Unit Testing with JUnit

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Many Levels of Software Testing

Software testing is critical!

❑ Testing of specification

❑ Unit Testing

❑ Integration Testing

❑ Acceptance Testing

❑ Usability Testing

❑ ...

Why Test?

1. Saves time!

- *Testing is faster than fixing "bugs".*

2. Testing finds more errors than debugging.

3. Prevent re-introduction of old faults (regression errors).

Programmers often recreate an error (that was already fixed) when they modify code.

4. Validate software: does it match the specification?

Psychological Advantages

□ *Keeps you **focused** on current tasks.*

   ■ ***Test-driven development (TDD):***

   *write the **tests first** ... what the code should do.*

   Then write code that passes the tests

□ *Increase **satisfaction**.*

□ ***Confidence** to make changes.*

Testing is part of development

Agile Development Practices

- *Test early.*
- *Test continually!*

Design

Test

Code

Test

Code

Test

Design
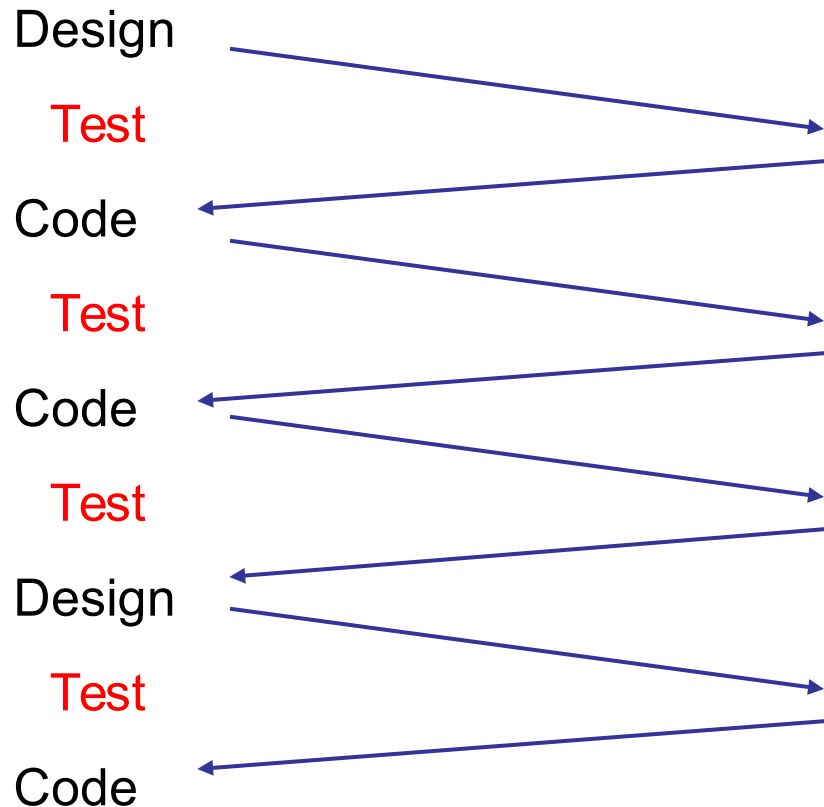
Test

Code

When To Test?

*- Test **while** you are writing the source code*

*- **Retest** whenever you modify the source code*

The Cost of Fixing "faults"

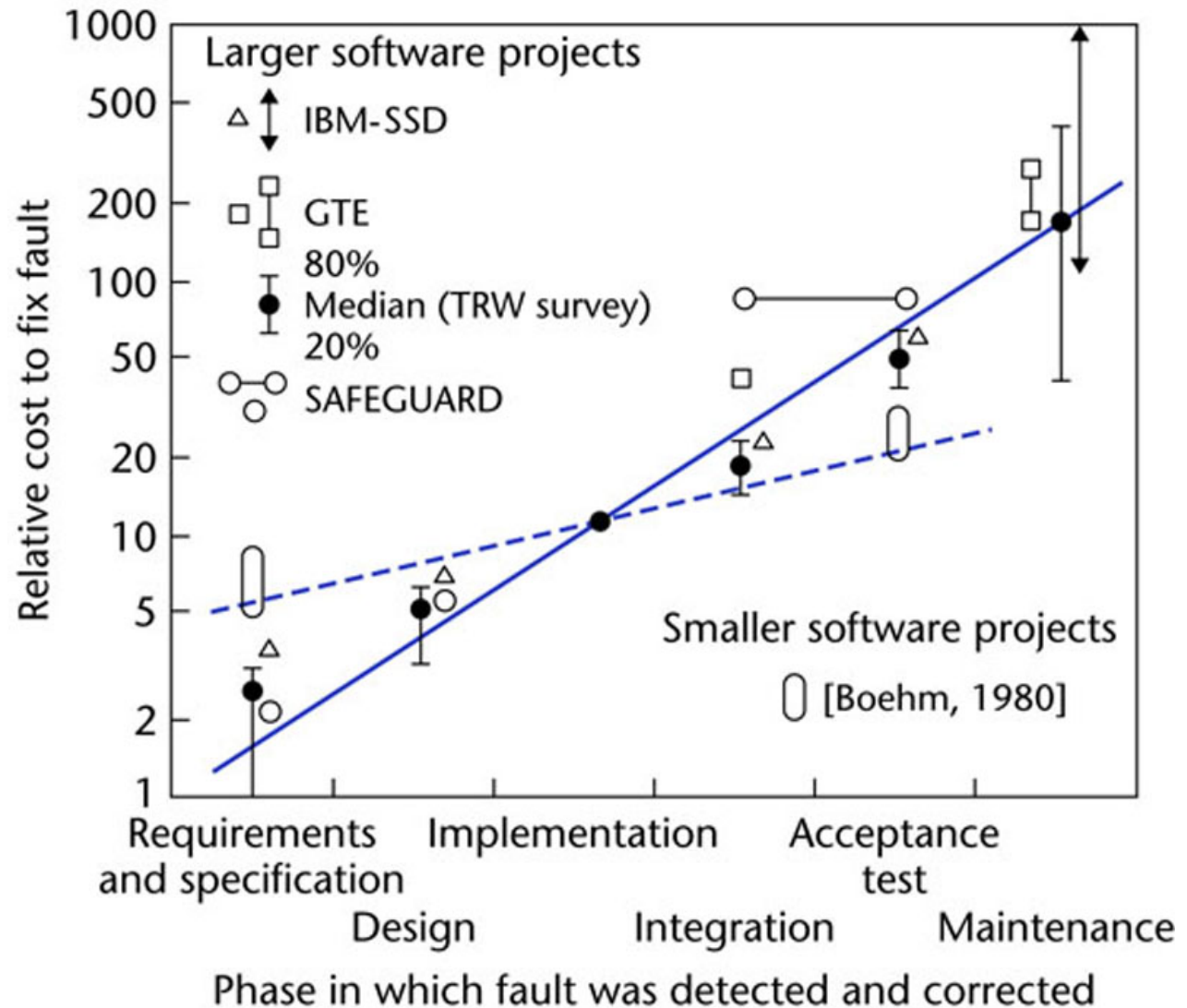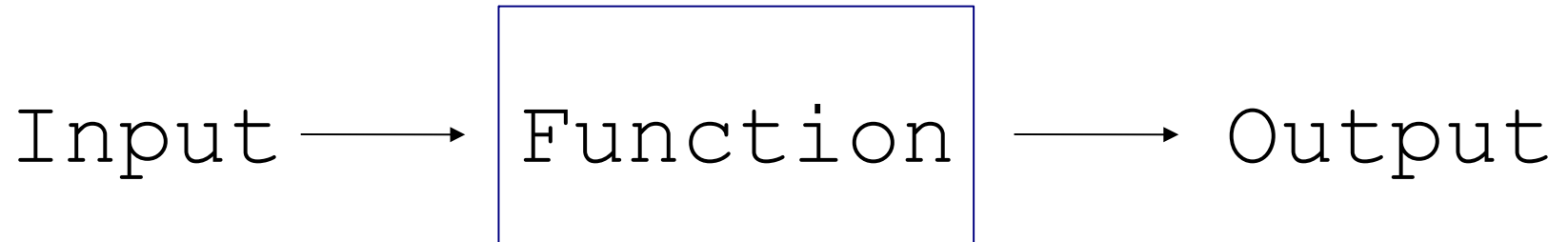Discover & fix a defect early is much cheaper (100X) than to fix it after code is integrated.

Figure 1.5

What to Test?

In unit testing, we test functions or methods in classes.

Input $\longrightarrow$ Function $\longrightarrow$ Output

How to Test?

We can't test <u>all</u> possible input / output.

- Divide input into categories, sets, or classes.

- Or, discover "rules" that govern different sets of input.

- Test a few samples from each set, category, or class.
  - Test boundary values.
  - Test "typical" values.
  - Test "extreme" values.
  - Test impossible values.
  - Try to make things fail.

Example

▫ Stack implements common stack data structure.

▫ Has a fixed capacity and methods shown below.

▫ Throws StackException if you do something stupid.

Stack<T>
+ Stack(capacity)
+ capacity( ): int
+ size( ): int
+ isEmpty( ): boolean
+ isFull( ): boolean
+ push(T): void
+ pop( ): T
+ peek( ): T

What to Test?

Border Case:

Stack with capacity 1

1. no elements in stack
   capacity() is 1
   isEmpty() -> true
   isFull() -> false
   size() -> 0
   peek() returns ???
2. push one element on stack
   isEmpty() -> false
   isFull() -> true
   size() -> 1
3. can peek()?
   push one element
   peek() returns element
   stack does not change
4. push element, peek it, then pop
   pop -> returns same object
   test all methods
   idea: a helper method for all
   tests of an empty stack or full stac

Test for Methods

push( )

Hard to test by itself!

Need to use peek( ), pop( ), or size( )

to verify something was pushed.

1. Stack of capacity 2.

push(x)

verify size=1 peek()==x, not full, not empty
push(y)
verify again

pop(y)

push(x) - should have 2 items both == x

Test by writing Java code

```java
Stack stack = new Stack(1);
// test empty stack behavior
if ( ! stack.isEmpty() )
     out.println("error: should be empty");
if ( stack.isFull() )
    out.println("error: should not be full");
if ( stack.capacity() != 1 )
    out.println("error: capacity incorrect" );
if ( stack.size() != 0 )
    out.println("error: size should be 0" );
if ( stack.peek() != null ) // what should it do?
    out.println("error: peek() should be null");
```

More Java code...

```java
// Test a Stack with 1 element
Stack stack = new Stack(1);
Object arg = "push-me";
if ( ! stack.push(arg) )
    out.println("error: should be able to push");
if ( stack.isEmpty() )
    out.println("error: should NOT be empty");
if ( ! stack.isFull() )
    out.println("error: should be full");

                And so on...
```

Too Slow, too boring

A lot of redundant code... even for simple tests.

Violates 2 Key Development Practices

1. *don't repeat yourself*

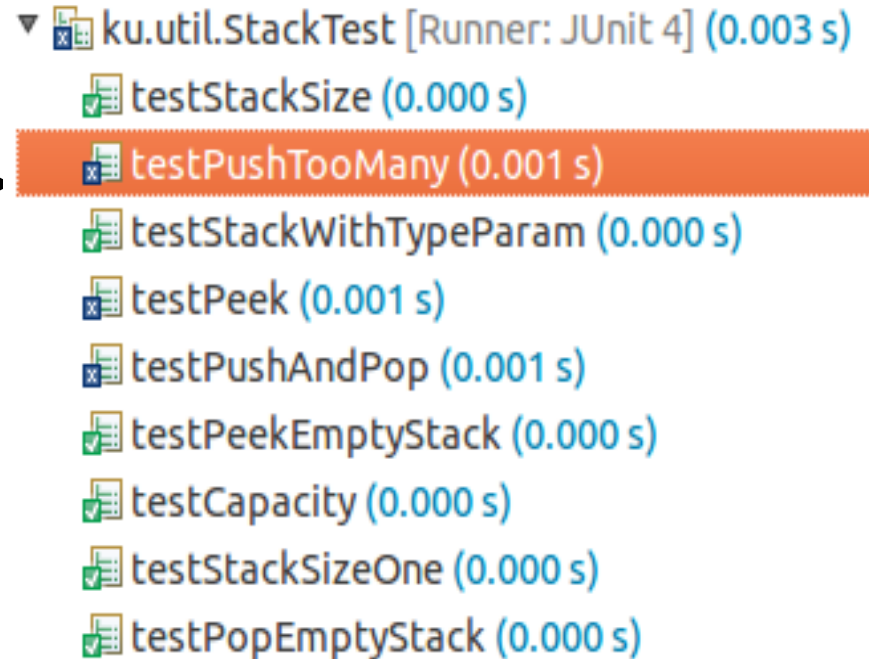2. *automate repetitive tasks*

Insight

The test code is mostly redundant "boiler plate" code.

□ *Automate the redundant code.*

□ *Create an automatic tool to perform tests and manage output.*

JUnit does it

```java
public class StackTest {
    @Test
    public void testStackSize( ) {
        ...
    }
    @Test
    public void testPeek() {
        ...
    }
    @Test
    public void testPushAndPop() {
        ...
    }
}
```

Runs: 9/9   ⊠ Errors: 0   ⊠ Failures: 3

▼ 📇 ku.util.StackTest [Runner: JUnit 4] (0.003 s)
  📑 testStackSize (0.000 s)
  📑 testPushTooMany (0.001 s)
  📑 testStackWithTypeParam (0.000 s)
  📑 testPeek (0.001 s)
  📑 testPushAndPop (0.001 s)
  📑 testPeekEmptyStack (0.000 s)
  📑 testCapacity (0.000 s)
  📑 testStackSizeOne (0.000 s)
  📑 testPopEmptyStack (0.000 s)

Using JUnit for Testing

- makes it *easy* to write test cases

- automatically runs your tests

- reports failures with context information

JUnit can also...

- test for Exceptions

- limit the execution time

- use parameters to vary the test data

Example: test the Math class

```java
import org.junit.*;
public MathTest {
    @Test                              // @Test identifies a test method
    public void testMax( ) {           // any public void method name
        Assert.assertEquals( 7,  Math.max(3, 7) );
        Assert.assertEquals( 14, Math.max(14, -15) );
    }
```

JUnit test methods are in the `Assert` class.

assertEquals(expected, actual)

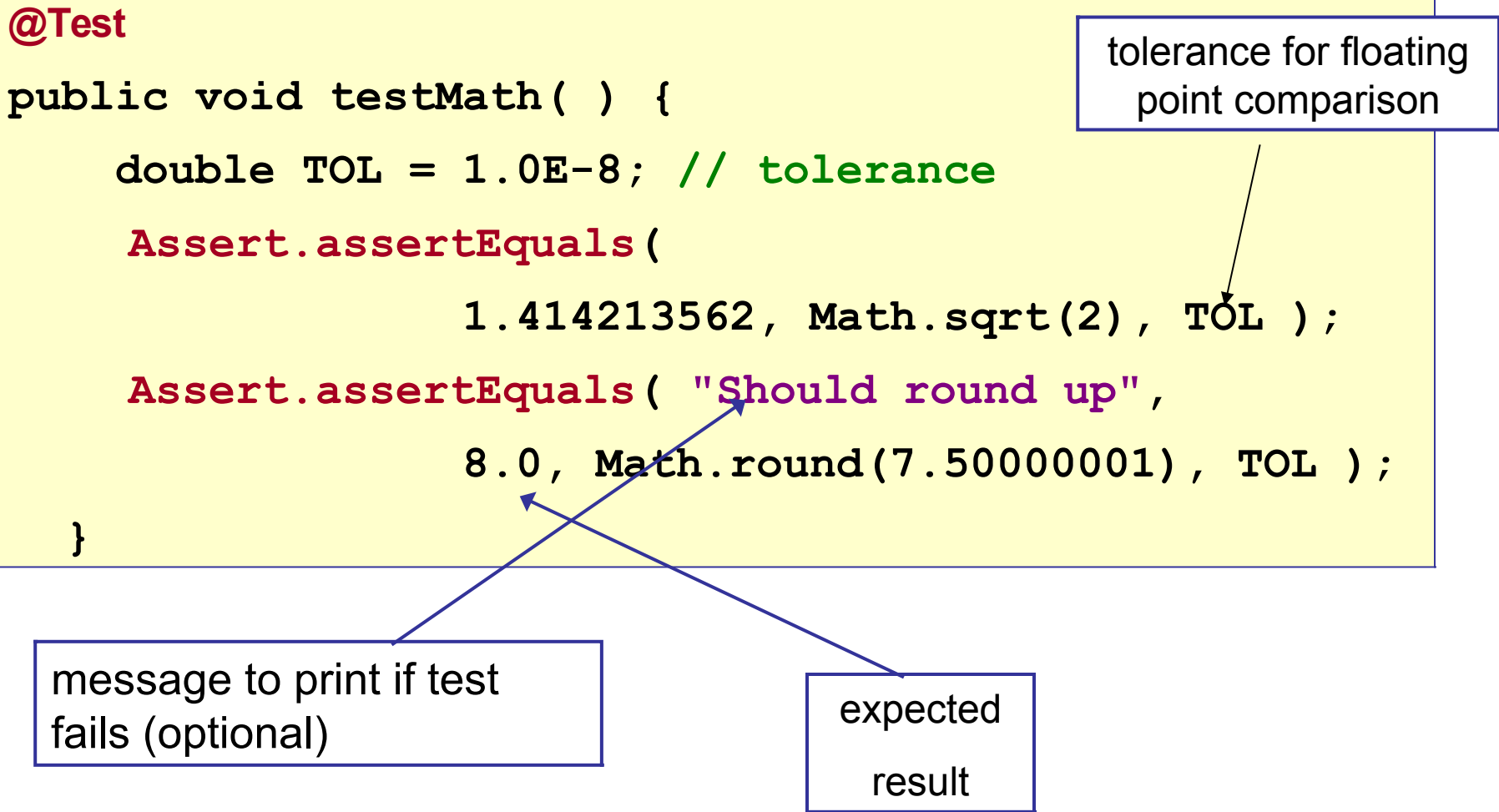assertTrue(expression)

assertSame(obja, objb)

expected
result

actual
result

Tests Using Floating Point Values

```java
@Test
public void testMath( ) {

    double TOL = 1.0E-8; // tolerance

    Assert.assertEquals(
                1.414213562, Math.sqrt(2), TOL );

    Assert.assertEquals( "Should round up",
                8.0, Math.round(7.50000001), TOL );

  }
```

tolerance for floating point comparison

message to print if test fails (optional)

expected result

Unit Testing Vocabulary

Test Suite - collection of unit tests. A test class.

Test Case - test method (`@Test`).

Test Fixture - attributes or local var that is being tested.

Test Runner - code that runs the tests, collects results.

Example: test the Stack constructor

```java
import org.junit.*;
import static org.junit.Assert.* ; // import names of all static methods
public StackTest  {
    @Test
    public void testStackConstructor( ) {
        Stack stack = new Stack(5);
        assertEquals("Stack should be empty", 0, stack.size() );
        assertEquals("Capacity should be 5", 5, stack.capacity() );
        assertFalse(  stack.isFull() );
        assertTrue( stack.isEmpty() );
    }
```

What can you Assert ?

JUnit Assert class provides many `assert` methods

```
Assert.assertTrue( 2*2 == 4 );

Assert.assertFalse( "Stupid Slogan", 1+1 == 3 );

Assert.assertEquals( new Double(2), new Double(2));

Assert.assertNotEquals( 1, 2 );

Assert.assertSame( "Yes", "Yes" ); // same object

Assert.assertNotSame("Yes", new String("Yes") );

double[] a = { 1, 2, 3 };

double[] b = Arrays.copyOf( a, 3 );

Assert.assertArrayEquals( a, b );

Assert.assertThat( patternMatcher, actualValue );
```

Use import static Assert.*

Tests almost always use static Assert methods:

```
@Test
public void testInsert( ) {
    Assert.assertTrue( 1+1 == 2 );
```

Use "import static" to reduce typing:

```
import static org.junit.Assert.*;
public class ArithmeticTest {
    @Test
    public void testInsert( ) {
        assertTrue( 1+1 == 2 );
```

Test Methods are *Overloaded*

Assert.assertEquals is overloaded (many param. types)

```
assertEquals( expected, actual );
assertEquals( "Error message", expected, actual );
```

can be any primitive data type or String or Object

```
// assertSame(a,b)  tests  a == b

assertSame( expected, actual );
```

AssertEquals for Floating Point

assertEquals for `float` and `double` require a **tolerance**

as allowance for limit on floating point accuracy.

```java
final static double TOL = 1.0E-8; // be careful
@Test
public void testPythagorus() {
    assertEquals( 5.0, Math.hypot(3.0,4.0), TOL );
}
@Test
public void testSquareRoot( ) {
    assertEquals( 1.41421356, Math.sqrt(2), TOL );
```

Expected Result

Actual Result

Tolerance for comparison

Running JUnit 4

1. Use Eclipse, Netbeans, or BlueJ (easiest)

   Eclipse, Netbeans, and BlueJ include JUnit.

2. Run JUnit from command line.

```
CLASSPATH=c:/lib/junit4.1/junit-4.1.jar;.
```

```
java org.junit.runner.JUnitCore PurseTest
```

3. Use Ant (automatic build and test tool)

JUnit 4 uses Annotations

❑ JUnit 4 uses annotations to identify methods

@Test   a test method

@Before a method to run before each test

@After   a method to run after each test

@BeforeClass   method to run one time before testing starts

Before and After methods

`@Before` indicates a method to run before each test

`@After` indicates a method to run after each test

```
public PurseTest  {
    private Purse purse;
    @Before
    public void runBeforeTest( ) { purse = new Purse( 10 ); }
    @After
    public void runAfterTest( ) { purse = null; }

    @Test  public void testPurse( ) {
        Assert.assertEquals( 0, purse.count() );
        Assert.assertEquals( 10, purse.capacity() );
    }
```
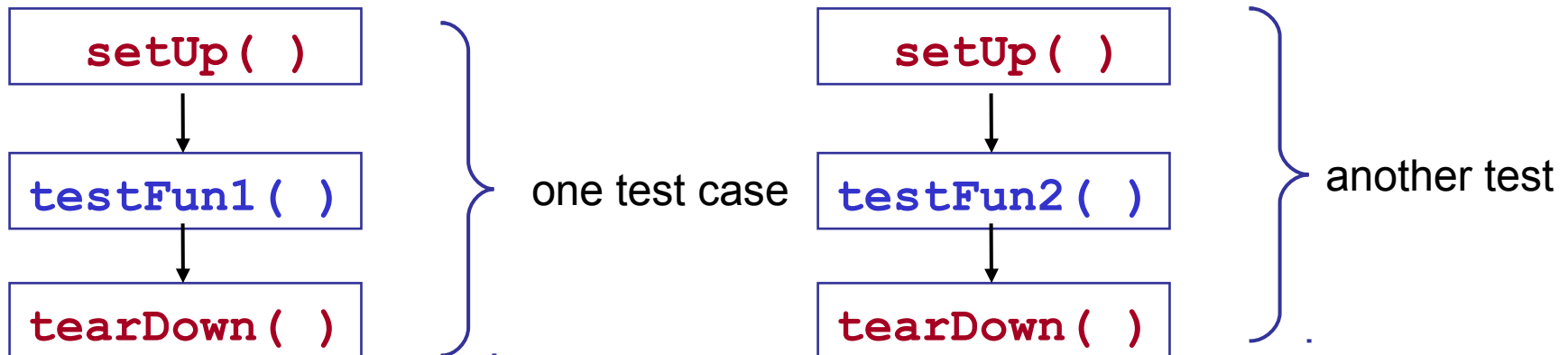
@Before (setUp) and @After (tearDown)

- **@Before** - method that is run before every test case.

    setUp( ) is the traditional name.

- **@After** - method that is run after every test case.

    tearDown( ) is the traditional name.

setUp( )		setUp( )
↓		↓
testFun1( )	one test case	testFun2( )	another test
↓		↓
tearDown( )		tearDown( )

Using @Before and @After

You want a *clean test environment* for each test.

This is called a "test fixture". Use @Before to initialize a test fixture. Use @After to clean up.

```java
private File file; // fixture for tests writing a local file

@Before
public void setUp( ) {
    file = new File( "/tmp/tempfile" );
}
@After
public void tearDown( ) {
    if ( file.exists() ) file.delete();
}
```
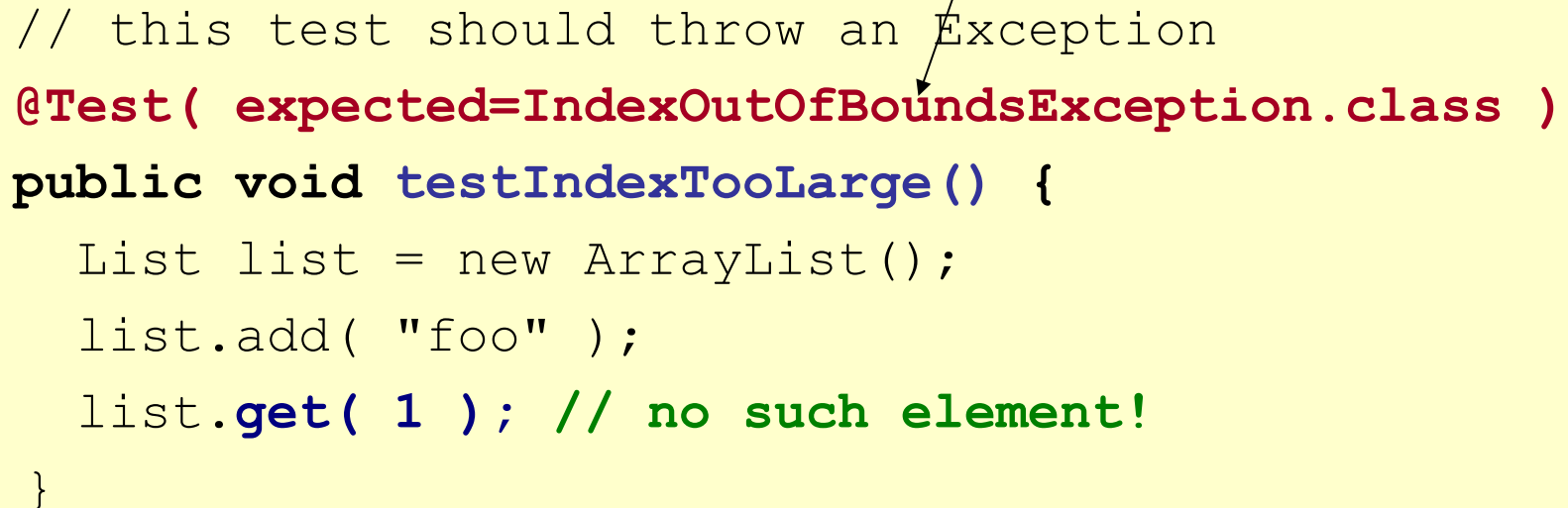
Testing for an Exception

you can indicate that a test *should* throw an exception.

List should throw IndexOutOfBoundsException if you go beyond the end of the list.

```java
// this test should throw an Exception
@Test( expected=IndexOutOfBoundsException.class )
public void testIndexTooLarge() {
   List list = new ArrayList();
   list.add( "foo" );
   list.get( 1 ); // no such element!
}
```

Stack Example

- If you pop an empty stack it throws StackException

```
@Test( expected=StackException.class )
public void testPopEmptyStack() {
    Stack stack = new Stack(3);
    Object x = stack.pop( );
}
```

Limit the Execution Time

- specify a time limit (milliseconds) for a test

- if time limit is exceeded, the test fails

```java
// this test must finish in less than 500 millisec
@Test( timeout=500 )
public void testWithdraw() {
   // test fixture already created using @Before
   // method, and inserted coins, too
   double balance = purse.getBalance();
   assertNotNull( purse.withdraw( balance ) );
}
```

fail!

- Signal that a test has failed

```java
@Test
public void testWithdrawStrategy() {
    //TODO write this test
    fail( "Test not implemented yet" );
}
```

What to Test?

❑ Test BEHAVIOR not just methods.

❑ One test may involve several methods.

❑ May have several tests for the <u>same</u> method, each testing different *behavior* or *test cases*.

Designing Tests

"borderline" cases:

- a Purse with capacity 0 or 1

- if capacity is 2, can you insert 1, 2, or 3 coins?

- can you withdraw 0? can you withdraw 1?

- can you withdraw *exactly* amount in the purse?

impossible cases:

- can you withdraw negative amount? -1?

- can you withdraw balance+1 ?

- can you withdraw Double.INFINITY ?

Designing Tests

typical cases

- Purse capacity 10. Insert many different coins.

- When you withdraw, do coins match what you inserted?

extreme cases

Purse with capacity 9.999,999.

Insert 9,999,999 of 1 Trillion Zimbabwe dollars.

Is balance correct? Can you withdraw everything?

Test *Behavior,* not *methods*

Test **behavior** ... not just methods

Stack:

- can I push until stack is full, then pop each one?

- do peek() and pop() return <u>same</u> object as push-ed?

Questions about JUnit 4

- Why use:

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

- How do you test if `Math.sin(Math.PI/2)` is 1 ???

- How do you test if a String named `str` is null ???

(2 ways)

Fluent JUnit

```
Assume.that( actual, matcher )

Assume.assumeTrue( stack.isEmpty() )
```

- skip a test unless some conditions are true

`Theories` - define more complex test conditions.

See:

https://dzone.com/articles/parameterized-tests-and-theories

Parameterized Tests

We want to test the `isPrime(long)` method.

```java
public class MathUtil {
    /**
     * Test if a number is prime.
     * @param n the numbe to test
     */
    public static boolean isPrime(long n) {
        //TODO complete the code
        return false;
    }
}
```

Redundant Tests

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

public class MathUtilTest {
    @Test
    public void testPrimeNumbers( ) {
        long[] primes = [2,3,5,29,163,839,...];
        for(long p: primes)
            assertTrue( MathUtil.isPrime(p) );
    }
    @Test
    public void testNonprimeNumbers() {
        long[] nonprime = [4,99,437,979,3827,...];
        for(long n: nonprime)
            assertFalse( MathUtil.isPrime(n) );
    }
}
```

Parameters for Unit Tests

JUnit **Parameterized Tests**

- set parameters as attributes or method arguments

- you inject (set) values directly to attributes.

- See JUnit docs for "Parameterized Tests"

Maybe Better (and simpler):

JUnitParams: add-on with easier syntax for parameters:

  https://github.com/Pragmatists/JUnitParams

  Tutorial: https://www.baeldung.com/junit-params

Using Parameter class

```java
@RunWith(Parameterized.class)
public class TestMathUtil {
    private long input;
    private boolean expected; // expected result

    public MathUtilTest(long n, boolean result) {
        this.input = n;
        this.expected = result;
     }
    @Test
    public void testPrimeNumber( ) {
      assertEquals(expected,MathUtil.isPrime(input));
    }
}

// ...continued
```

Method defines parameter values

```java
@Parameterized.Parameters
public static Collection makeTestValues() {
    // collection of (input,result) pairs
    return Arrays.asList( new Object[][] {
        {2, true},
        {3, true},
        {4, false},
        {19, true},
        {21, false},
        ...
    });
}
```

Use @Parameterized.Parameters annotation.
Each item in the Collection is injected into the test constructor
(MathUtilTest(long,boolean)) before running one test.

More Parameterized Tests

Previous example is <u>too simple</u> to show usefulness.

You can *inject values* directly into attributes (fields) or as method parameters.

JUnitParams

JUnitParams is an open-source add-on Test Runner for JUnit.

- Less coding to define parameters

- Many ways to inject values

- Easier to read - data is closer to test method

- https://github.com/Pragmatists/JUnitParams

Tutorial: https://www.baeldung.com/junit-params

Using JUnit in BlueJ

1. From "Tools" menu select "Preferences..."

2. Select "Miscellaneous" tab.

3. Select "Show unit testing tools".
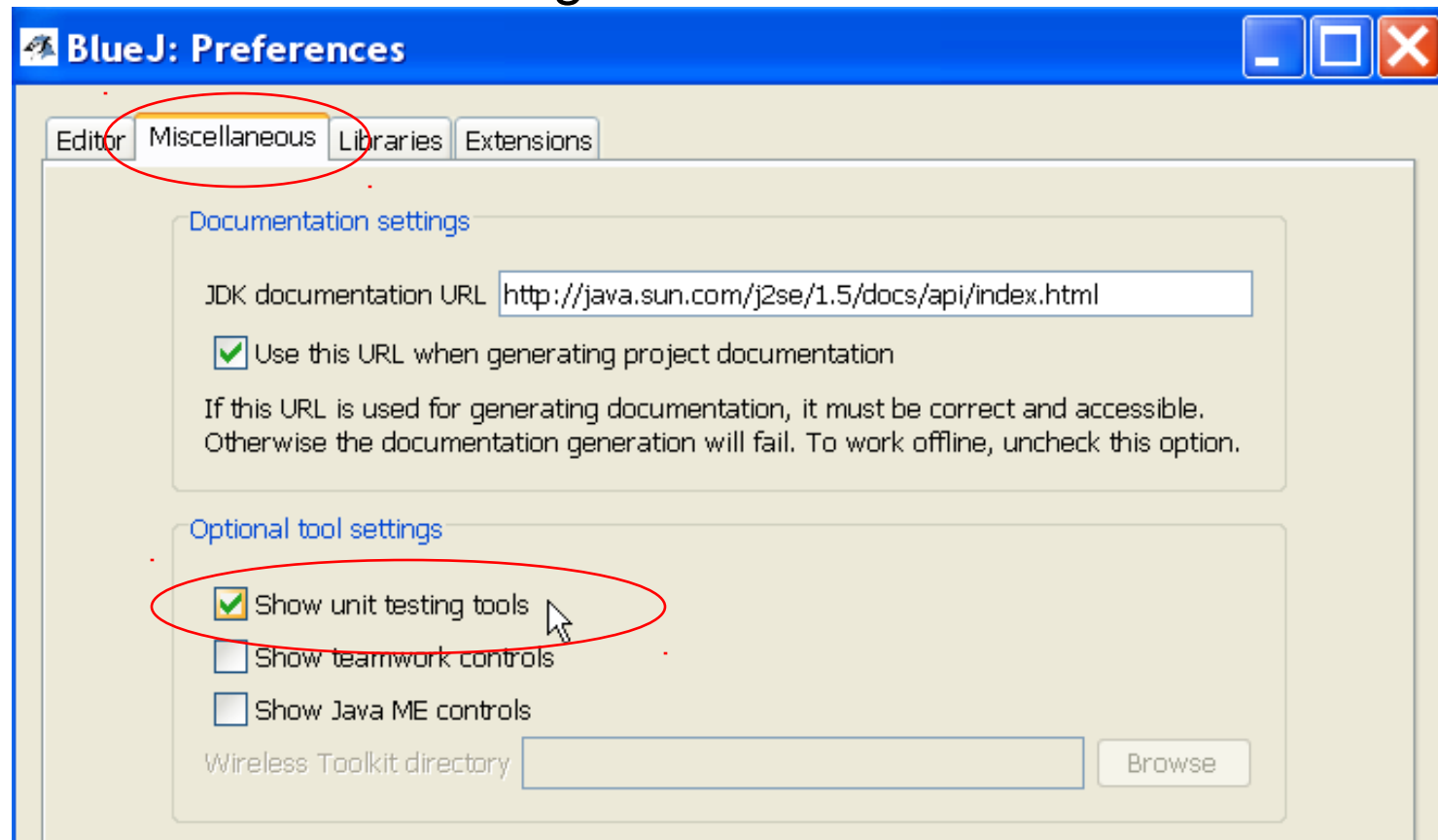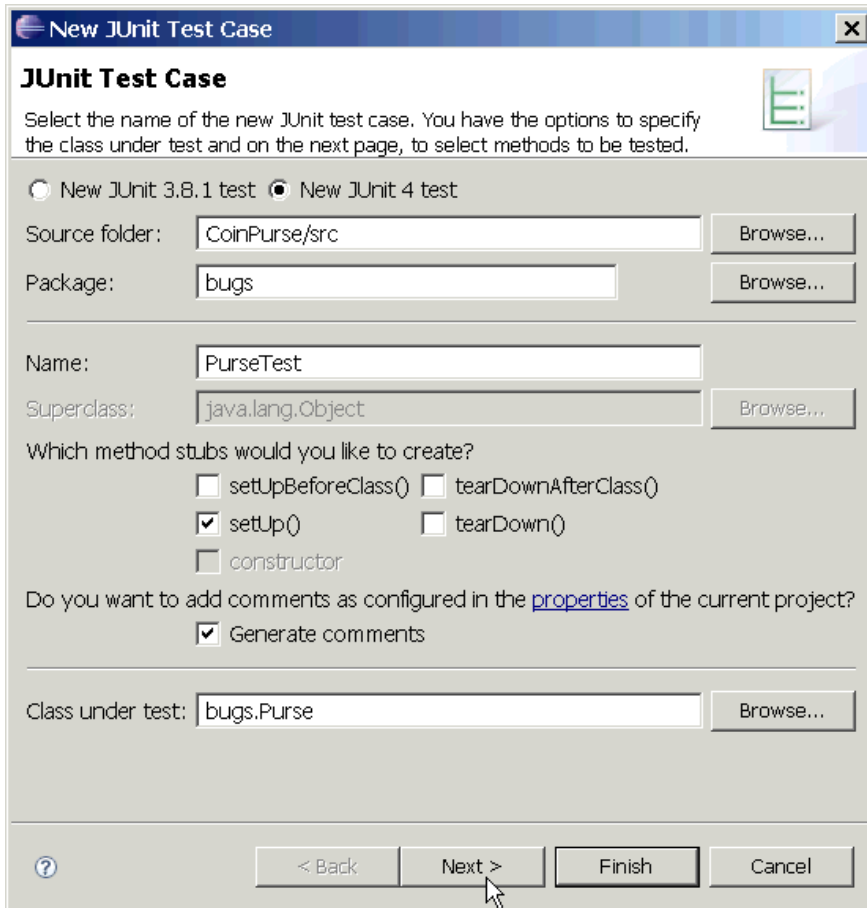
Using JUnit in Eclipse

- Eclipse includes JUnit 3.8 and 4.x libraries
  - you should use Junit 4 on your projects
- eclipse will manage running of tests.
  - *but,* you can write your own test running in the main method
- Select a source file to test and then...
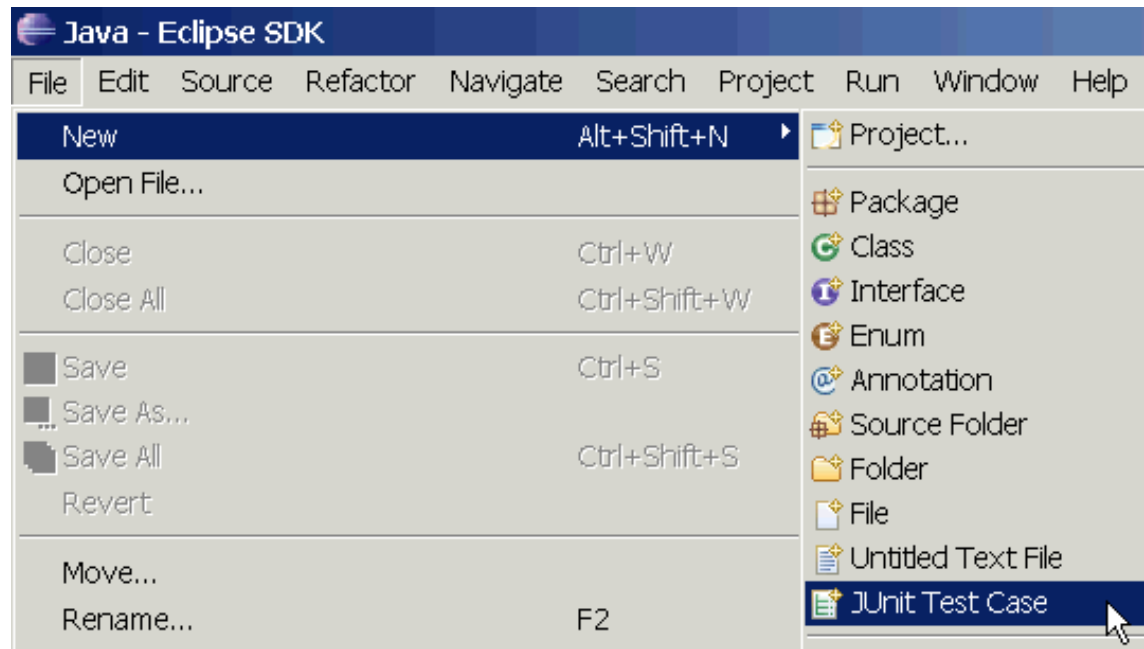
Using JUnit in Eclipse (2)

□ Select test options and methods to test.
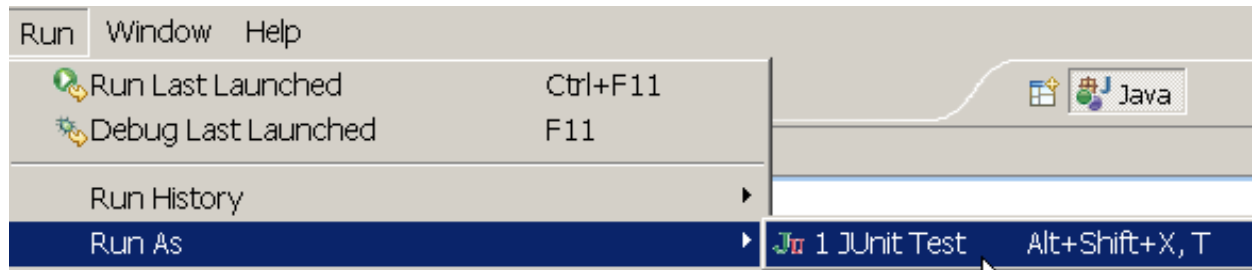
Using JUnit in Eclipse (3)

```java
/** Test of the Purse class
 * @author James Brucker
 */
public class PurseTest {
  private Purse purse;
  private static final int CAPACITY = 10;
  /** create a new purse before each test */
  @Before
  public void setUp() throws Exception {
    purse = new Purse( CAPACITY );
  }
  @Test
  public void testCapacity() {
    assertEquals("capacity wrong",
        CAPACITY, purse.capacity());
  }
```

Write your test cases. Eclipse can't help much with this.

Run JUnit in Eclipse (4)

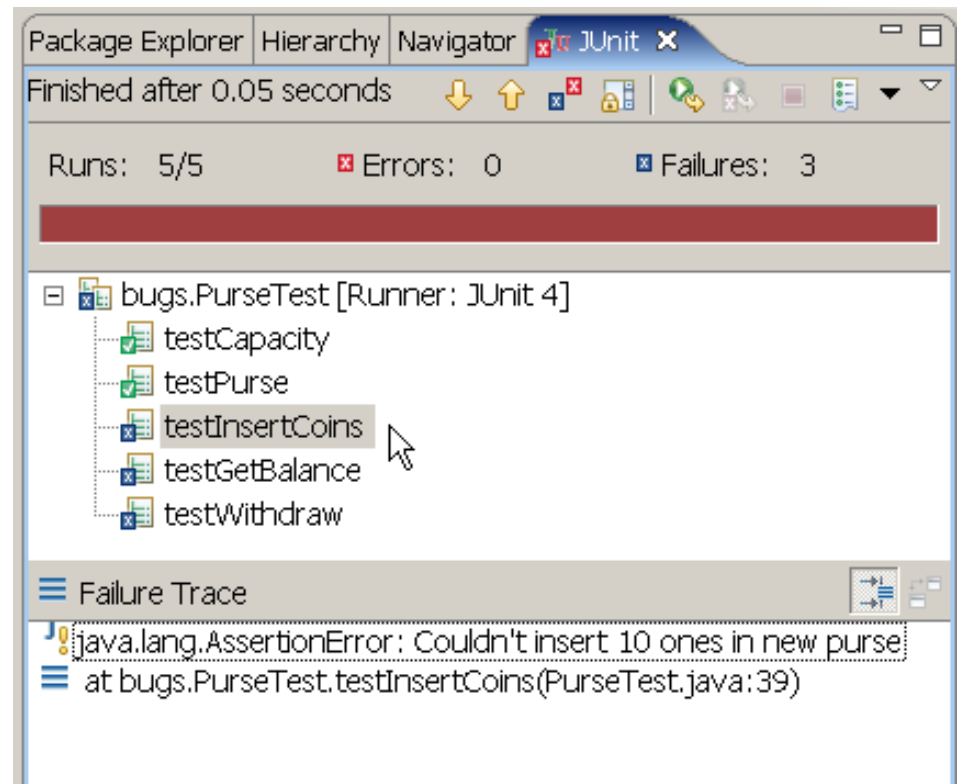| Run	Window	Help
Run Last Launched	Ctrl+F11	
Debug Last Launched	F11	
Run History	▶	
Run As	▶	Jᴜ 1 JUnit Test Alt+Shift+X, T

Java

Select the JUnit test case file and choose

Run => Run As => JUnit Test

Results appear in a new JUnit tab.

Click on any result for details and to go to the source code.

Package Explorer | Hierarchy | Navigator | JUnit ✕

Finished after 0.05 seconds

Runs: 5/5   Errors: 0   Failures: 3

☐ bugs.PurseTest [Runner: JUnit 4]
    testCapacity
    testPurse
    testInsertCoins
    testGetBalance
    testWithdraw

≡ Failure Trace

java.lang.AssertionError: Couldn't insert 10 ones in new purse
≡ at bugs.PurseTest.testInsertCoins(PurseTest.java:39)

References

JUnit Home

`http://www.junit.org`

JUnit Software & documentation

`http://www.sf.net/projects/junit`

- Eclipse & Netbeans include Junit, but you still need to install JUnit to get documentation

Quick Starts

JUnit 4 in 60 Seconds

http://www.cavdar.net/2008/07/21/junit-4-in-60-seconds/

JUnit Tutorial by Lars Vogel

includes how to use JUnit in Eclipse.
http://www.vogella.de/articles/JUnit/article.html

JUnit 4 in 10 Minutes

on JUnit web site

Other Software for Testing

JUnit 5 - The new version of JUnit

TestNG - a "better" JUnit, but not widely used

`http://www.testng.org`

NUnit - Unit testing for .Net Applications

`http://www.nunit.org`