# CS/CE/SE 6367
# Software Testing, Validation and Verification

Lecture 2
Software Testing
JUnit

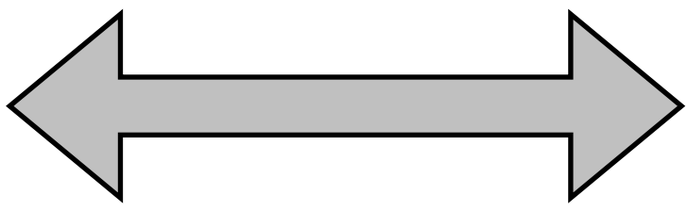
# Today's class

- Software Testing
  - Concepts
  - Granularity
  - Unit Testing
- JUnit

# Black-Box and White-Box Testing

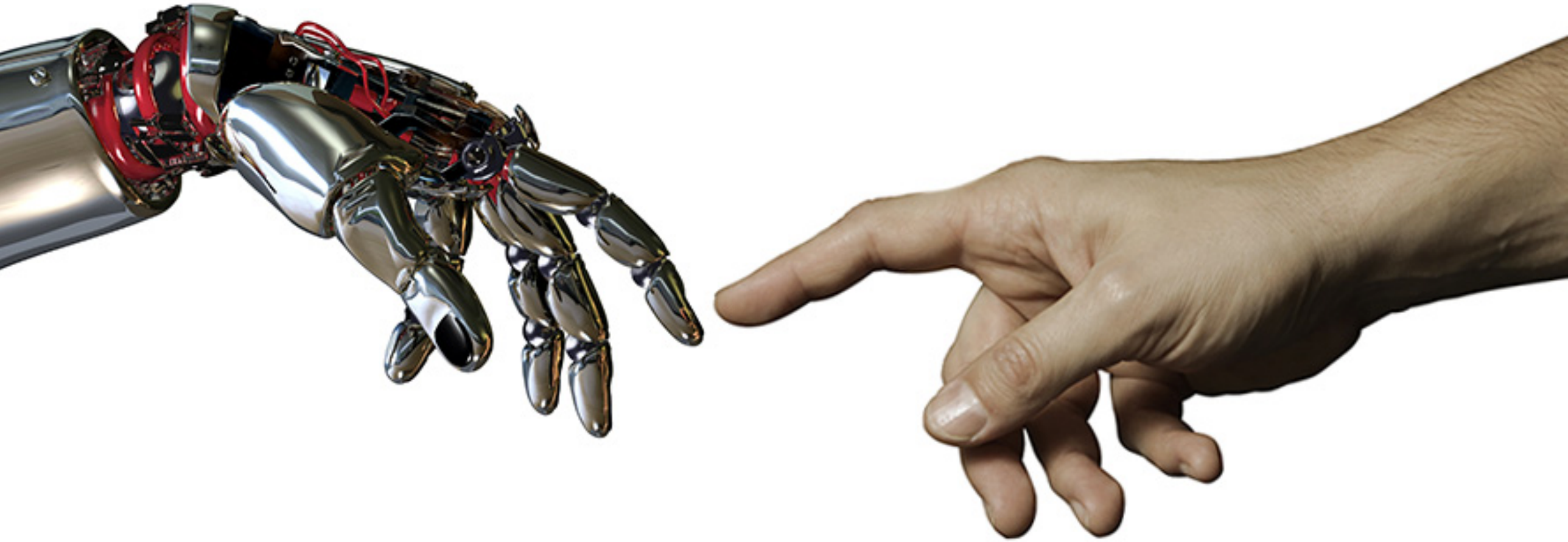
- Black Box (aka Functional , aka Spec-Based)
  - Tests derived from functional requirements
  - Input/Output Driven
  - Internal source code of software is not relevant to design the tests

- White Box (aka Code-Based, aka Structural)
  - Tests derived from source code structure
  - Tests are evaluated in terms of coverage of the source code



Many others in between (Gray Box)

# Manual and Automated Testing



# Testing: Concepts

Test case

Test suite

Test script

Test oracle

Test driver

Test fixture

Test adequacy

# Testing: Concepts

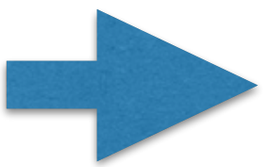
- Test case (or, simply test)
  - An execution of the software with a given test input, including:
    - Input values
    - Sometimes include execution steps
    - Expected outputs

```
int actual_output=sum(1,2)
assertTrue(actual_output==3);
```

Example JUnit test case for testing "sum(int a, int b)"

# Testing: Concepts

- Test oracle
  - The expected outputs of software for given input
  - A part of test cases
  - Hardest problem in auto-testing: test oracle generation



```
int actual_output=sum(1,2)
assertTrue(actual_output==3);
```

Example JUnit test case for testing "sum(int a, int b)"

# Testing: Concepts

- Test fixture: a fixed state of the software under test used as a baseline for running tests; also known as the test context, e.g.,
  - Loading a database with a specific, known set of data
  - Preparation of input data and set-up/creation of fake or mock objects

# Testing: Concepts

- Test suite
  - A collection of test cases
  - Usually these test cases share similar pre-requisites and configuration
  - Usually can be run together in sequence
  - Different test suites for different purposes
    - Certain platforms, Certain feature, performance, …
- Test Script
  - A script to run a sequence of test cases or a test suite automatically

# Testing: Concepts

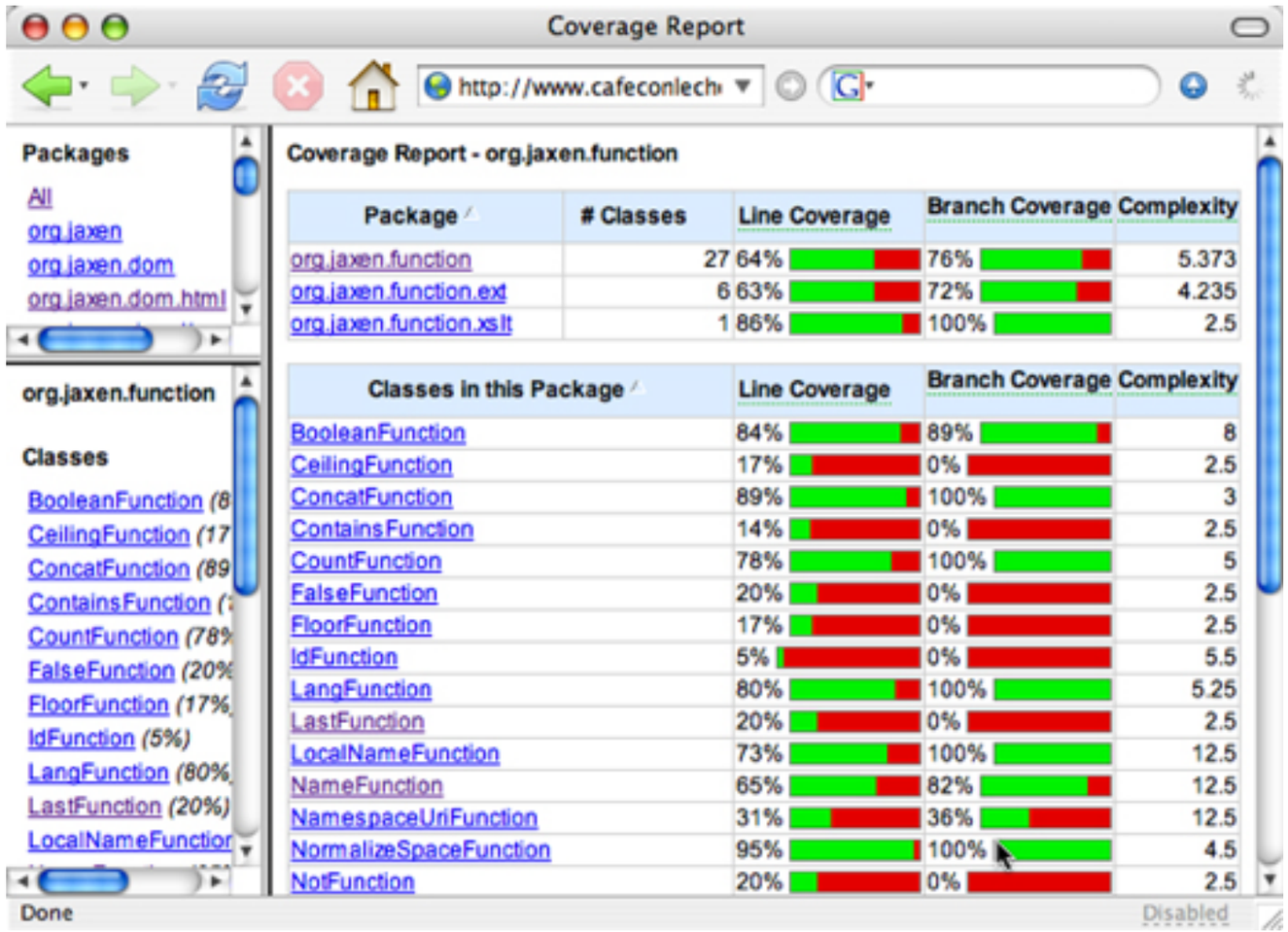
- Test driver
  - A software framework that can load a collection of test cases or a test suite
  - It can also handle the configuration and comparison between expected outputs and  actual outputs

# Testing: Concepts

- Test adequacy
  - We can’t always use all test inputs, so which do we use and when do we stop?
  - We need a strategy to determine when we have done enough
- Adequacy criterion: A rule that lets us judge the sufficiency of a set of test data for a piece of software

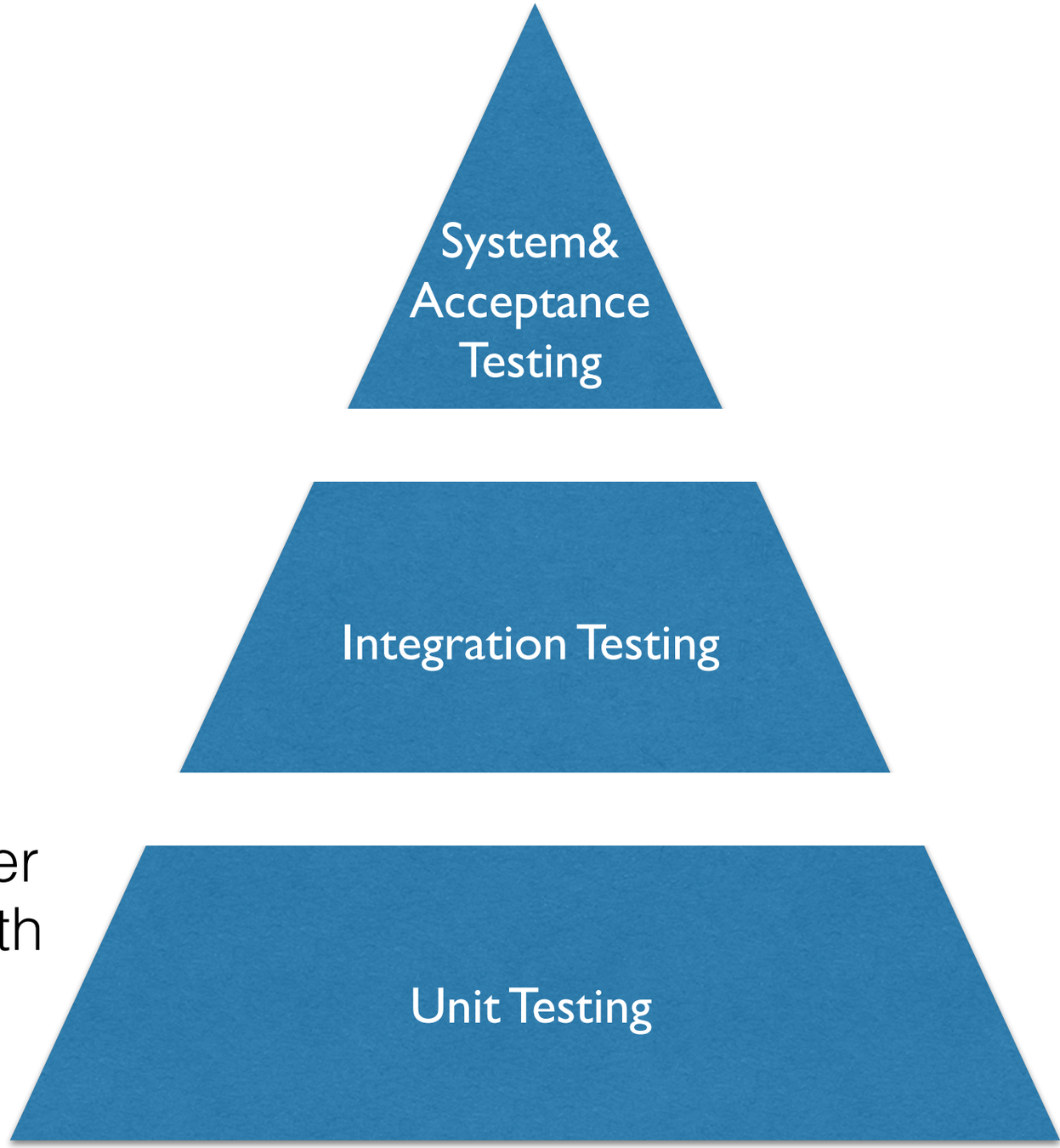
# Testing: Concepts

- Test adequacy example: test coverage
  - A measurement to evaluate the percentage of code tested
  - Statement coverage
  - Branch coverage, ...



# Granularity of Testing

- Unit Testing
  - Test of each single module
- Integration Testing
  - Test the interaction between modules
- System Testing
  - Test the system as a whole, by developers
- Acceptance Testing
  - Validate the system against user requirements, by customers with no formal test  cases



# Unit testing

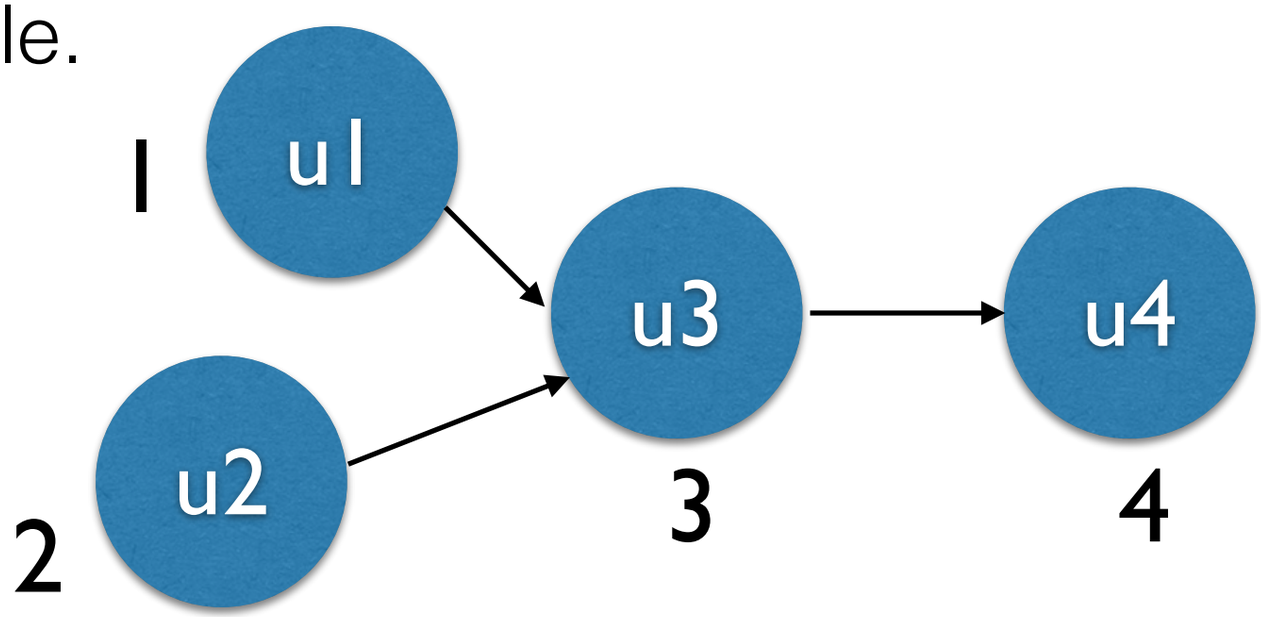
- Testing of an basic module of the software
  - A function, a class, a component
- Typical problems revealed
  - Local data structures
  - Algorithms
  - Boundary conditions
  - Error handling

# Why Unit Testing?

- Divide-and-conquer approach
  - Split system into units
  - Debug unit individually
  - Narrow down places where bugs can be
  - Don’t want to chase down bugs in other units

# How to Do Unit Testing

- Build systems in layers
  - Starts with classes that don’t depend on others.
  - Continue testing building on already tested classes.
- Benefits
  - Avoid having to write mock classes
  - When testing a module, ones it depends on are reliable.



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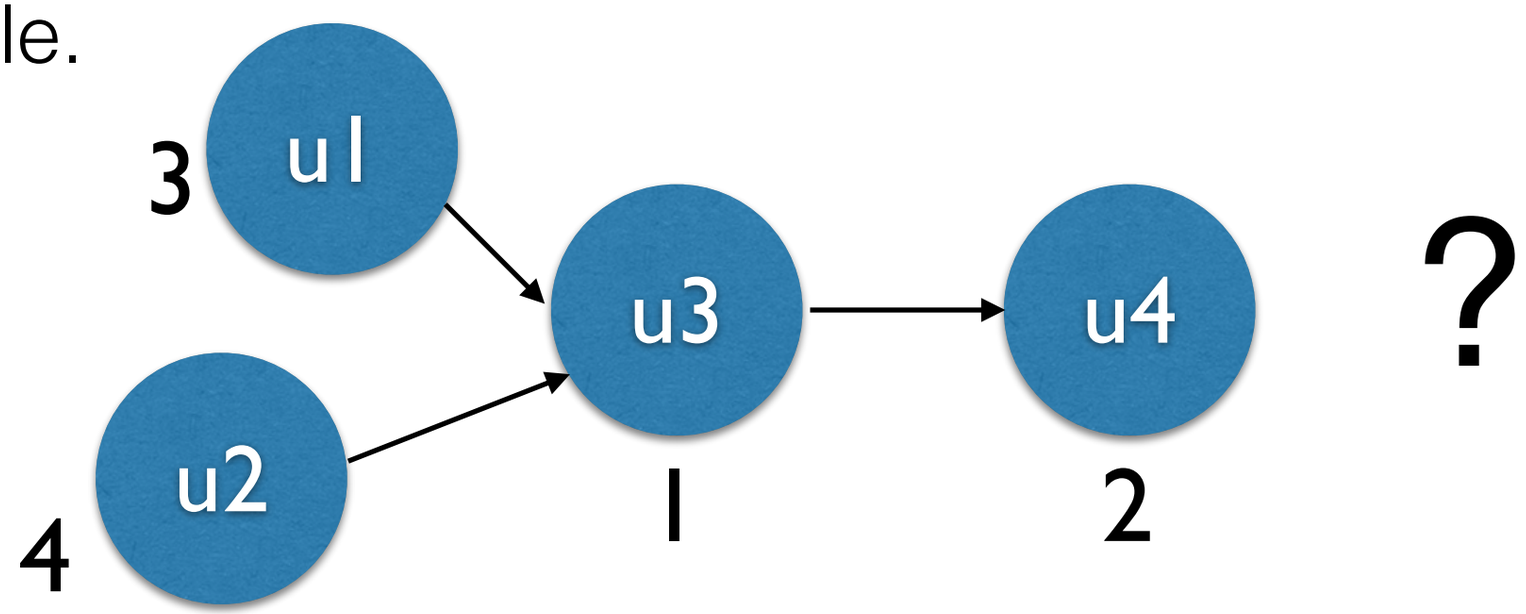

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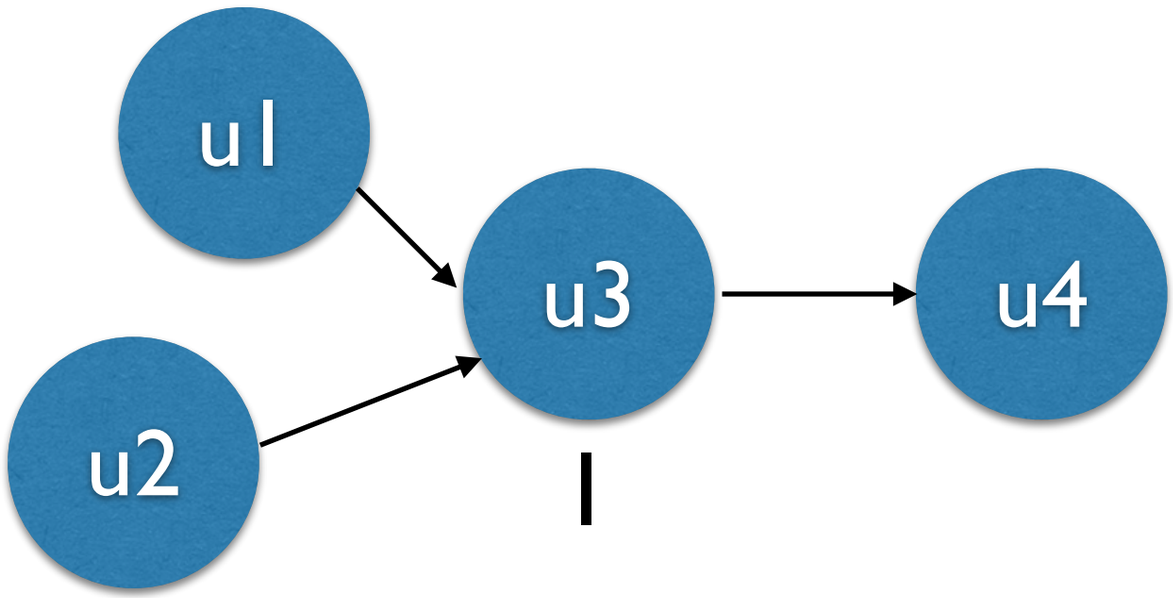

# How to Do Unit Testing

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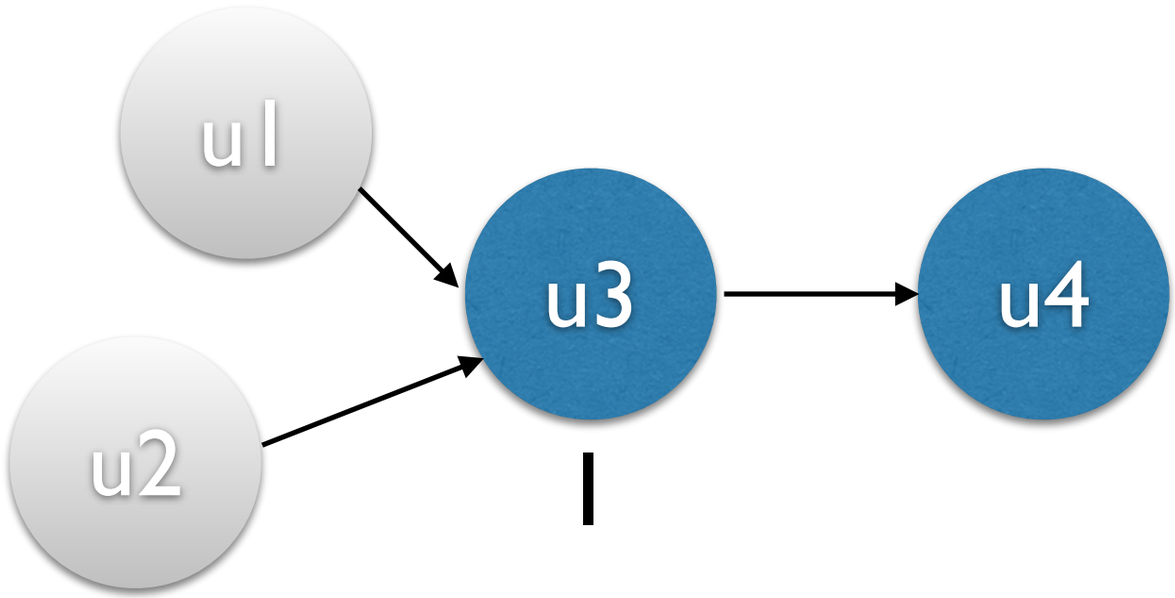
mock classes



# Unit test framework

- xUnit
  - Created by Kent Beck in 1989
    - This is the same guy who invented XP and TDD
    - The first one was sUnit (for smalltalk)
- JUnit
  - The most popular xUnit framework
  - There are about 70 xUnit frameworks for corresponding languages

> Never in the annals of software engineering was so much owed by so many to so few lines of code
>
> --Martin Fowler

# Today's class

- Software Testing
  - Concepts
  - Granularity
  - Unit Testing
- JUnit

# Program to Test

```
public class IMath {

   /**
    * Returns an integer to the square root of x (discarding the fractional parts)
    */
   public int isqrt(int x) {
        int guess = 1;
        while (guess * guess < x) {
             guess++;
        }
        return guess;
    }
}
```

# Conventional Testing

```
/** A class to test the class IMath. */
public class IMathTestNoJUnit {
   /** Runs the tests. */
   public static void main(String[] args) {
       printTestResult(0);
       printTestResult(1);
       printTestResult(2);
       printTestResult(3);
       printTestResult(100);
    }
  private static void printTestResult(int arg) {
       IMath tester=new IMath();
       System.out.print("isqrt(" + arg + ") ==> ");
       System.out.println(tester.isqrt(arg));
    }
}
```

# Conventional Test Output

- What does this say about the code? Is it right?
- What's the problem with this kind of test output?

```
Isqrt(0) ==> 1
Isqrt(1) ==> 1
Isqrt(2) ==> 2
Isqrt(3) ==> 2
Isqrt(100) ==> 10
```

# Solution?

- Automatic verification by testing program
  - Can write such a test program by yourself, or
  - Use testing tool supports, such as JUnit
- JUnit
  - A simple, flexible, easy-to-use, open-source, and practical unit testing framework for Java.
  - Can deal with a large and extensive set of test cases.
  - Refer to www.junit.org.

# Testing with JUnit (1)

```
import org.junit.Test;
import static org.junit.Assert.*;

/** A JUnit test class to test the class IMath. */
public class IMathTestJUnit1 {

    /** A JUnit test method to test isqrt. */
    @Test
    public void testIsqrt() {
        IMath tester = new IMath();
        assertTrue(0 == tester.isqrt(0));
        assertTrue(1 == tester.isqrt(1));
        assertTrue(1 == tester.isqrt(2));
        assertTrue(1 == tester.isqrt(3));
        assertTrue(10 == tester.isqrt(100));
    }

    /** Other JUnit test methods*/
}
```

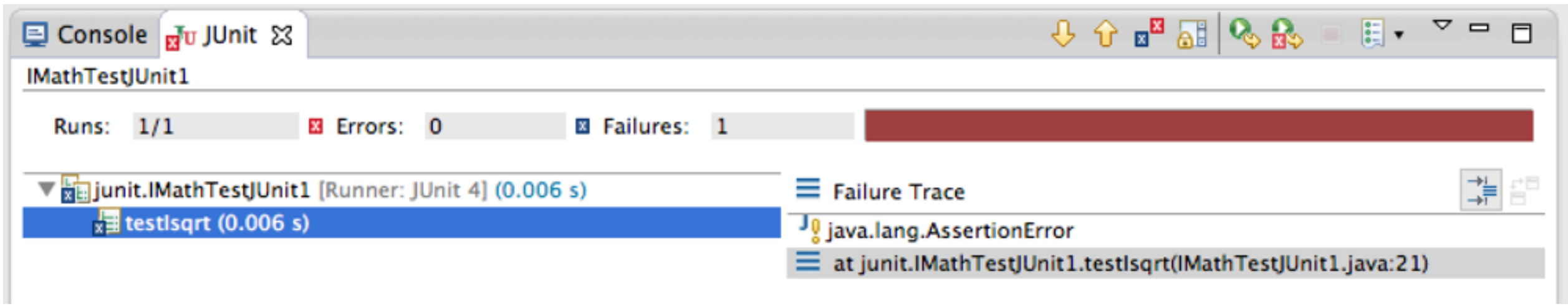
Test driver

Test case

Test oracle

# JUnit Execution (1)

- Right click the JUnit class, and select “Run As” => “JUnit Test”




Not so good, why?

# Testing with JUnit (2)

```
import org.junit.Test;
import static org.junit.Assert.*;
```

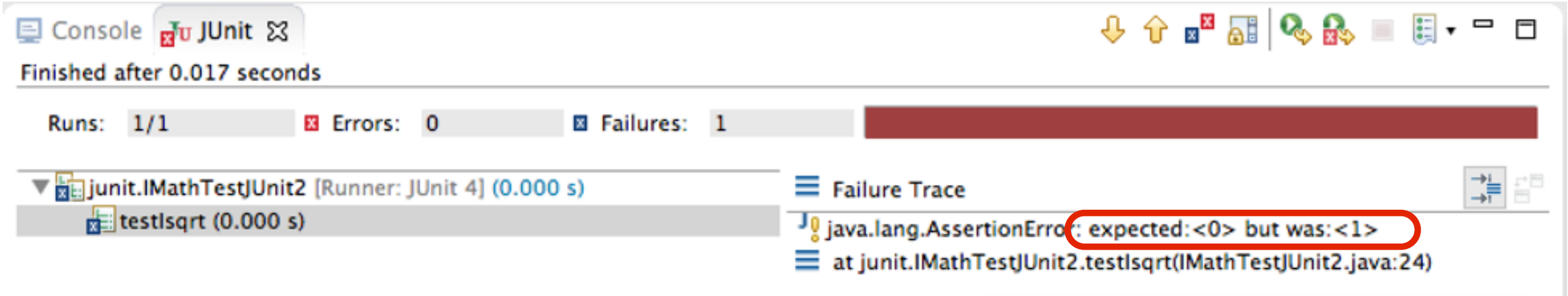
```
/** A JUnit test class to test the class IMath. */
public class IMathTestJUnit2 {

    /** A JUnit test method to test isqrt. */
    @Test
    public void testIsqrt() {
        IMath tester = new IMath();
        assertEquals(0, tester.isqrt(0));
        assertEquals(1, tester.isqrt(1));
        assertEquals(1, tester.isqrt(2));
        assertEquals(1, tester.isqrt(3));
        assertEquals(10, tester.isqrt(100));
    }

    /** Other JUnit test methods*/
}
```

```
assertTrue(0 == tester.isqrt(0));
assertTrue(1 == tester.isqrt(1));
assertTrue(1 == tester.isqrt(2));
assertTrue(1 == tester.isqrt(3));
assertTrue(10 == tester.isqrt(100));
```

# JUnit Execution (2)

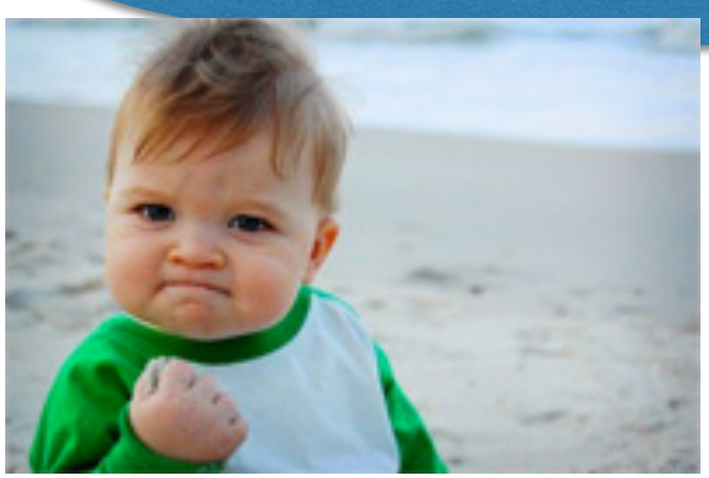



- Why now better error info?
  - assertTrue(0==tester.isqrt(0))
  - assertEquals(0, tester.isqrt(0))

detailed result is abstracted into boolean before passed to JUnit

the detailed result is passed to JUnit

**Can we make it better?**



# Testing with JUnit (3)

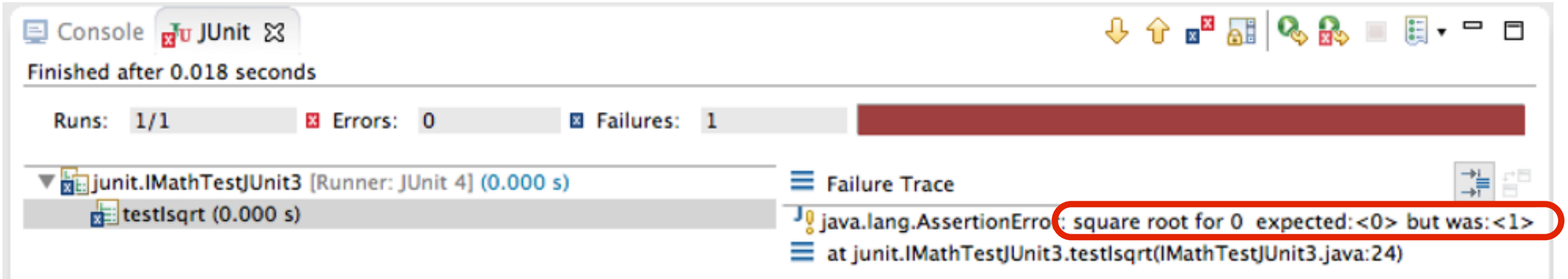
```
import org.junit.Test;
import static org.junit.Assert.*;
```

```
/** A JUnit test class to test the class IMath. */
public class IMathTestJUnit3 {

    /** A JUnit test method to test isqrt. */
    @Test
    public void testIsqrt() {
        IMath tester = new IMath();
        assertEquals("square root for 0 ", 0, tester.isqrt(0));
        assertEquals("square root for 1 ", 1, tester.isqrt(1));
        assertEquals("square root for 2 ", 1, tester.isqrt(2));
        assertEquals("square root for 3 ", 1, tester.isqrt(3));
        assertEquals("square root for 100 ", 10, tester.isqrt(100));
    }

    /** Other JUnit test methods*/
}
```

# JUnit Execution (3)




Still have problems, why?

We only see the error info for the first input...

# Testing with JUnit (4)

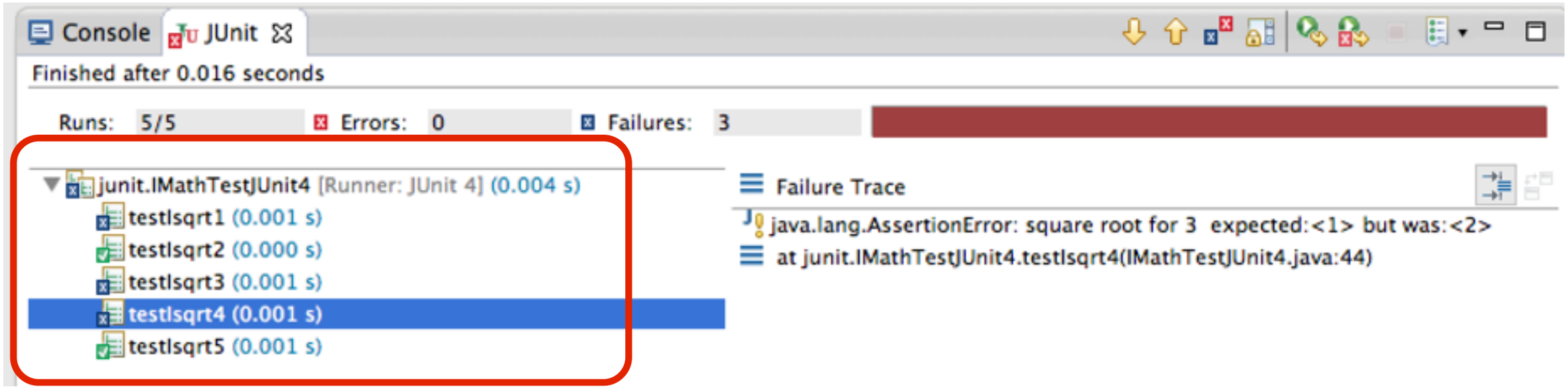
```
public class IMathTestJUnit4 {
    private IMath tester;

    @Before /** Setup method executed before each test */
    public void setup(){
        tester=new IMath();
    }

    @Test /** JUnit test methods to test isqrt. */
    public void testIsqrt1() {
        assertEquals("square root for 0 ", 0, tester.isqrt(0));
    }
    @Test
    public void testIsqrt2() {
        assertEquals("square root for 1 ", 1, tester.isqrt(1));
    }
    @Test
    public void testIsqrt3() {
        assertEquals("square root for 2 ", 1, tester.isqrt(2));
    }
    ...
}
```

Test fixture

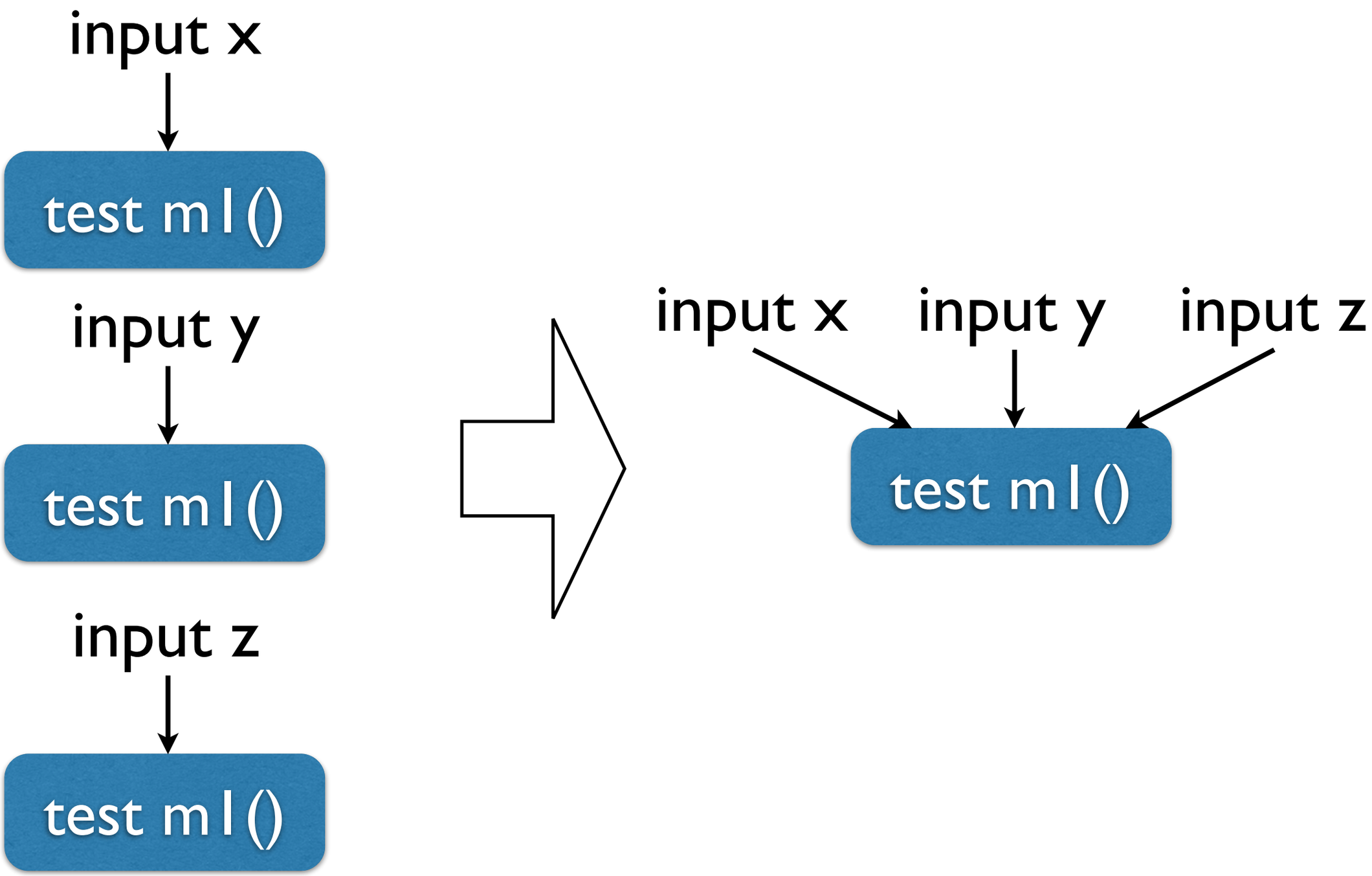
# JUnit Execution (4)




Still may have trouble, why?

We need to write so many similar test methods...

# Parameterized Tests: Illustration



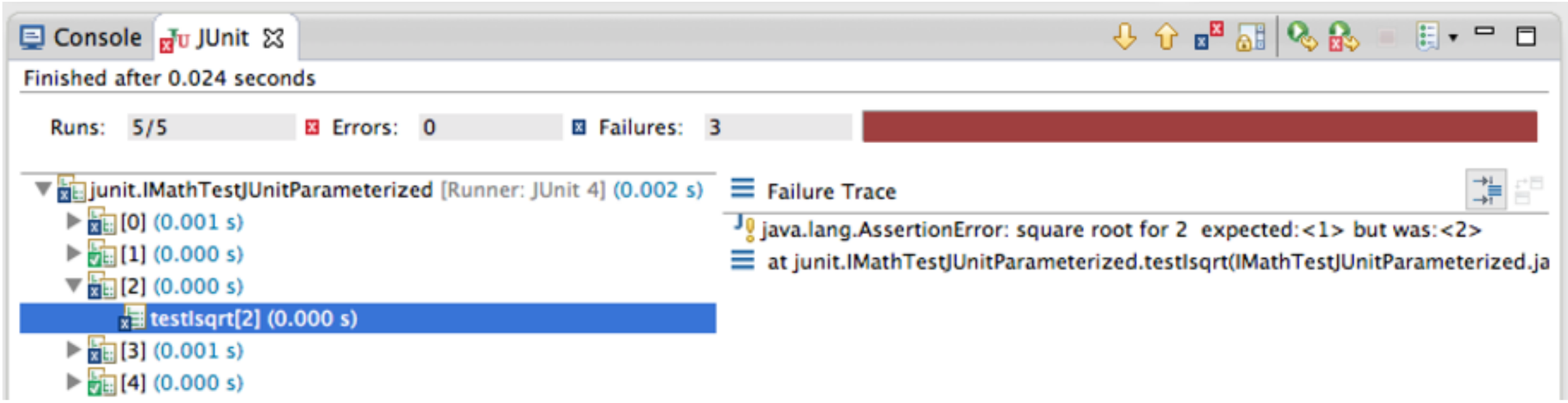
# Testing with JUnit: Parameterized Tests

Indicate this is a parameterized test class

To store input-output pairs

```
@RunWith(Parameterized.class)
public class IMathTestJUnitParameterized {
    private IMath tester;
    private int input;
    private int expectedOutput;
    /** Constructor method to accept each input-output pair*/
    public IMathTestJUnitParameterized(int input, int expectedOutput) {
        this.input = input;
        this.expectedOutput = expectedOutput;
    }
    @Before /** Set up method to create the test fixture */
    public void initialize() {tester = new IMath(); }
    @Parameterized.Parameters /** Store input-output pairs, i.e., the test data */
    public static Collection<Object[]> valuePairs() {
        return Arrays.asList(new Object[][] { { 0, 0 }, { 1, 1 }, { 2, 1 }, { 3, 1 }, { 100, 10 } });
    }
    @Test /** Parameterized JUnit test method*/
    public void testIsqrt() {
        assertEquals("square root for " + input + " ", expectedOutput, tester.isqrt(input));
    }
}
```

# JUnit Execution: Parameterized Tests




Note that not all tests can be abstract into parameterized tests

# A Counter Example

```
public class ArrayList {
        ...
        /** Return the size of current list */
        public int size() {
                ...
        }
        /** Add an element to the list */
        public void add(Object o) {
                ...
        }
        /** Remove an element from the list */
        public void remove(int i) {
                ...
        }
}
```

```
public class ListTestJUnit {
        List list;
        @Before /** Set up method to create the test fixture */
        public void initialize() {
                list = new ArrayList();
        }
        /** JUnit test methods*/
        @Test
        public void test1() {
                list.add(1);
                list.remove(0);
                assertEquals(0, list.size());
        }
        @Test
        public void test2() {
```

These tests cannot be abstract into parameterized tests, because the tests contains different method invocations

# JUnit Test Suite

- Test Suite: a set of tests (or other test suites)
  - Organize tests into a larger test set.
  - Help with automation of testing
- Consider the following case, how can I organize all the tests to make testing easier?
  - I need to test the List data structure
  - I also need to test the Set data structure

```
@RunWith(Suite.class)
@SuiteClasses({ ListTestJUnit.class, SetTestJUnit.class })
public class MyJUnitSuite {

}
```

```
@RunWith(Suite.class)
@SuiteClasses({ MyJUnit.class, ... })
public class MyMainJUnitSuite {

}
```

# JUnit: Annotations

| Annotation | Description |
|---|---|
| @Test | Identify test methods |
| @Test (timeout=100) | Fail if the test takes more than 100ms |
| @Before | Execute before each test method |
| @After | Execute after each test method |
| @BeforeClass | Execute before each test class |
| @AfterClass | Execute after each test class |
| @Ignore | Ignore the test method |

# JUnit: Assertions

| Assertion | Description |
|---|---|
| fail([msg]) | Let the test method fail, optional msg |
| assertTrue([msg], bool) | Check that the boolean condition is true |
| assertFalse([msg], bool) | Check that the boolean condition is false |
| assertEquals([msg], expected, actual) | Check that the two values are equal |
| assertNull([msg], obj) | Check that the object is null |
| assertNotNull([msg], obj) | Check that the object is not null |
| assertSame([msg], expected, actual) | Check that both variables refer to the same object |
| assertNotSame([msg], expected, actual) | Check that variables refer to different objects |

# More on JUnit?

- Hompage:
  - www.junit.org
- Tutorials
  - http://www.vogella.com/tutorials/JUnit/article.html
  - http://www.tutorialspoint.com/junit/
  - https://courses.cs.washington.edu/courses/cse143/11wi/eclipse-tutorial/junit.shtml

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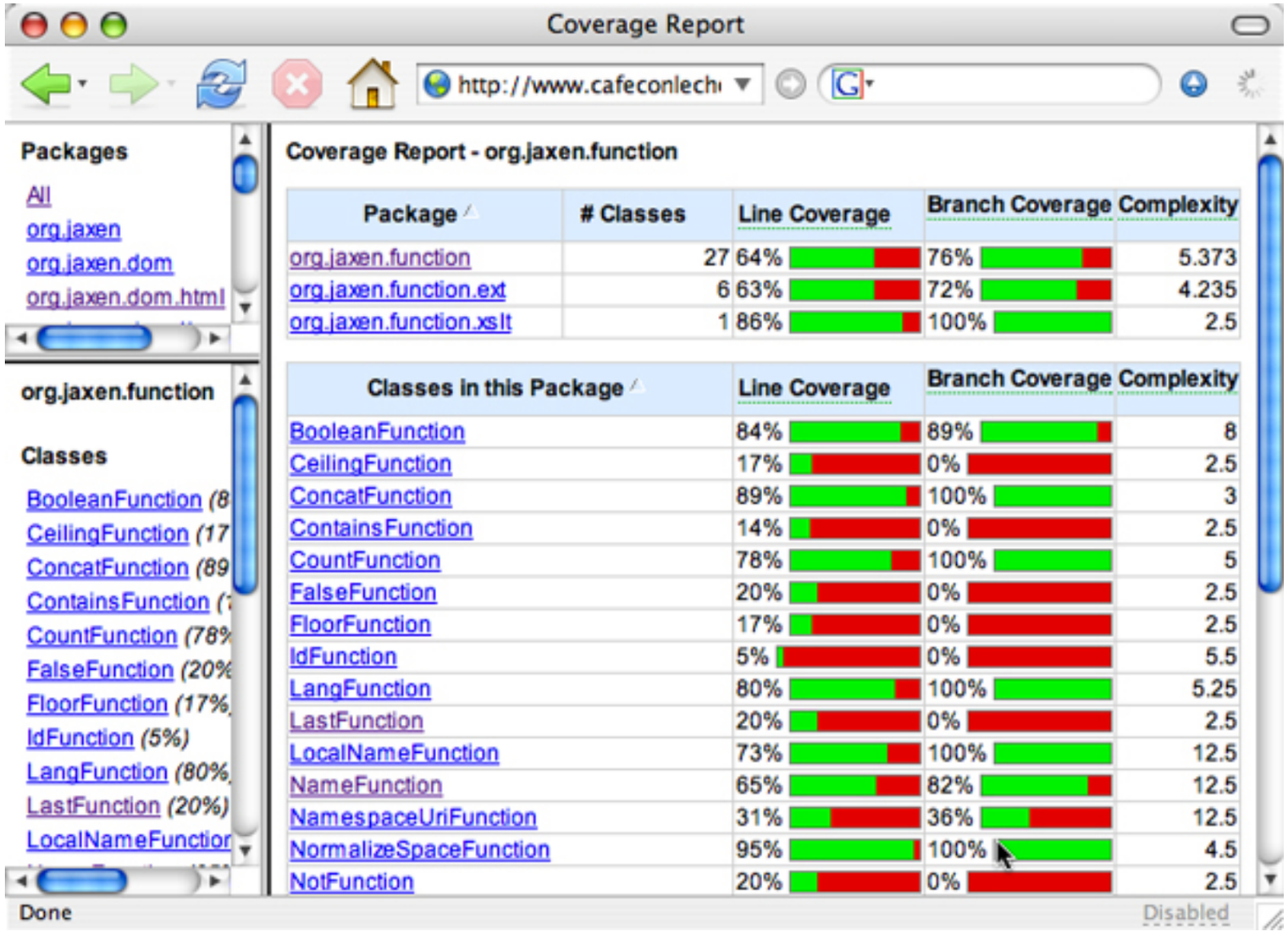
# Next class

- Test Coverage



# Thanks!