Unit Testing

Publicity

- Would you like to get your name, or the name of your project, in the newspapers?
- Here are some of the more well-known stories about computer programs:
  - **Mariner 1 to Venus**--Incorrect data smoothing caused the spacecraft to be destroyed 5 minutes after launch.
  - **The Hubble Space Telescope**--Astronauts had to correct a problem caused by using imperial rather than metric measurements.
  - **The Therac-25**--Due to programming errors, it sometimes gave cancer patients radiation doses that were thousands of times greater than normal.
  - **Ashley Madison** ("Life is short. Have an affair.")--Inadequate security allowed hackers to obtain information about 37 million users.
- While these are fairly famous, every week there are one or two articles in the newspapers about computer errors

Error rate

- If you had only one error in a thousand lines of code, you would think that is pretty good, right?
  - Yes, it really is
- But...
  - **Facebook** has about **30 million** lines of code
- 30,000,000 lines / 1000 line per error = 30,000 errors
- Is that ***good enough?***
  - You tell me...
- Of course, most programs are a lot smaller than Facebook
  - The space shuttle's primary software, for example, is only 400,000 lines

Testing

- Kinds of tests:
  - ***Unit test*:** when it fails, it tells you what piece of your code needs to be fixed.
  - ***Integration test*:** when it fails, it tells you that the pieces of your application are not working together as expected.
  - ***Acceptance test*:** when it fails, it tells you that the application is not doing what the customer expects it to do.
  - ***Regression test*:** when it fails, it tells you that the application no longer behaves the way it used to.
- In this course we will be concerned almost entirely with unit testing
- Source: Mathias, http://stackoverflow.com/questions/7672511/unit-test-integration-test-regression-test-acceptance-test

Kinds of tests

Division of labor

- Programs are written as a large collection of small ***functions*** (or ***methods***)
- **A function should *either* do computation *or* do input/output, *not both*.**
  - Following this rule makes computational functions reusable in other contexts
  - More important for this talk, following this rule makes testing computational functions easier
    - If a function under test requests input from the user, the function can't be tested with a "single click"
    - If a function under test produces output, the output must be examined for correctness
    - Anything that slows down testing makes it less probably that adequate testing will be done
- It is also possible to test I/O functions, but that is an advanced topic

`import` statements

- Larger programs are often written in more than one file (or ***module***)
- Unit tests are usually written in a different module than the module being tested
- To use functions that are in a different module, you need to ***import*** that module
  - `import` statements should be the first lines in your module
- For example, suppose you want to call a function named `myfun` in a file named `myprog.py` -- you can do this in either of two ways:

  1. At the top of the program, say `import myprog`
     In the code, call the function by saying `myprog.myfun(`*`args`*`)`

  2. At the top of the program, say `from myprog import *`
     In the code, call the function by saying `myfun(`*`args`*`)`

Structure of the test file

- The test file has a moderately complex structure

- ```
  import unittest
  from name_of_module import *

  class NameOfClass(unittest.TestCase):
      # You can define variables
      # and functions here

      # Test methods go here--
      #   the name of each test method
      #   begins with "test_"

  unittest.main()
  ```
  ```

Structure of test methods

- Each test has a name beginning with **`test_`** and has one parameter named **`self`**

- Inside the test function is just normal Python code--you can use all the usual Python statements (if statements, assignment statements, loops, function calls, etc.) but you ***should not do input or output***

  - I/O in tests will just slow down testing and make it more difficult

  - For the same reason, the code being tested should also be free of I/O

- Here are the three most common tests you can use:

  - **`self.assertTrue(`***`boolean_expression_that_should_be_true`***`)`**

  - **`self.assertFalse(`***`boolean_expression_that_should_be_false`***`)`**

  - **`self.assertEqual(`***`first_expression, second_expression`***`)`**

- Of these, **`self.assertEqual`** gives you more information when it fails, because it tells you the value of the two expressions

Example code to be tested

- This is on file **parity.py**:

```
def is_even(n):
    """Test if the argument is even"""
    return n % 2 == 0

def is_odd(n):
    """Test if the argument is odd"""
    return n % 2 == 1
```

Example test and result

```
import unittest
from parity import *

class TestEvenOrOdd(unittest.TestCase)

    def test_even(self):
        self.assertTrue(is_even(6))
        self.assertFalse(is_even(9))

unittest.main()
```

```
>>> ========================== RESTART ==========================
>>>
.
----------------------------------------------------------------------
Ran 1 test in 0.032s

OK
>>>
```

Example of test failure

- Suppose we do: `self.assertTrue(is_even(9))`

- ```
  >>> ================================ RESTART ================================
  >>>
  F
  ======================================================================
  FAIL: test_even (__main__.TestEvenOrOdd)
  ----------------------------------------------------------------------
  Traceback (most recent call last):
    File "/Users/dave/Box Sync/Programming/Python3_programs/
  parity_test.py", line 8, in test_even
      self.assertTrue(is_even(9))
  AssertionError: False is not true

  ----------------------------------------------------------------------
  Ran 1 test in 0.041s

  FAILED (failures=1)
  >>>
  ```
  ```

Another example failure

- ```
  def test_arithmetic(self):
      n = 0
      for i in range(0, 10): # do ten times
          n = n + 0.1
      self.assertEqual(1.0, n)
  ```
- ```
  AssertionError: 1.0 != 0.9999999999999999
  ```
- **Moral:** Never trust floating point numbers to be exactly equal
- To test floating point numbers, don't use `assertEquals(`*x*`, `*y*`)`
- Instead, use `assertAlmostEqual(`*x*`, `*y*`)` or `assertAlmostEqual(`*x*`,`*y*`,`*d*`)`, where *d* is the number of digits after the decimal point to round to (default 7)

Testing philosophy

- When testing, you are **not** trying to prove that your code is correct--you are trying to **find and expose flaws,** so that the code may be fixed

- If you were a lawyer, you would be a lawyer for the prosecution, not for the defense

- If you were a hacker, you would be trying to break into protected systems and networks

  - A ***white hat hacker*** tries to find security flaws in order to get the company to fix them--these are the "good guys"

  - A ***black hat hacker*** tries to find security flaws in order to exploit them--these are the "bad guys"

Testing “edge” cases

- Testing only the simple and most common cases is sometimes called ***garden path*** testing
  - All is sweetness and light, butterflies and flowers
  - Garden path testing is better than nothing
- Of course, you need to test these simple and common cases, but ***don’t stop there***
- To find the most flaws, **also** test the “edge” cases, those that are extreme or unexpected in one way or another

Example “edge” case

- Recall our code for **`is_odd`**:

```
def is_odd(n):
    """Test if the argument is odd"""
    return n % 2 == 1
```

- Here is another test for it:

```
def test_odd_when_negative(self):
    self.assertTrue(is_odd(-3))
    self.assertFalse(is_odd(-4))
```

- What is the result of **`-3 % 2`**? Is it **`1`**, or is it **`-1`**?

- In either event, here is some better code:

```
def is_odd(n):
    """Test if the argument is odd"""
    return not is_even(n)
```

Must I write tests?

- Students don't like to write tests, and want to write a few as possible
  - I don't blame you; it seems like extra work, and no one likes to do unnecessary work
  - For small programs, you can often get by with just some informal testing
  - Since I am **not** teaching "***programming in the small***," **formal testing is required in this course**
- Besides,
  - Writing code, even test code, is at least a creative activity...unlike debugging, which almost everyone finds unpleasant
  - Minutes of writing tests will sometimes save you hours (or even days) of debugging
  - Your programs will be graded using our ***extensive*** unit tests!

How much is enough?

- **Rule:** Write ***at least one*** test method for each computational method
  - You can write more than one test method (with different names) for methods that do more than one thing, or handle more than one case
- There is no need for redundant testing; if `is_odd` works for both 5 and 6, it probably also works for 7 and 8
  - ...but it may not work for negative numbers, so test those as well
- There is no need to write unit tests to see if Python itself works
- **Rule:** Test every ***case*** you can think of that might possibly go wrong

Do it backwards and iteratively!

- The obvious thing to do is to write the code first, then write the tests for the code

- Here is a better way:

    1. Begin by writing a simple test for the code you plan to write

    2. Write the code

    3. Run the test, and debug until everything works (remember, errors might be in the test itself)

    4. Clean up (***refactor***) the code, making sure that it still works

    5. If the code doesn't yet do everything you want it to do, write a test for the next feature you want to add, and go to step 2.

- This is approach is called ***Test Driven Development*** (***TDD***)

Why is TDD better?

- When you start with the code, it is easy to write a function that is too complicated and difficult to test

- Writing the test first helps clarify what the code is supposed to do and how it is to be used

- Writing the test first helps keeps functions small and single-purpose

- TDD promotes steady, step-by-step progress, and helps avoid long, painful debugging sessions

- TDD simplifies and encourages code modification when updates are needed

Refactoring

- ***Refactoring*** is changing the code to make it better (cleaner, simpler, easier to use) ***without changing what it does***

- Refactoring should be a normal part of your programming

  - Each time you get a function to work correctly (or even sooner), you should see if there's a way you can make it better

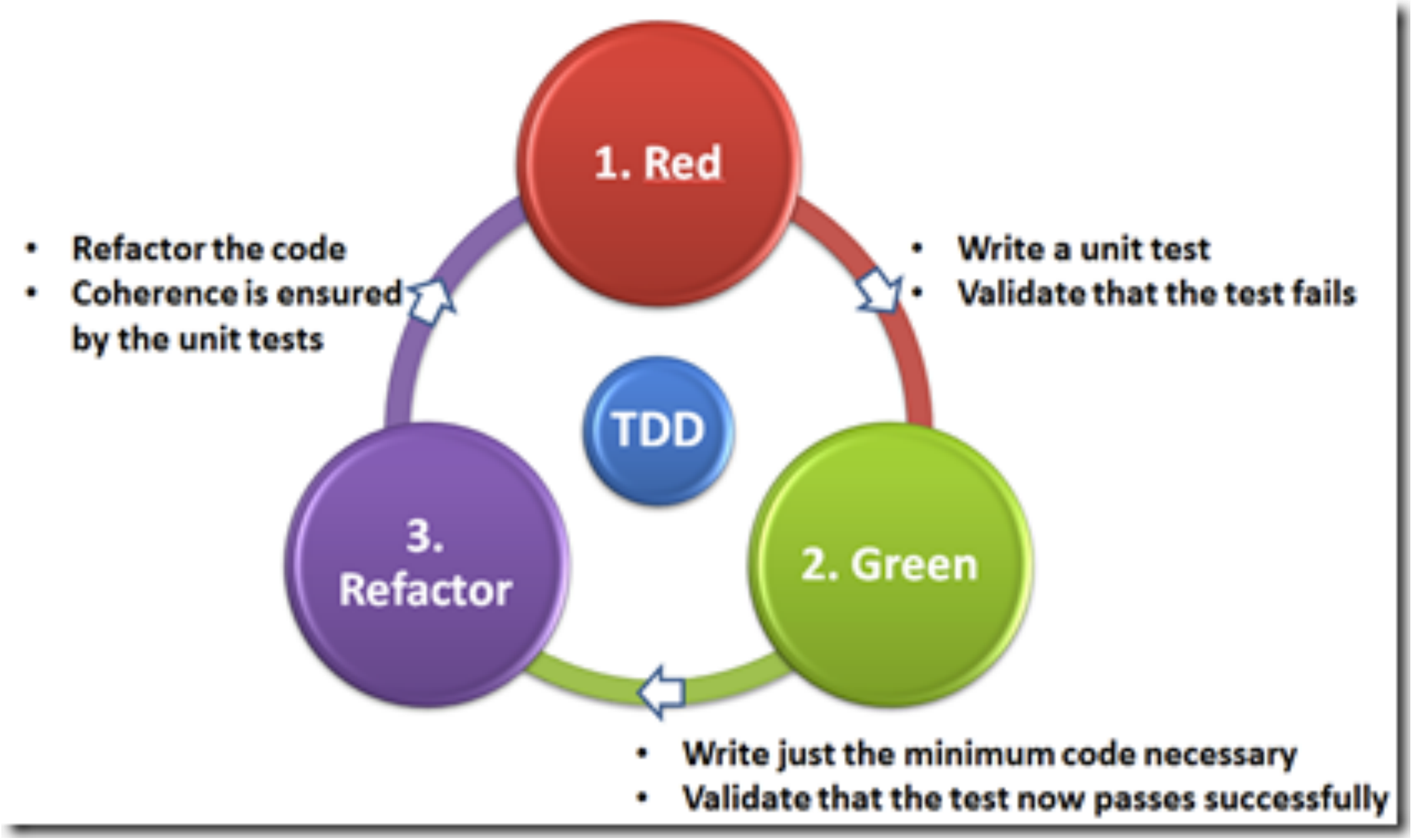
- Common refactorings include:

  - Changing the name of variables or functions to better express their meaning

  - Eliminating useless or redundant code (such as `if success == True:`)

  - Breaking a function that does two or more things into two or more single-purpose functions

  - Simplifying a complex arithmetic expression by giving names to the parts, then using those names in the expression



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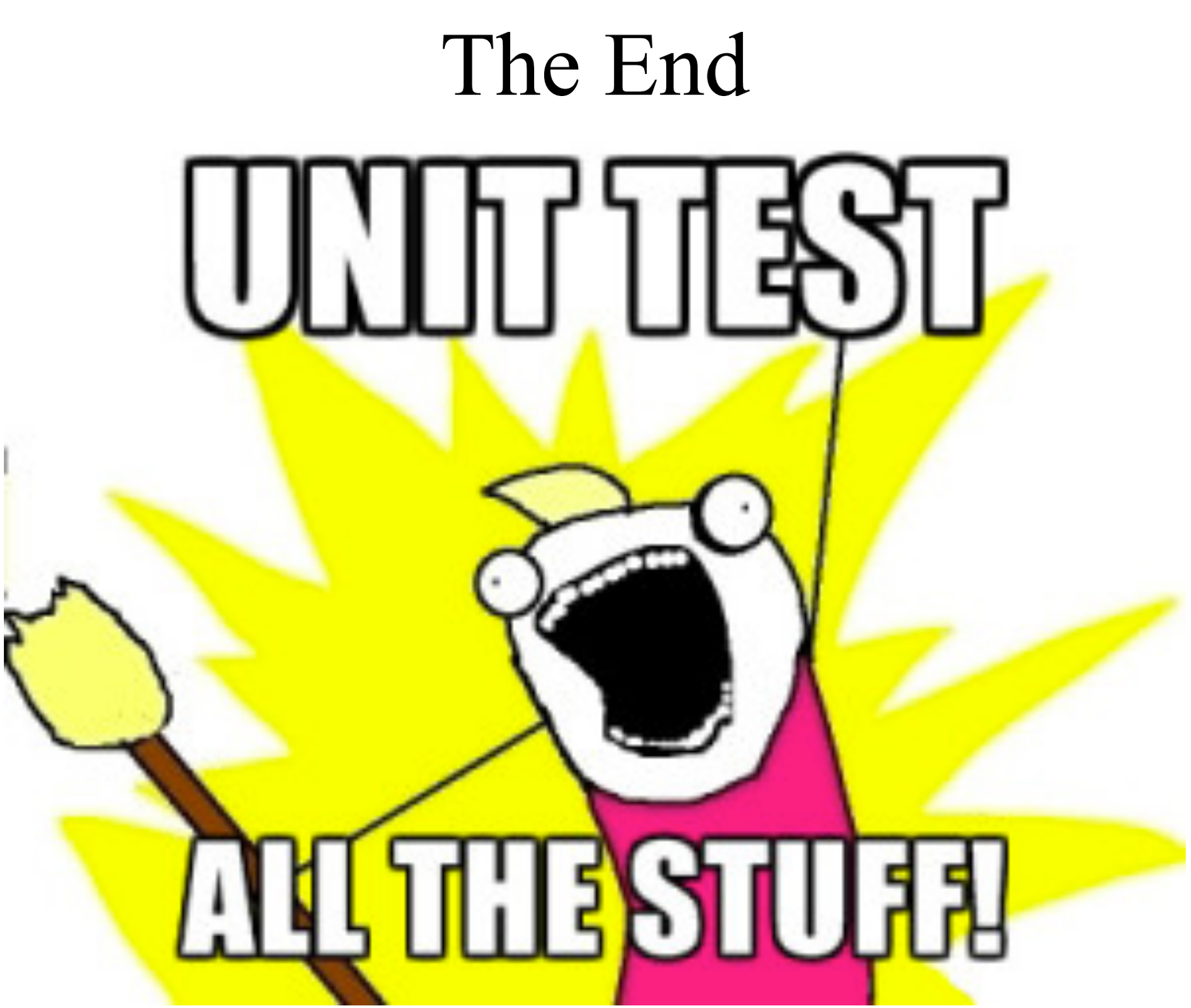
Special code in the program

- Programs typically have a method named **`main`** which is the starting point for everything that happens in the program
  - The program can be started automatically when it is loaded by putting this as the last line in the program:
    ```
    main()
    ```
  - If you are testing the individual methods of the program, you don't want to start the program automatically
- The following "magic" code, placed at the end of the program, will call the **`main`** method to start the program *if and only if* you run the code from this file:
  - ```
    if __name__ == '__main__':
        main()
    ```
- If you run tests from a separate file, the above code does not call the main method to start the program running
    ```



The End

http://www.adamslair.net/blog/?p=1463