py
    setup.py
```

- Advanced framework for testing – python **unittest** module
- Put all tests in a file hierarchy which is **separate** from our main program
- Create a **test module for each program module** and put them all in a **separate test directory**

SOURCE http://python-textbok.readthedocs.io/en/1.0/Packaging_and_Testing.html#testing

UNITTESTS

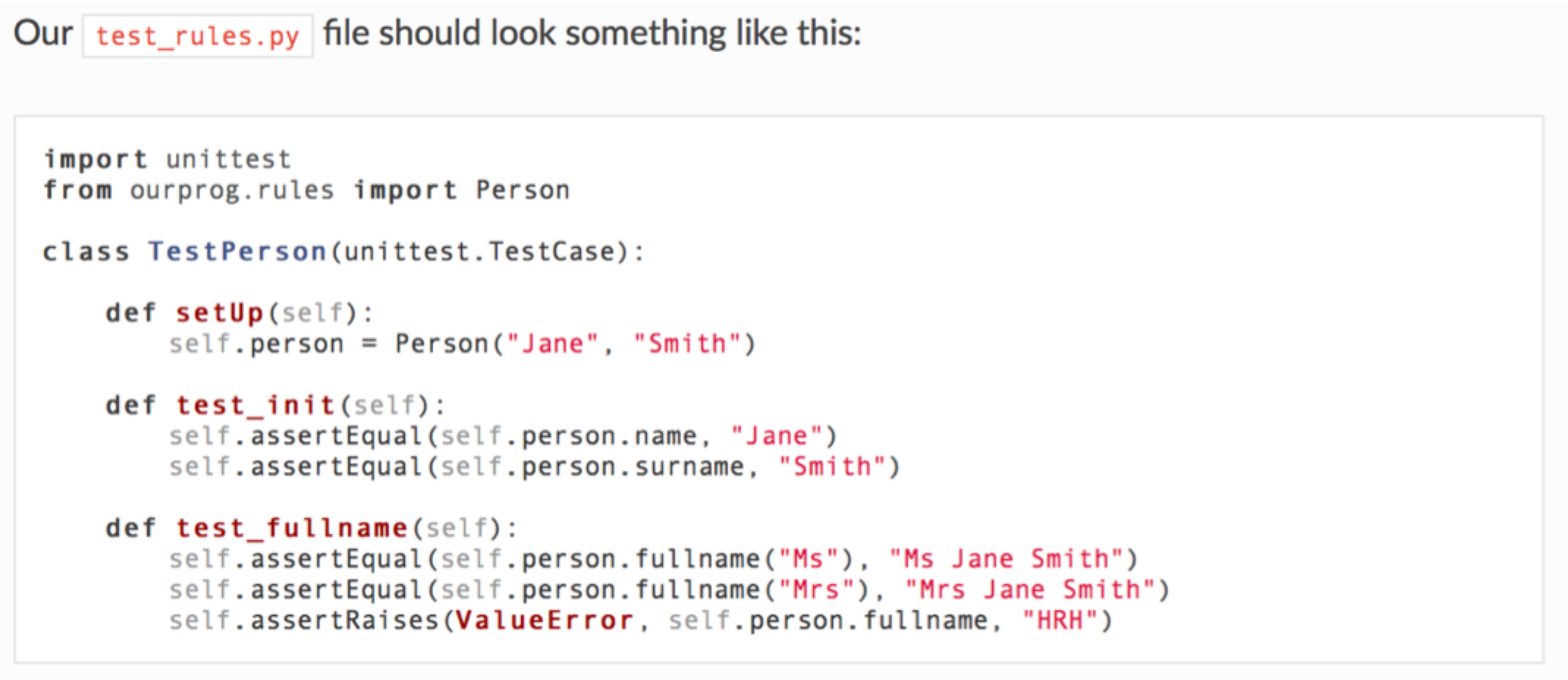


Suppose that our `rules.py` file contains a single class:

```
class Person:
    TITLES = ('Dr', 'Mr', 'Mrs', 'Ms')

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

    def fullname(self, title):
        if title not in self.TITLES:
            raise ValueError("Unrecognised title: '%s'" % title)

        return "%s %s %s" % (title, self.name, self.surname)
```

SOURCE http://python-textbok.readthedocs.io/en/1.0/Packaging_and_Testing.html#testing

UNITTESTS

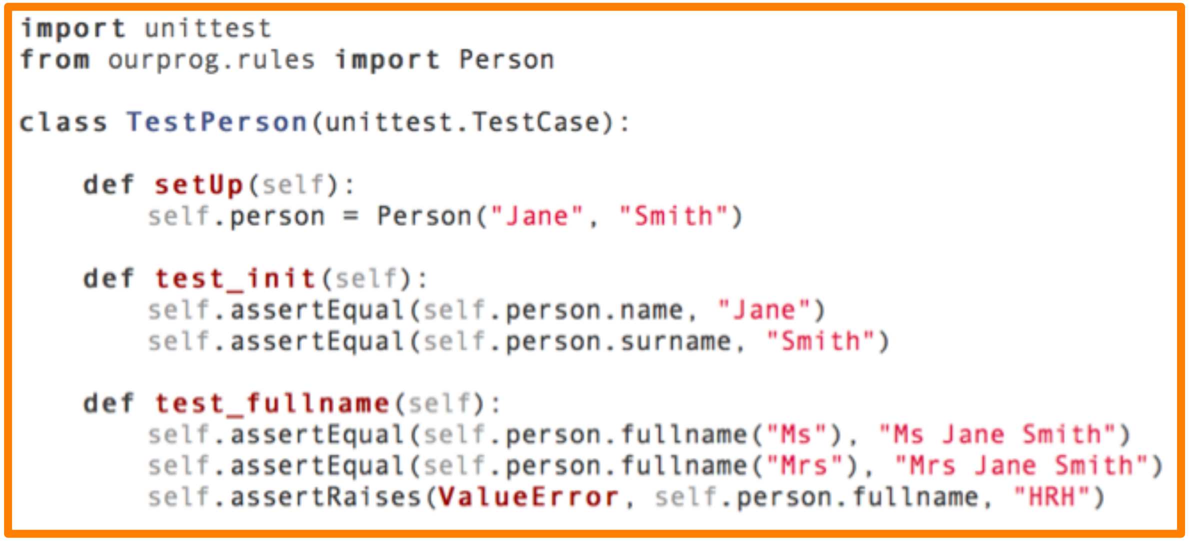


Our `test_rules.py` file should look something like this:

```
import unittest
from ourprog.rules import Person

class TestPerson(unittest.TestCase):

    def setUp(self):
        self.person = Person("Jane", "Smith")

    def test_init(self):
        self.assertEqual(self.person.name, "Jane")
        self.assertEqual(self.person.surname, "Smith")

    def test_fullname(self):
        self.assertEqual(self.person.fullname("Ms"), "Ms Jane Smith")
        self.assertEqual(self.person.fullname("Mrs"), "Mrs Jane Smith")
        self.assertRaises(ValueError, self.person.fullname, "HRH")
```

SOURCE http://python-textbok.readthedocs.io/en/1.0/Packaging_and_Testing.html#testing

UNITTESTS



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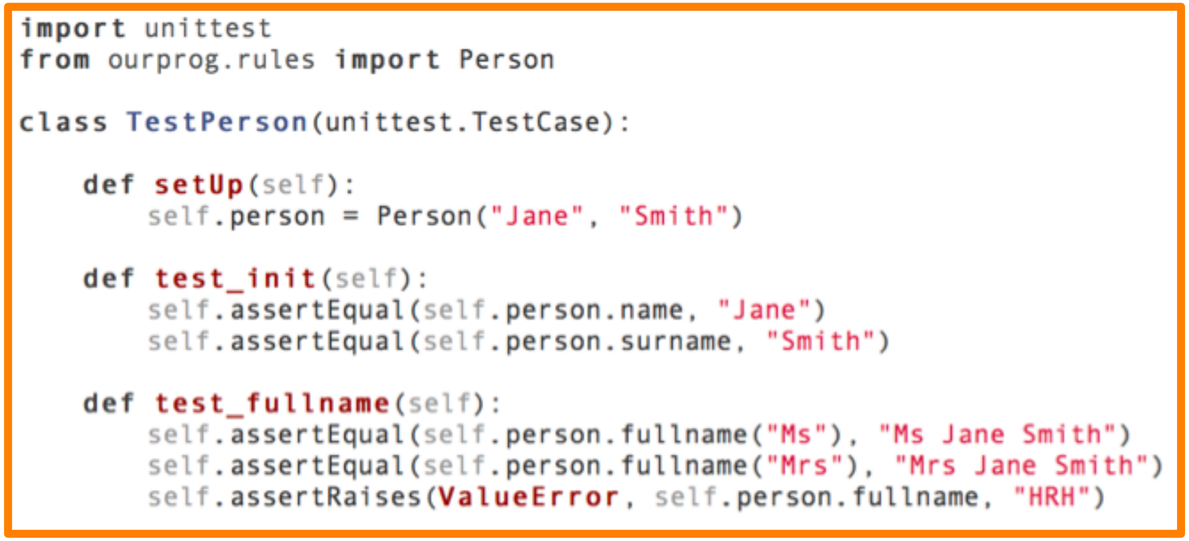
        self.assertEqual(self.person.surname, "Smith")

    def test_fullname(self):
        self.assertEqual(self.person.fullname("Ms"), "Ms Jane Smith")
        self.assertEqual(self.person.fullname("Mrs"), "Mrs Jane Smith")
        self.assertRaises(ValueError, self.person.fullname, "HRH")
```

- In the **unittest** package, the **TestCase** class serves as a container for tests to share data
- For each collection of tests define a class that inherits from **TestCase** and define all tests as methods on that class
- All the tests in this **TestCase** test the same class, and there is one test per method (including the initialization method)
- Multiple **TestCase** classes to test each of own classes

SOURCE http://python-textbok.readthedocs.io/en/1.0/Packaging_and_Testing.html#testing

UNITTESTS



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        self.assertEqual(self.person.fullname("Mrs"), "Mrs Jane Smith")
        self.assertRaises(ValueError, self.person.fullname, "HRH")
```
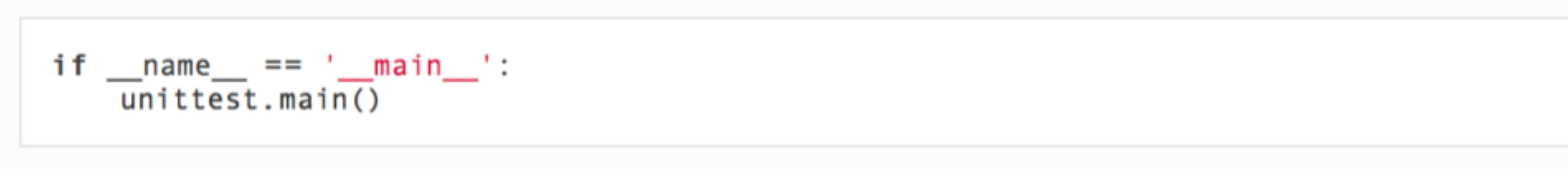
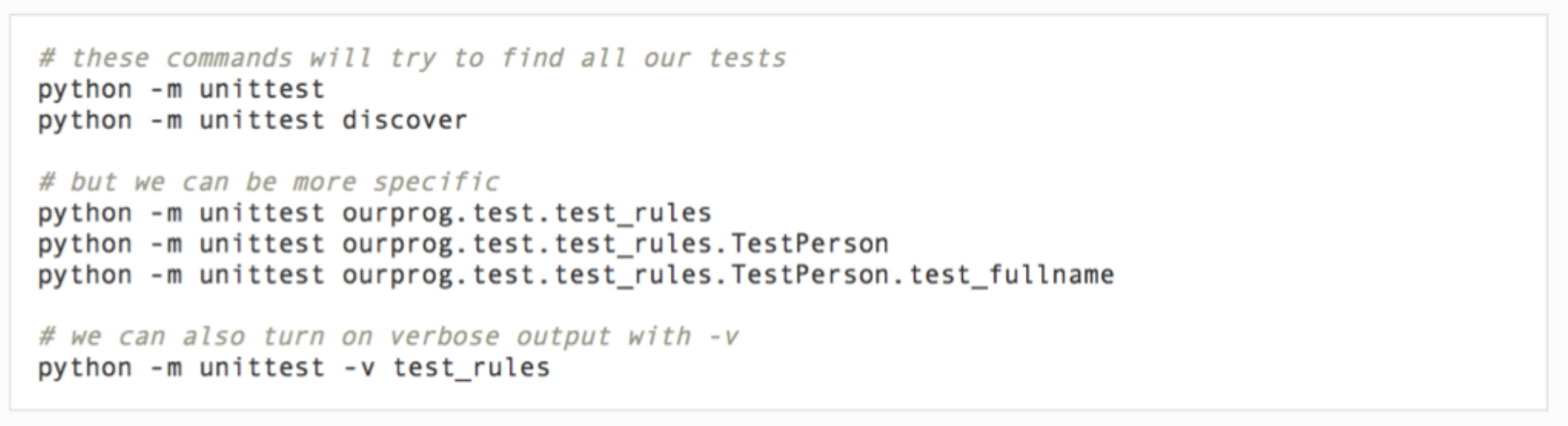

- Set up the class to be tested in the **setUp** method (*special method will be executed before each test is run*)
- Use **tearDown** method to execute statements after test is run
- Use the **assertion methods** of **TestCase** to check if certain things are true about our program behavior (*as soon as one assertion statement fails, the whole test fails*)

SOURCE http://python-textbok.readthedocs.io/en/1.0/Packaging_and_Testing.html#testing

UNITTESTS



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

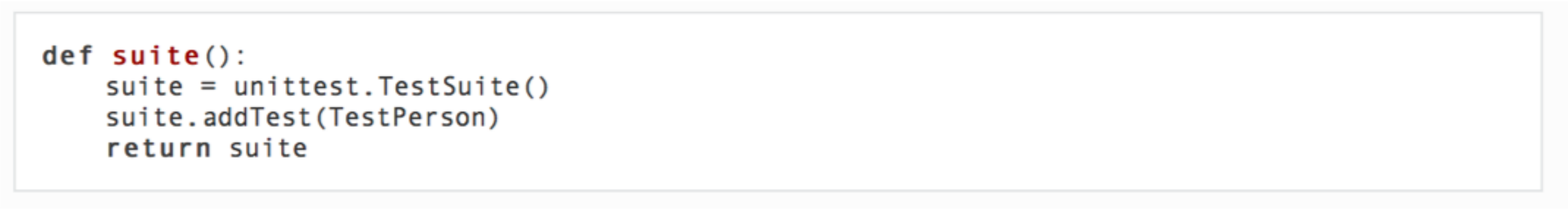


```
# these commands will try to find all our tests
python -m unittest
python -m unittest discover

# but we can be more specific
python -m unittest ourprog.test.test_rules
python -m unittest ourprog.test.test_rules.TestPerson
python -m unittest ourprog.test.test_rules.TestPerson.test_fullname

# we can also turn on verbose output with -v
python -m unittest -v test_rules
```

- *Many ways of running the tests*
- To run all the tests from a single file by adding **unittest.main()** at the bottom of test_rules.py and **execute as a script**
- To execute the unittest module on the **commandline** and use it to import and run some or all of our tests

SOURCE http://python-textbok.readthedocs.io/en/1.0/Packaging_and_Testing.html#testing

UNITTESTS



```
def suite():
    suite = unittest.TestSuite()
    suite.addTest(TestPerson)
    return suite
```

- The unittest package allows to group some or all of our tests into suites
- This way many related tests can be executed at once

- EXAMPLE: One way to add all the tests from the **TestPerson** class to a suite is to add for example **suite()** function to the **test_rules.py** file

SOURCE http://python-textbok.readthedocs.io/en/1.0/Packaging_and_Testing.html#testing

Lecture 13 – Exceptions

https://cw.fel.cvut.cz/wiki/courses/be5b33prg/start

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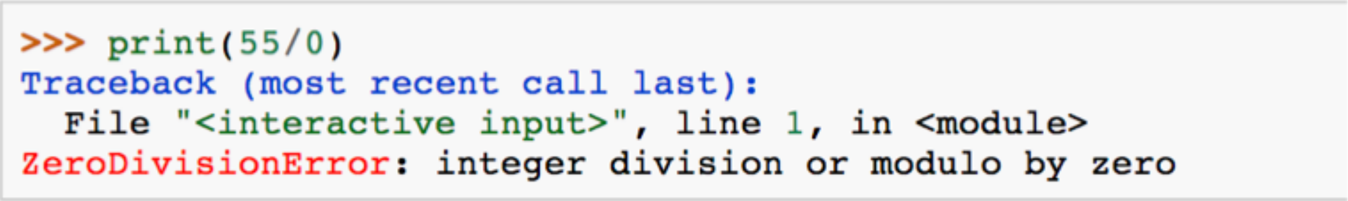
EXCEPTIONS

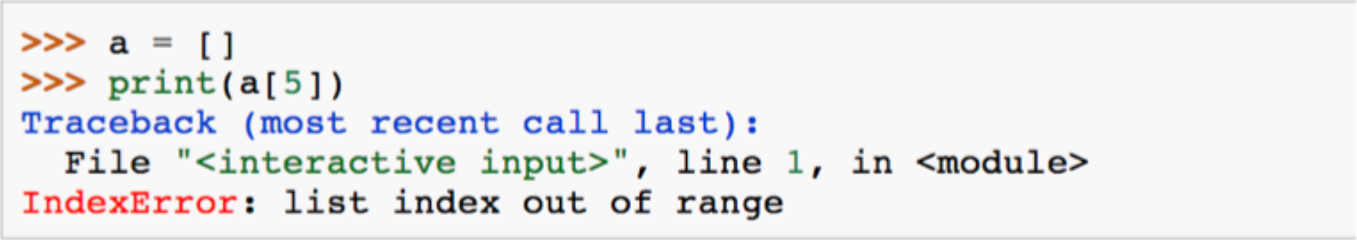
- Whenever a **runtime error** occurs, it creates an exception object.
- The **program stops running** at this point and Python prints out the traceback, which ends with an **error message** describing the exception that occurred
- **Exception** – An error that occurs at runtime.
- **Handle an exception** – To prevent an exception from causing our program to crash, by wrapping the block of code in a try ... except construct.
- **Raise** – To create a deliberate exception by using the raise statement.

SOURCE http://openbookproject.net/thinkcs/python/english3e/exceptions.html

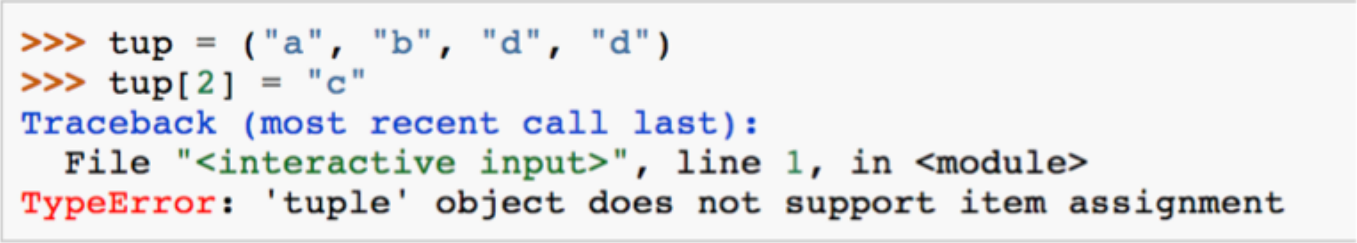
EXCEPTIONS



```
>>> print(55/0)
Traceback (most recent call last):
  File "<interactive input>", line 1, in <module>
ZeroDivisionError: integer division or modulo by zero
```



```
>>> a = []
>>> print(a[5])
Traceback (most recent call last):
  File "<interactive input>", line 1, in <module>
IndexError: list index out of range
```

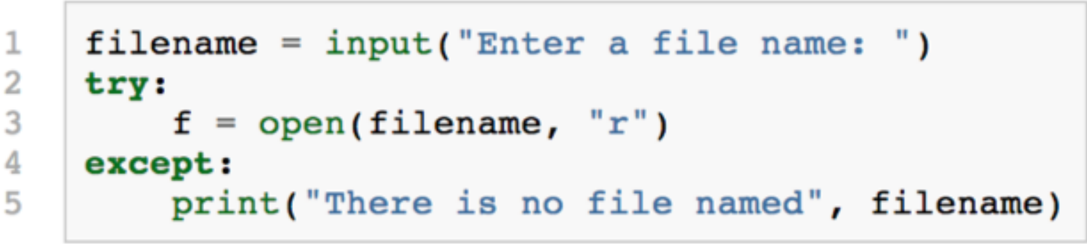


```
>>> tup = ("a", "b", "d", "d")
>>> tup[2] = "c"
Traceback (most recent call last):
  File "<interactive input>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
```

- The **error message** on the last line has two parts: the **type of error** before the colon, and **specifics** about the error after the colon

SOURCE http://openbookproject.net/thinkcs/python/english3e/exceptions.html

EXCEPTIONS



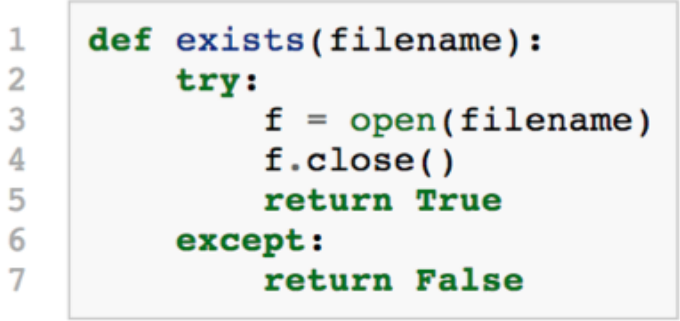
```
filename = input("Enter a file name: ")
try:
    f = open(filename, "r")
except:
    print("There is no file named", filename)
```

- To execute an operation that might cause an exception but does not stop the program
- Handle the exception using the try statement to “wrap” a region of code

- EXAMPLE: prompt the user for the name of a file and then try to open it. If the file does not exist, we do not want the program to crash

SOURCE http://openbookproject.net/thinkcs/python/english3e/exceptions.html

EXCEPTIONS

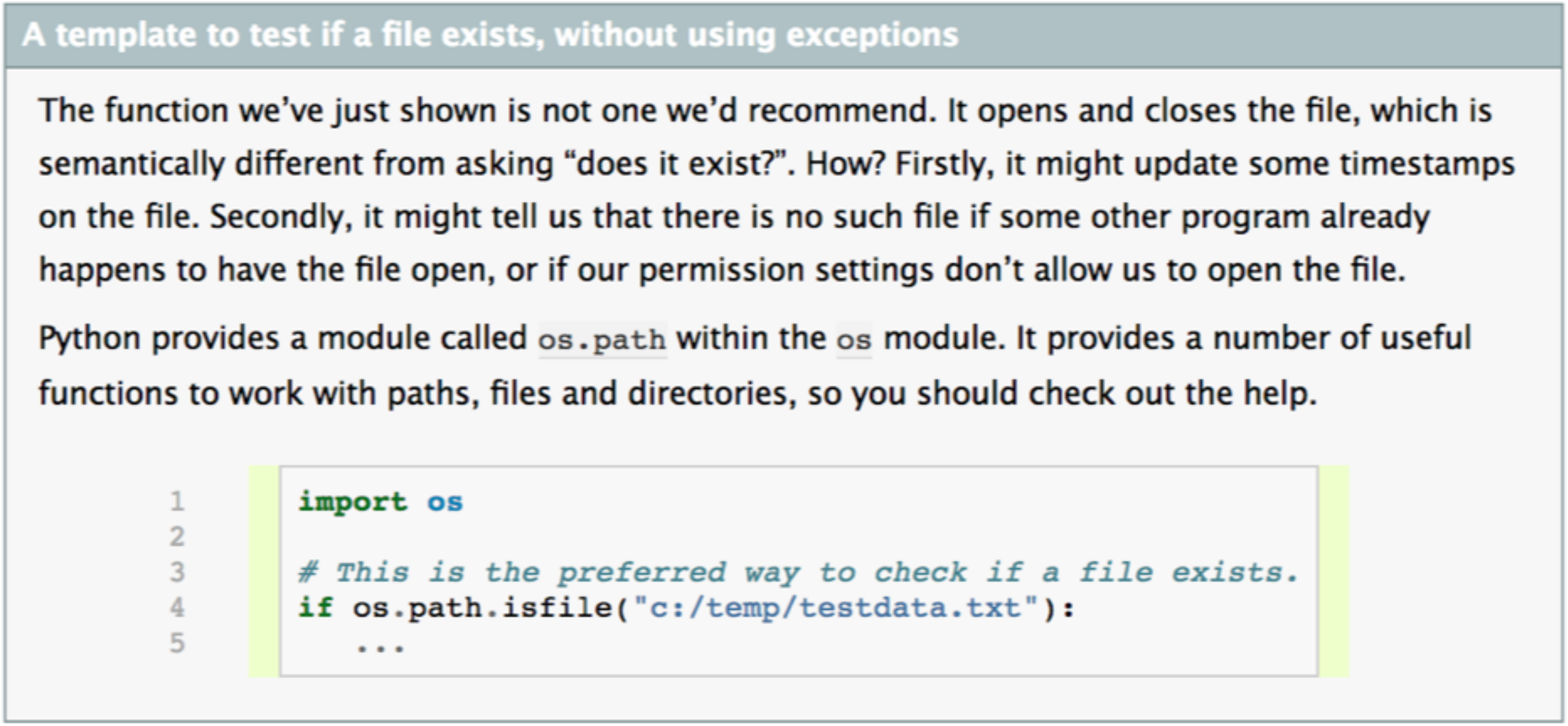


```
def exists(filename):
    try:
        f = open(filename)
        f.close()
        return True
    except:
        return False
```

- The **try statement** has three separate clauses, or parts, introduced by the keywords **try ... except ... finally**
- Either the **except** or the **finally** clauses can be omitted
- The try statement executes and **monitors the statements** in the first block and If no exceptions occur, it skips the block under the except clause
- If any exception occurs, it executes the statements in the **except clause** and then continues

SOURCE http://openbookproject.net/thinkcs/python/english3e/exceptions.html

EXCEPTIONS



A template to test if a file exists, without using exceptions

The function we've just shown is not one we'd recommend. It opens and closes the file, which is semantically different from asking "does it exist?". How? Firstly, it might update some timestamps on the file. Secondly, it might tell us that there is no such file if some other program already happens to have the file open, or if our permission settings don't allow us to open the file.

Python provides a module called `os.path` within the `os` module. It provides a number of useful functions to work with paths, files and directories, so you should check out the help.

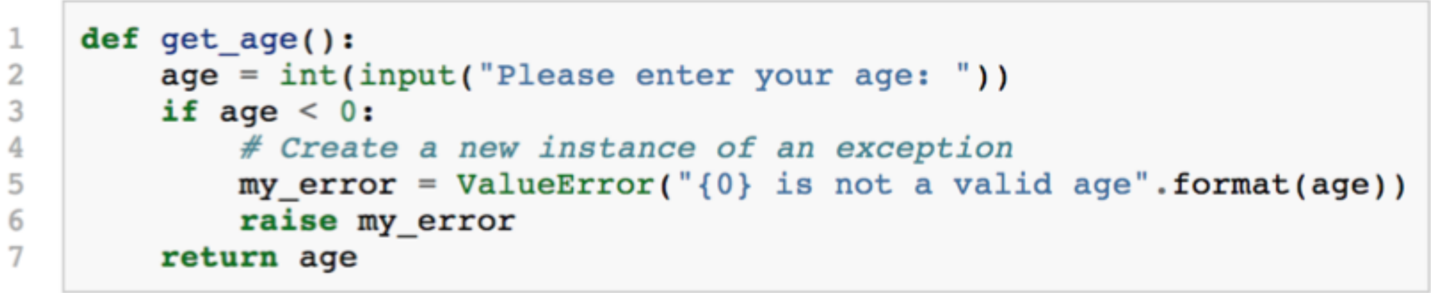
```
import os

# This is the preferred way to check if a file exists.
if os.path.isfile("c:/temp/testdata.txt"):
    ...
```

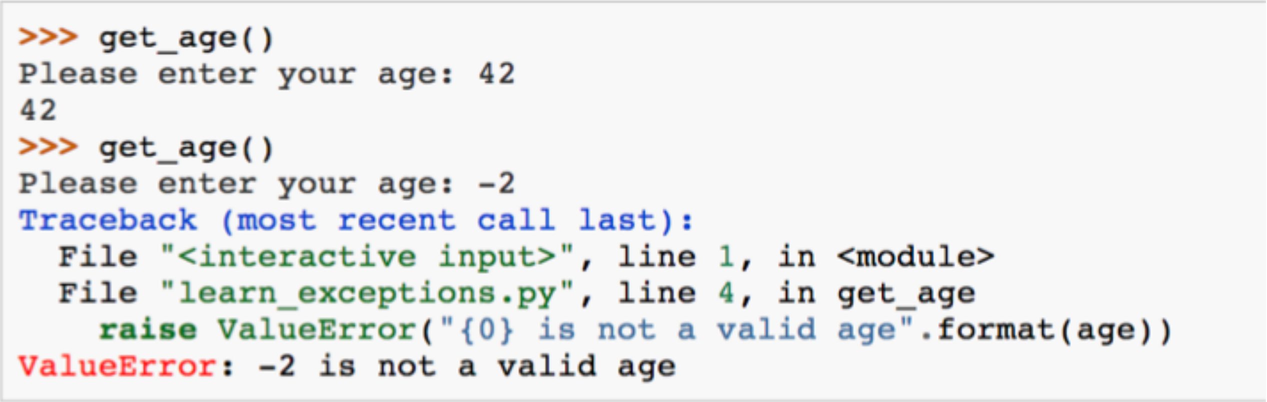
- **ERRORS** – multiple except clauses to handle different kinds of exceptions https://docs.python.org/3/tutorial/errors.html

SOURCE http://openbookproject.net/thinkcs/python/english3e/exceptions.html

EXCEPTIONS



```python
def get_age():
    age = int(input("Please enter your age: "))
    if age < 0:
        # Create a new instance of an exception
        my_error = ValueError("{0} is not a valid age".format(age))
        raise my_error
    return age
```



```
>>> get_age()
Please enter your age: 42
42
>>> get_age()
Please enter your age: -2
Traceback (most recent call last):
  File "<interactive input>", line 1, in <module>
  File "learn_exceptions.py", line 4, in get_age
    raise ValueError("{0} is not a valid age".format(age))
ValueError: -2 is not a valid age
```

- If the program detects an error condition, an exception can be **raised** manually.
- EXAMPLE: input from the user and checks that the number is non-negative:

SOURCE http://openbookproject.net/thinkcs/python/english3e/exceptions.html

EXCEPTIONS

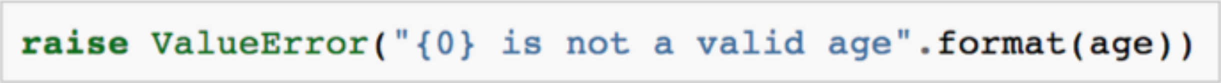
- Line 5 creates an **exception object** – **ValueError object** in this case that encapsulates specific information about the error

- EXAMPLE: Assume that in this case function A called B which called C which called D which called get_age*:*

  - *The raise statement on line 6 carries this object out as a kind of “return value”, and immediately exits from get_age() to its caller D*
  - *Then D again exits to its caller C, and C exits to B and so on, each returning the exception object to their caller, until it encounters a try ... except that can handle the exception*

SOURCE http://openbookproject.net/thinkcs/python/english3e/exceptions.html

EXCEPTIONS



```python
raise ValueError("{0} is not a valid age".format(age))
```

- It is often the case that lines 5 and 6 (**creating the exception** object, then **raising the exception**) are combined into a single statement
- Those are **two different and independent things**, so it makes sense to keep the two steps separate

SOURCE http://openbookproject.net/thinkcs/python/english3e/exceptions.html

REFERENCES

This lecture re-uses selected parts of the OPEN BOOK PROJECT

Learning with Python 3 (RLE)

http://openbookproject.net/thinkcs/python/english3e/index.html

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- Version date: October 2012
- by Peter Wentworth, Jeffrey Elkner, Allen B. Downey, and Chris Meyers (based on 2nd edition by Jeffrey Elkner, Allen B. Downey, and Chris Meyers)
- Source repository is at https://code.launchpad.net/~thinkcspy-rle-team/thinkcspy/thinkcspy3-rle
- For offline use, download a zip file of the html or a pdf version from http://www.ict.ru.ac.za/Resources/cspw/thinkcspy3/

This lecture re-uses selected parts of the PYTHON TEXTBOOK

Object-Oriented Programming in Python

http://python-textbok.readthedocs.io/en/1.0/Packaging_and_Testing.html#testing

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