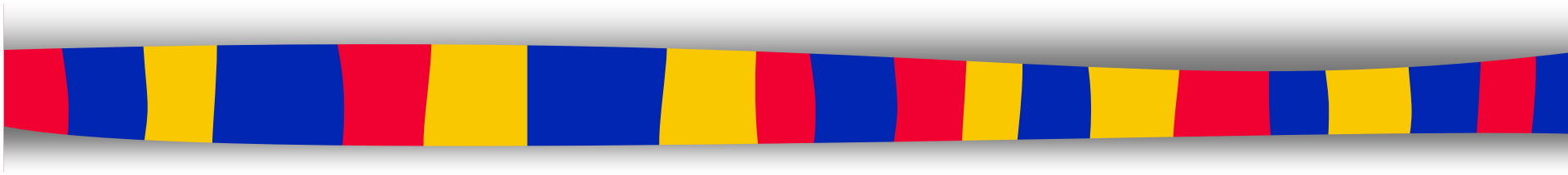
EECS 4313

Software Engineering Testing



Topic 03:

Test automation / JUnit

- Building automatically repeatable test suites

Zhen Ming (Jack) Jiang

Acknowledgement

- Some slides are from Prof. Alex Orso

Relevant Readings

- [Jorgensen] chapter 19

Test automation

- Test automation is software that automates any aspect of testing
  - Generating test inputs and expected results
  - Running test suites without manual intervention
  - Evaluating pass/no pass
- Testing must be automated to be effective and repeatable

Automated testing steps

- Exercise the implementation with the automated test suite
- Repair faults revealed by failures
- Rerun the test suite on the revised implementation
- Evaluate test suite coverage
- Enhance the test suite to achieve coverage goals
- Rerun the automated test suite to support regression testing

Automated testing advantages

- Permits quick and efficient verification of bug fixes
- Speeds debugging and reduces “bad fixes”
- Allows consistent capture and analysis of test results
- Its cost is recovered through increased productivity and better system quality
- More time to design better tests, rather than entering and reentering tests
- Unlike manual testing, it is not error-prone and tedious
- Only feasible way to do regression testing
- Necessary to run long and complex tests
- Easily evaluates large quantities of output

Limitations and caveats

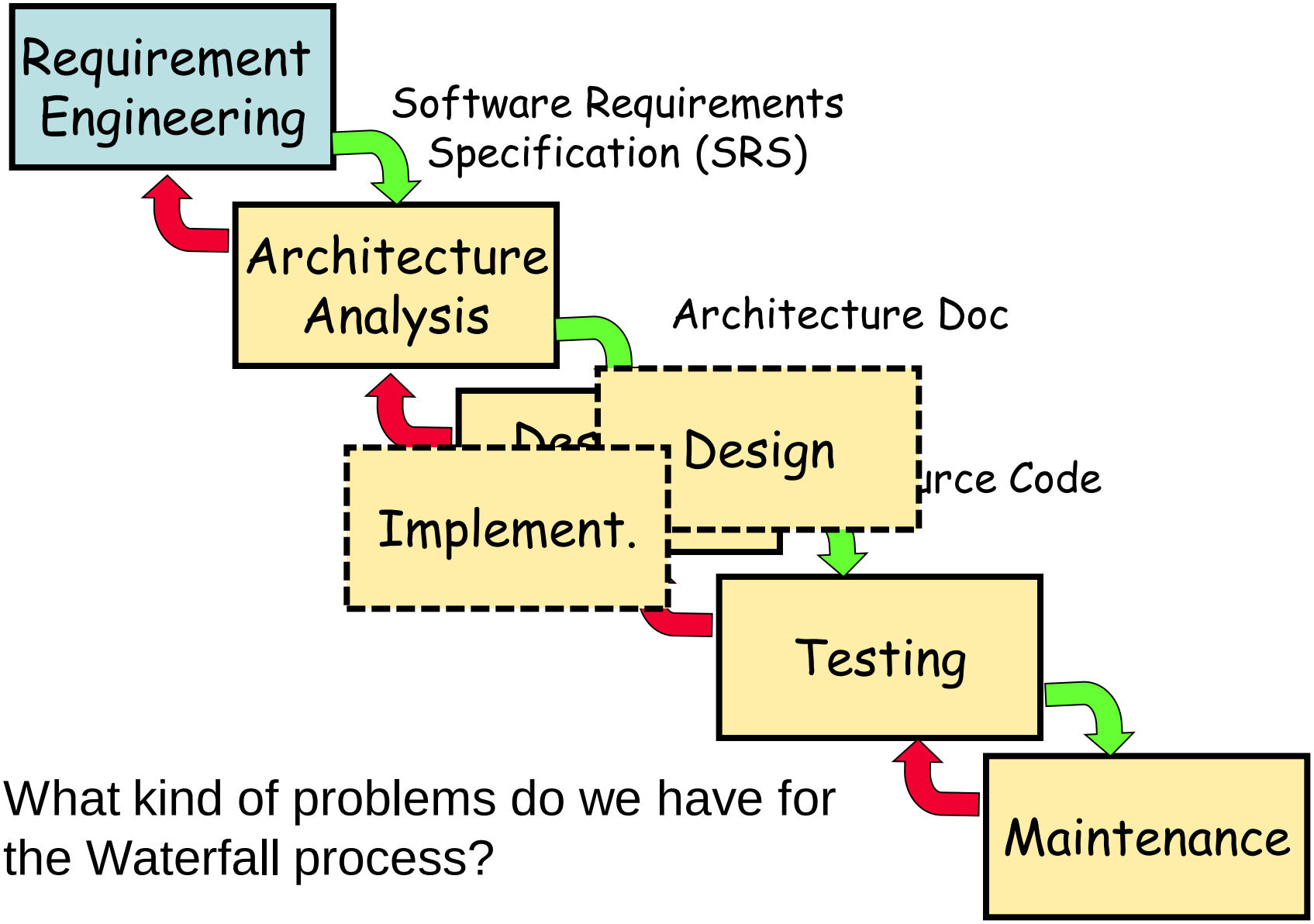
- A skilled tester can use his experience to react to manual testing results by improvising effective tests
- Automated tests are expensive to create and maintain
- Some of the test results cannot be easily checked automatically
- If the implementation is changing frequently, maintaining the test suite might be hard

XP approach to testing

- In the Extreme Programming approach
  - Tests are written before the code itself
  - If the code has no automated test cases, it is assumed not to work
  - A testing framework is used so that automated testing can be done after every small change to the code
    - This may be as often as every 5 or 10 minutes
  - If a bug is found after development, a test is created to keep the bug from coming back

Introduction to the Agile Development Process

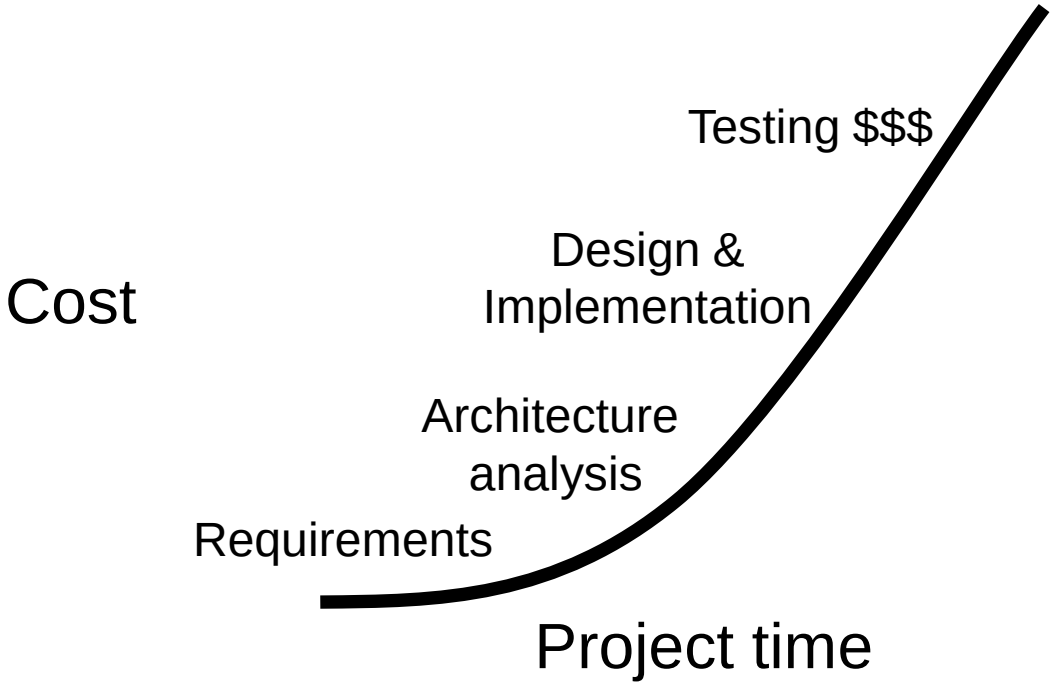
Waterfall Development Process



What kind of problems do we have for the Waterfall process?

The cost of change grows exponentially with time

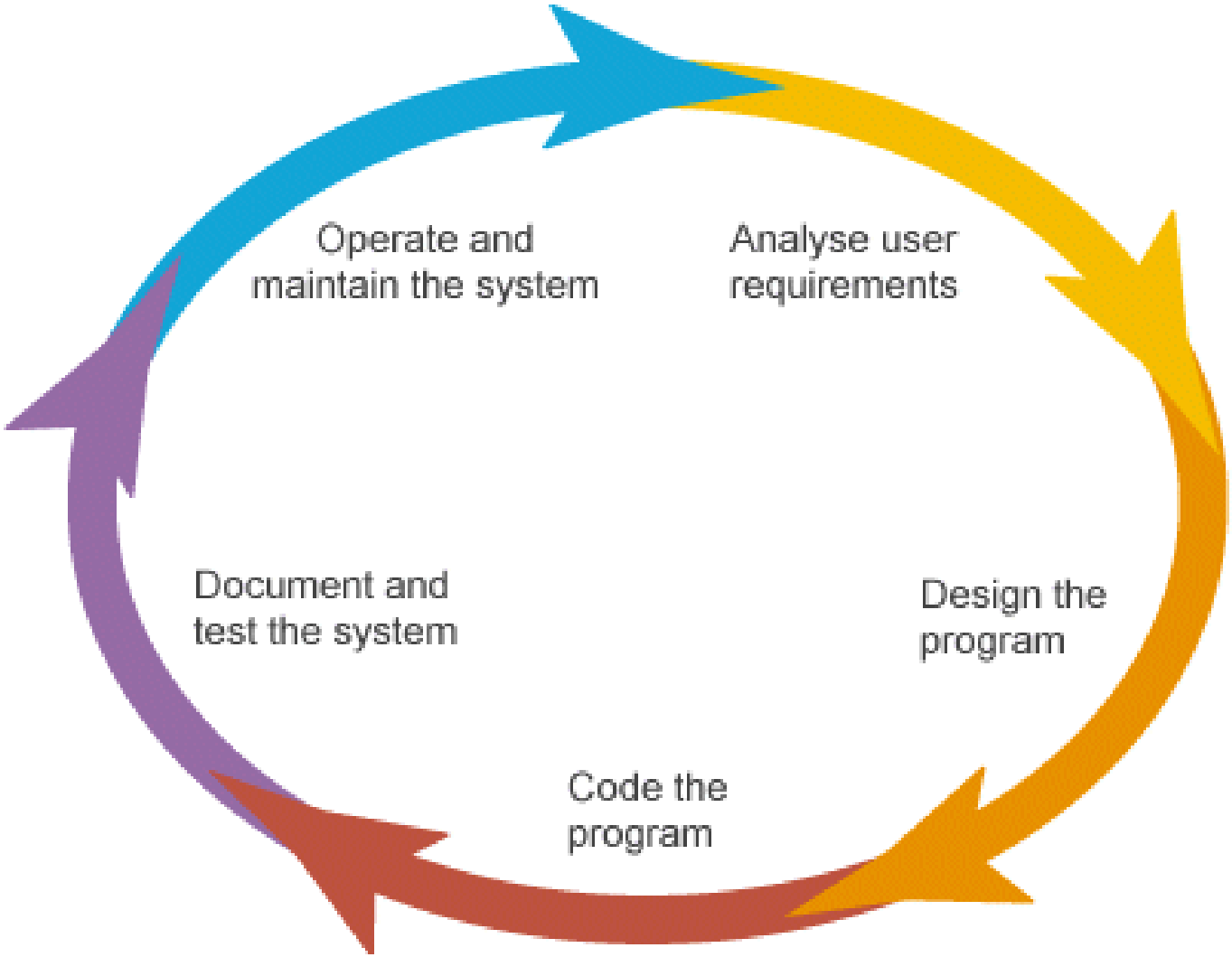
- Barry Boehm



The agile methods aim at flat cost

- Focus on the code
- People over process
- Iterative approach
- Customer involvement
- Expectation that requirements will change
- Simplicity

The Agile Iterative Software Development Process



XP

“XP is a lightweight methodology for small to medium sized teams developing software in the face of vague or rapidly changing requirements”

- Kent Beck

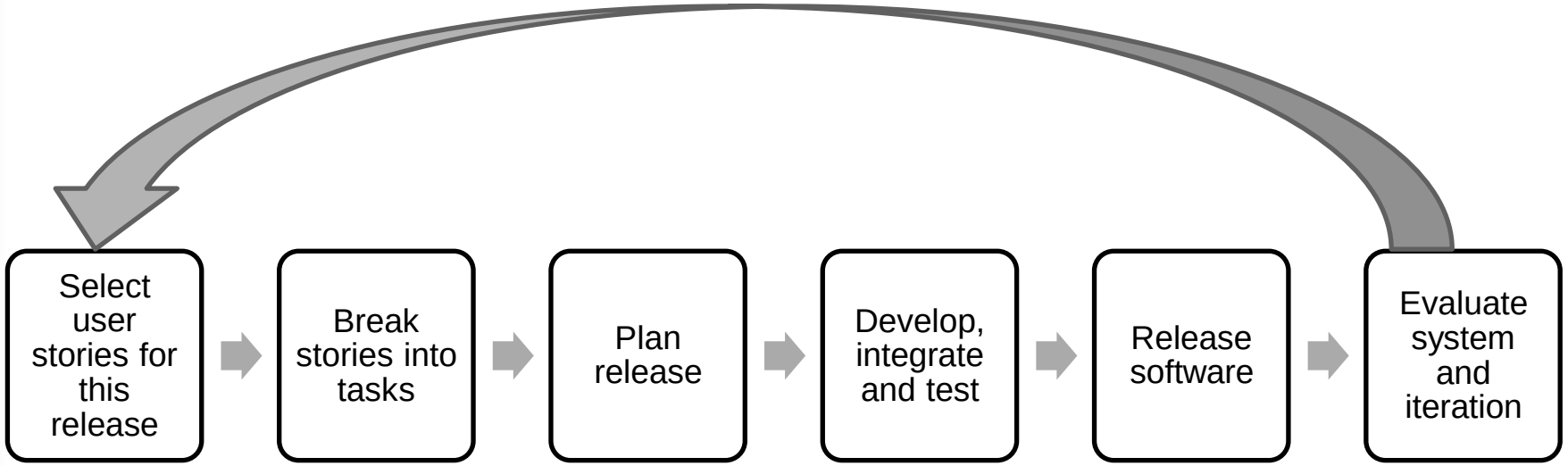
- Lightweight
- Humanistic (focus on people)
- Discipline
- Software development

XP’s practices

- **Incremental planning**
- Small releases
- Simple design
- Test first
- Refactoring
- Pair programming
- Continuous integration
- On-site customer

…

Incremental planning



XP's practices

- Incremental planning
- **Small releases**
  - Accomplishment, reduce risk, quickly adapt to change, etc.
- Simple design
- Test first
- Refactoring
- Pair programming
- Continuous integration
- On-site customer

…

XP’s practices

- Incremental planning
- Small releases
- **Simple design**
  - Enough to meet the requirements
  - No duplicated functionality
  - Fewest possible classes and methods
- Test first
- Refactoring
- Pair programming
- Continuous integration
- On-site customer

…

XP’s practices

- Incremental planning
- Small releases
- Simple design
- **Test first**
  - Create test cases before implementation
  - Test Driven Development (TDD)
- Refactoring
- Pair programming
- Continuous integration
- On-site customer

…

XP’s practices

- Incremental planning
- Small releases
- Simple design
- Test first
- **Refactoring**
  - Refactoring on demand
- Pair programming
- Continuous integration
- On-site customer

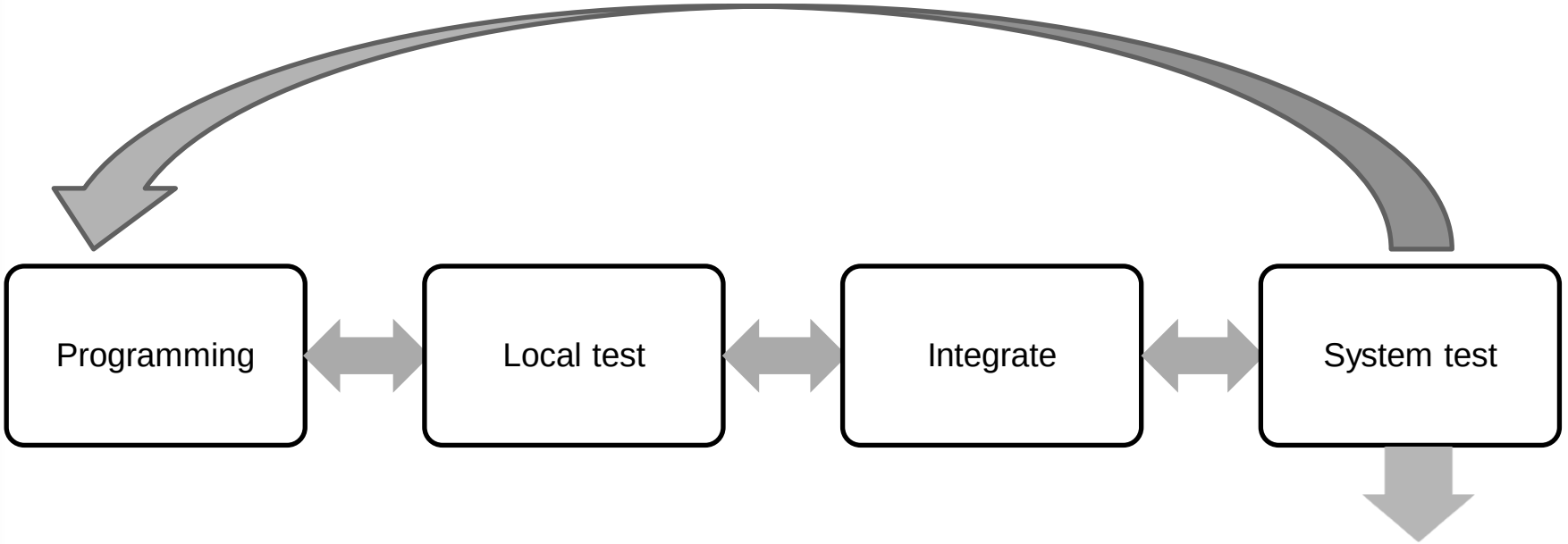
…

XP’s practices

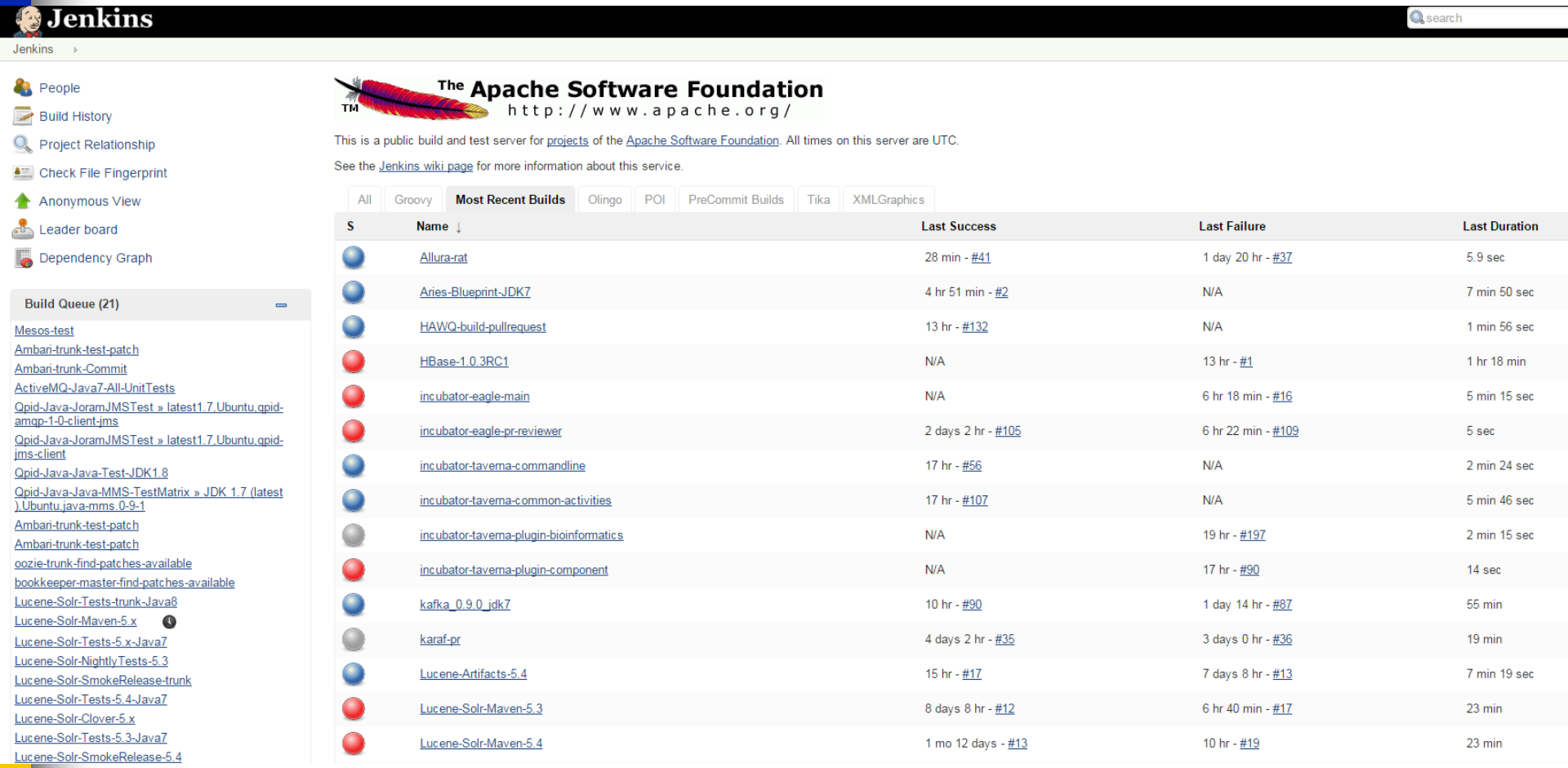
- Incremental planning
- Small releases
- Simple design
- Test first
- Refactoring
- **Pair programming**
  - Programming <=> Strategizing
- Continuous integration
- On-site customer

…

Continuous Integration



Apache Jenkins



XP's practices

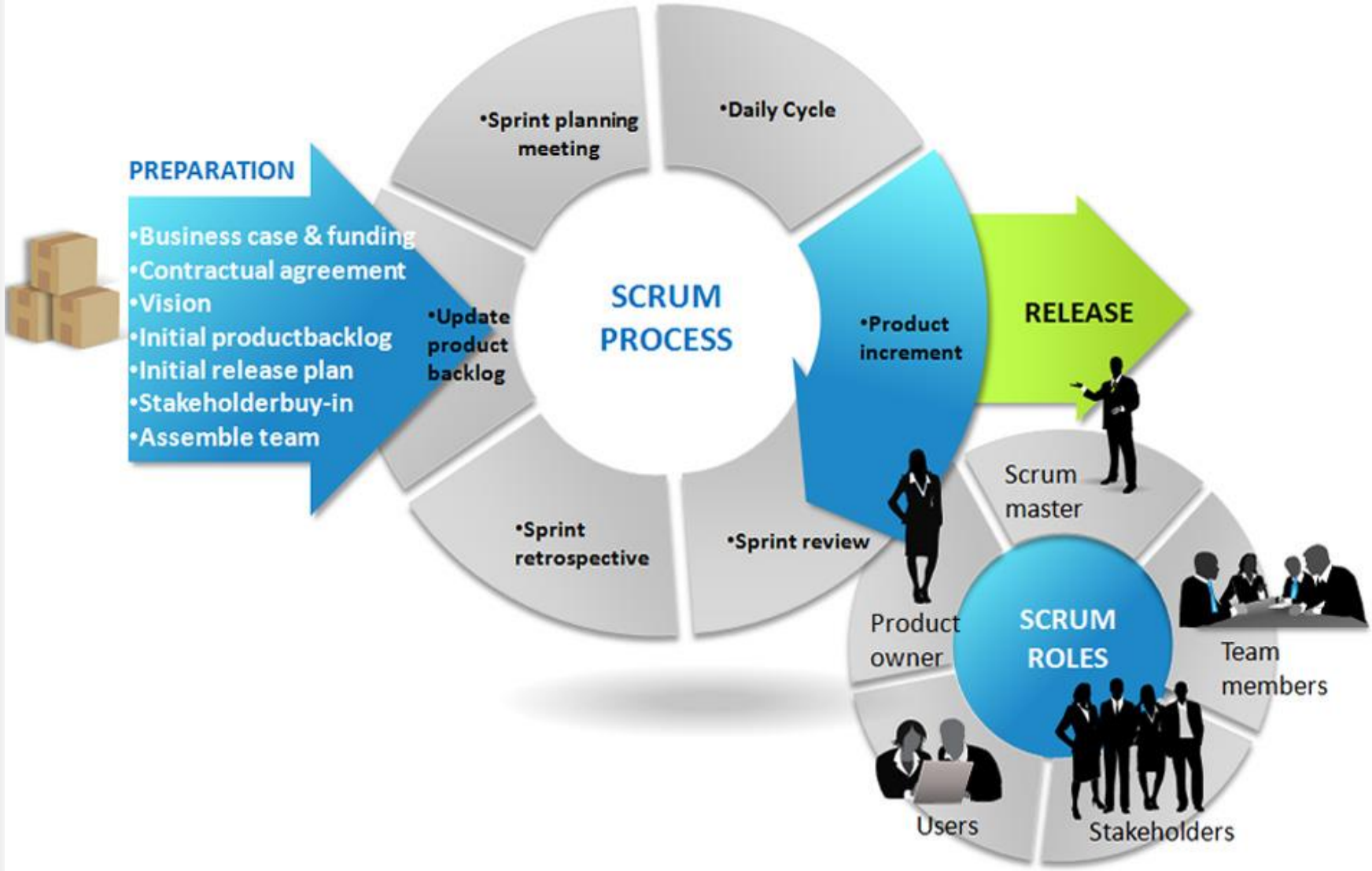
- Incremental planning
- Small releases
- Simple design
- Test first
- Refactoring
- Pair programming
- Continuous integration
- **On-site customer**
  - The customer is an actual member of the team
    - Sits with the team
    - Brings requirements

…

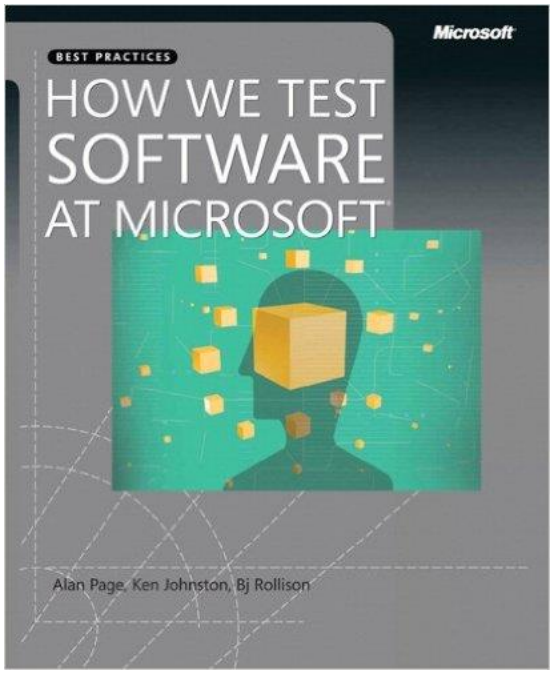
XP consequences

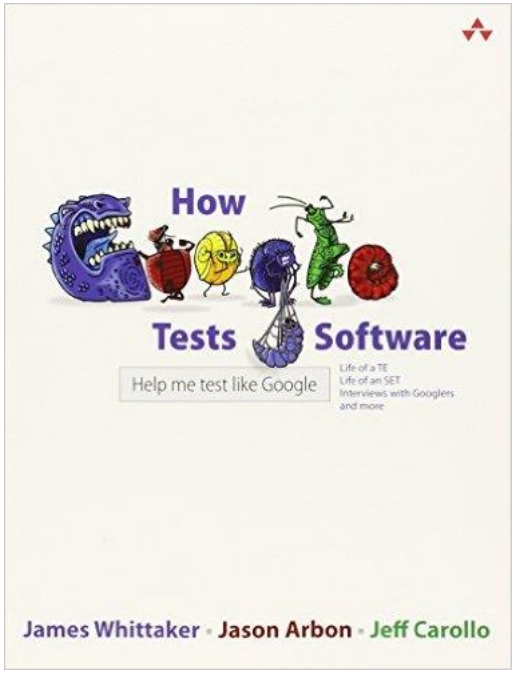
- Fewer bugs
- More maintainable code
- The code can be refactored without fear
- Continuous integration
  - During development, the program *always works*
  - It may not do everything required, but what it does, it does right

SCRUM PROCESS



James Whittaker





JUnit

JUnit

- JUnit is a framework for writing tests
  - Written by Erich Gamma (of Design Patterns fame) and Kent Beck (creator of XP methodology)
  - Uses Java 5 features such as annotations and static imports
  - JUnit helps the programmer:
    - define and execute tests and test suites
    - formalize requirements
    - write and debug code
    - integrate code and always be ready to release a working version

Terminology

- A test fixture sets up the data (both objects and primitives) that are needed for every test
  - Example: If you are testing code that updates an employee record, you need an employee record to test it on
- A unit test is a test of a *single* class
- A test case tests the response of a single method to a particular set of inputs
- A test suite is a collection of test cases
- A test runner is software that runs tests and reports results

Structure of a JUnit test class

- To test a class named **`Fraction`**
- Create a test class **`FractionTest`**

```
import org.junit.*;
import static org.junit.Assert.*;
public class FractionTest
{
        …
}
```

Test fixtures

- Methods annotated with `@Before` will execute before every test case (`@test`)
- Methods annotated with `@After` will execute after every test case (`@test`)

```
@Before
public void setUp()  {…}
@After
public void tearDown()  {…}
```

Class Test fixtures

- Methods annotated with `@BeforeClass` will execute once before all test cases
- Methods annotated with `@AfterClass` will execute once after all test cases
- These are useful if you need to allocate and release expensive resources (e.g., connect/disconnect to a database) once

Test cases

- Methods annotated with `@Test` are considered to be test cases

```
@Test
public void testadd() {…}
@Test
public void testToString() {…}
```

JUnit annotations

Annotation	Description
@Test public void method()	The `@Test` annotation identifies a method as a test method.
@Test (expected = Exception.class)	Fails if the method does not throw the named exception.
@Test(timeout=100)	Fails if the method takes longer than 100 milliseconds.
@Before public void method()	This method is executed before each test. It is used to prepare the test environment (e.g., read input data, initialize the class).
@After public void method()	This method is executed after each test. It is used to cleanup the test environment (e.g., delete temporary data, restore defaults). It can also save memory by cleaning up expensive memory structures.
@BeforeClass public static void method()	This method is executed once, before the start of all tests. It is used to perform time intensive activities, for example, to connect to a database. Methods marked with this annotation need to be defined as `static` to work with JUnit.
@AfterClass public static void method()	This method is executed once, after all tests have been finished. It is used to perform clean-up activities, for example, to disconnect from a database. Methods annotated with this annotation need to be defined as `static` to work with JUnit.
@Ignore or @Ignore("Why disabled")	Ignores the test method. This is useful when the underlying code has been changed and the test case has not yet been adapted. Or if the execution time of this test is too long to be included. It is best practice to provide the optional description, why the test is disabled.

http://www.vogella.com/tutorials/JUnit/article.html

What JUnit does

- For *each* test case t:
  - JUnit executes all `@Before` methods
    - Their order of execution is not specified
  - JUnit executes t
    - Any exceptions during its execution are logged
  - JUnit executes all `@After` methods
    - Their order of execution is not specified
- A report for all test cases is presented

Within a test case

- Call the methods of the class being tested
- Assert what the correct result should be with one of the provided assert methods
- These steps can be repeated as many times as necessary
- An assert method is a JUnit method that performs a test, and throws an AssertionError if the test fails
  - JUnit catches these exceptions and shows you the results

List of assert methods 1

- `assertTrue(boolean b)`
  `assertTrue(String s, boolean b)`
  - Throws an AssertionError if `b` is False
  - The optional message `s` is included in the Error
- `assertFalse(boolean b)`
  `assertFalse(String s, boolean b)`
  - Throws an AssertionError if `b` is True
  - All assert methods have an optional message

Example: Counter class

- Consider a trivial “counter” class
  - The constructor creates a counter and sets it to zero
  - The increment method adds one to the counter and returns the new value
  - The decrement method subtracts one from the counter and returns the new value
  - The corresponding JUnit test class…

```
public class CounterTest {
    Counter counter1;

    @Before
    public void setUp() {    // creates a (simple) test fixture
        counter1 = new Counter();
    }

    @Test
    public void testIncrement() {
        assertTrue(counter1.increment() == 1);
        assertTrue(counter1.increment() == 2);
    }

    @Test
    public void testDecrement() {
        assertTrue(counter1.decrement() == -1);
    }
}
```

Note that each test begins with a *brand new* counter

This means you don't have to worry about the order in which the tests are run

List of assert methods 2

- `assertEquals(Object ***expected***, Object ***actual***)`

- Uses the equals method to compare the two objects
- Primitives can be passed as arguments thanks to autoboxing
- Casting may be required for primitives
- There is also a version to compare arrays

List of assert methods 3

- `assertSame(Object expected, Object actual)`
  - Asserts that two references are attached to the same object (using `==`)
- `assertNotSame(Object expected, Object actual)`
  - Asserts that two references are not attached to the same object

List of assert methods 4

- `assertNull(Object object)`
  - Asserts that a reference is null
- `assertNotNull(Object object)`
  - Asserts that a reference is not null
- `fail()`
  - Causes the test to fail and throw an AssertionError
  - Useful as a result of a complex test, or when testing for exceptions

Testing for exceptions

- If a test case is expected to raise an exception, it can be noted as follows

```
@Test(expected = Exception.class)
public void testException() {
   //Code that should raise an exception
   fail("Should raise an exception");
}
```

Testing for exceptions - example

```
public void testAnIOExceptionIsThrown {
   try
   {
      // Code that should raise an IO exception
      fail("Expected an IO exception");
   }
   catch (IOException e)
   {
      // This is the expected result, so
      // leave it empty so that the test
      // will pass. If you care about
      // particulars of the exception, you
      // can test various assertions about
      // the exception object
   }
}
```

The assert statement

- A statement such as

  ```
  assert boolean_condition;
  ```

  will also throw an AssertionError if the ***boolean_condition*** is false
- Can be used instead of the JUnit assertTrue method

Ignoring test cases

- Test cases that are not finished yet can be annotated with `@Ignore`
- JUnit will not execute the test case but will report how many test cases are being ignored

Automated testing issues

- It is not easy to see how to unit test GUI code
- JUnit is designed to call methods and compare the results they return against expected results
  - This works great for methods that *just* return results, but many methods have side effects

Automated testing issues

- To test methods that do output, you have to capture the output
  - It's possible to capture output, but it's an unpleasant coding chore
- To test methods that change the state of the object, you have to have code that checks the state
  - It's a good idea to have methods that test state invariants

First steps toward solutions

- You can redefine `System.out` to use a different `PrintStream` with `System.setOut(PrintStream)`

- You can “automate” GUI use by “faking” events
  - We will see this in more detail later

JUnit in Eclipse

- JUnit can be downloaded from http://junit.org/
  - JUnit 4.x, which supports Java 5 or higher
  - JUnit 5.x, which supports Java 8 or higher
  - *For this course's assignment, you should use JUnit 4.x*
- If you use Eclipse, as in this course, you do not need to download anything
- Eclipse contains wizards to help with the development of test suites with JUnit
- JUnit results are presented in an Eclipse window

JUnit Demo # 1
- HelloWorld

Hello World demo

- Run Eclipse
  - Change the configuration file to increase the Eclipse memory if necessary
- File -> New -> Project, choose Java Project, and click Next. Type in a project name, e.g., ProjectWithJUnit.
  - Click Next
  - Click Create New Source Folder, name it test
  - Click Finish
- Click Finish

Create a class

- Right-click on ProjectWithJUnit
  Select New -> Package
  Enter package name, e.g., **code**
  Click Finish
- Right-click on code
  Select New -> Class
  Enter class name, e.g., **HelloWorld**
  Click Finish

Create a class - 2

- Add a dummy method such as
  public String say() { return null; }
- Right-click in the editor window and select Save

Create a test class

- Right-click on the HelloWorld class
  Select New -> JUnit Test Case
- Make sure pick JUnit 4 test (not JUnit 3)
- Change the source folder to test as opposed to src
- Check to create a setup method
- Click Next

Create a test class

- Check the checkbox for the say method
  - This will create a stub for a test case for this method
- Click Finish
- Click OK to “Add JUnit 4 library to the build path”
- The HelloWorldTest class is created
- The first version of the test suite is ready

Run the test class - 1st try

- Right click on the HelloWorldTest class
- Select Run as -> JUnit Test
- The results appear in the left
- The automatically created test case fails

Create a better test case

- Import the class under test

```
import code.HelloWorld;
```

- Declare an attribute of type HelloWorld

```
HelloWorld hi;
```

- The setup method should create a HelloWorld object

```
hi = new HelloWorld();
```

- Modify the testSay method body to

```
assertEquals("Hello World!",
                    hi.say());
```

Run the test class - 2nd try

- Save the new version of the test class and re-run
- This time the test fails due to expected and actual not being equal
- The body of the method say has to be modified to
  `return “Hello World!”;`
  for the test to pass

JUnit Demo # 2
- Currency

Currency Demo

- Run Eclipse
  - Change the configuration file to increase the Eclipse memory if necessary
- File -> New -> Project, choose Java Project, and click Next. Type in a project name “currency”.
  - Click Next
  - Click Create New Source Folder, name it test
  - Click Finish
- Click Finish

Create source code class

- Right-click on currency
  Select New -> Package
  Enter package name, e.g. **code**
  Click Finish
- Right-click on code
  Select New -> Class
  Enter class name, e.g. **Currency**
  Click Finish
- The content of the Currency class can be found on the class webpage

Create a test class

- Right-click on the Currency class
  Select New -> JUnit Test Case
- Make sure pick JUnit 4 test (not JUnit 3)
- Change the source folder to test as opposed to src
- Check to create a setup method
- Click Next

Create a test class

- Check the checkbox for the times and equals method
  - This will create a stub for a test case for this method
- Click Finish
- Click OK to “Add JUnit 4 library to the build path”
- The CurrencyTest class is created
- The first version of the test suite is ready

Run the test class - 1st try

- Right click on the CurrencyTest class
- Select Run as -> JUnit Test
- The results appear in the left
- The automatically created test case fails

Create fill in the test cases

- Modify the testEqualsObject method body to

```
assertEquals(5,5);
  assertTrue(new Currency(5,
"Currency").equals(new Currency(5,
"Currency")));
  assertFalse(new Currency(5,
"Currency").equals(new Currency(6,
"Currency")));
  assertTrue(new Currency(5, "Euro").equals(new
Currency(5, "Euro")));
  assertFalse(new Currency(5, "Euro").equals(new
Currency(6, "Euro")));
  assertFalse(new Currency(5, "Euro").equals(new
Currency(5, "Currency")));
```

Create fill in the test cases

- Modify the testTimes method body to

```
assertEquals(5,5);
Currency five = new Currency(5, "Dollar");
assertEquals(new Currency(15, "Dollar"),
      five.times(3));
```

Run the test class - 2nd try

- Save the new version of the TestMoney class and re-run, this time both tests should pass

TestMoney2 class

- Create a new JUnitTest class called TestMoney2
- Pick dollar and euro from the Currency class to test
- Fill in the testDollar method with this content:

```
assertEquals("Dollar", Currency.dollar(1).type);
```

- Fill in the testEuro method with this content:

```
assertEquals("Euro", Currency.euro(1).type);
```

- Run this TestMoney2 as JUnitTest and ensure both test cases pass

Create a test suite

- Right-click on the code package in the test source folder -> New -> Other -> Java, under Java, pick JUnit, then pick JUnit test suite
- Name this class AllTest
- include both “TestMoney” and “TestMoney2”
- Click Finish