Unit Testing with JUnit

(being revised)

Many Levels of Software Testing

Software testing is critical!

- Testing the specification
- Unit Testing - test one class
- Integration Testing - test components and application
- 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 errors (regression errors).*

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

4. *Validate software: does it match the specification?*

Psychological Advantage

- *Makes you **focus** on current tasks.*
    - ***Test-driven development**:*

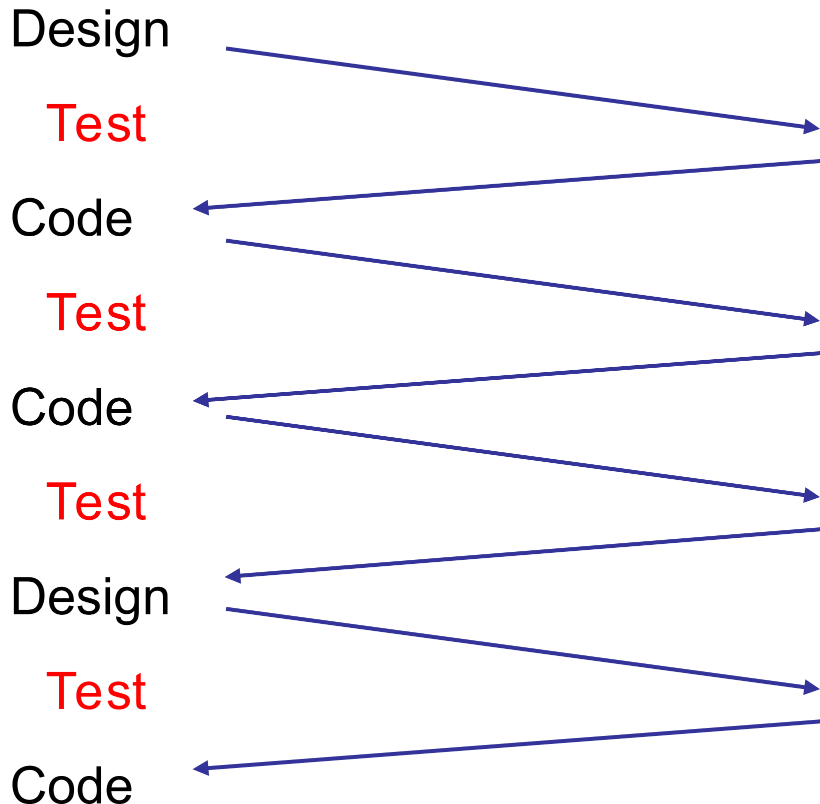
      *write tests **first** ... what the code should do.*

      Then write code that passes the tests
- *Increase **satisfaction**.*
- ***Confidence** to make changes.*

Testing is part of development

Agile Development philosophy

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



When To Test?

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

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

The Cost of Fixing Defects

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

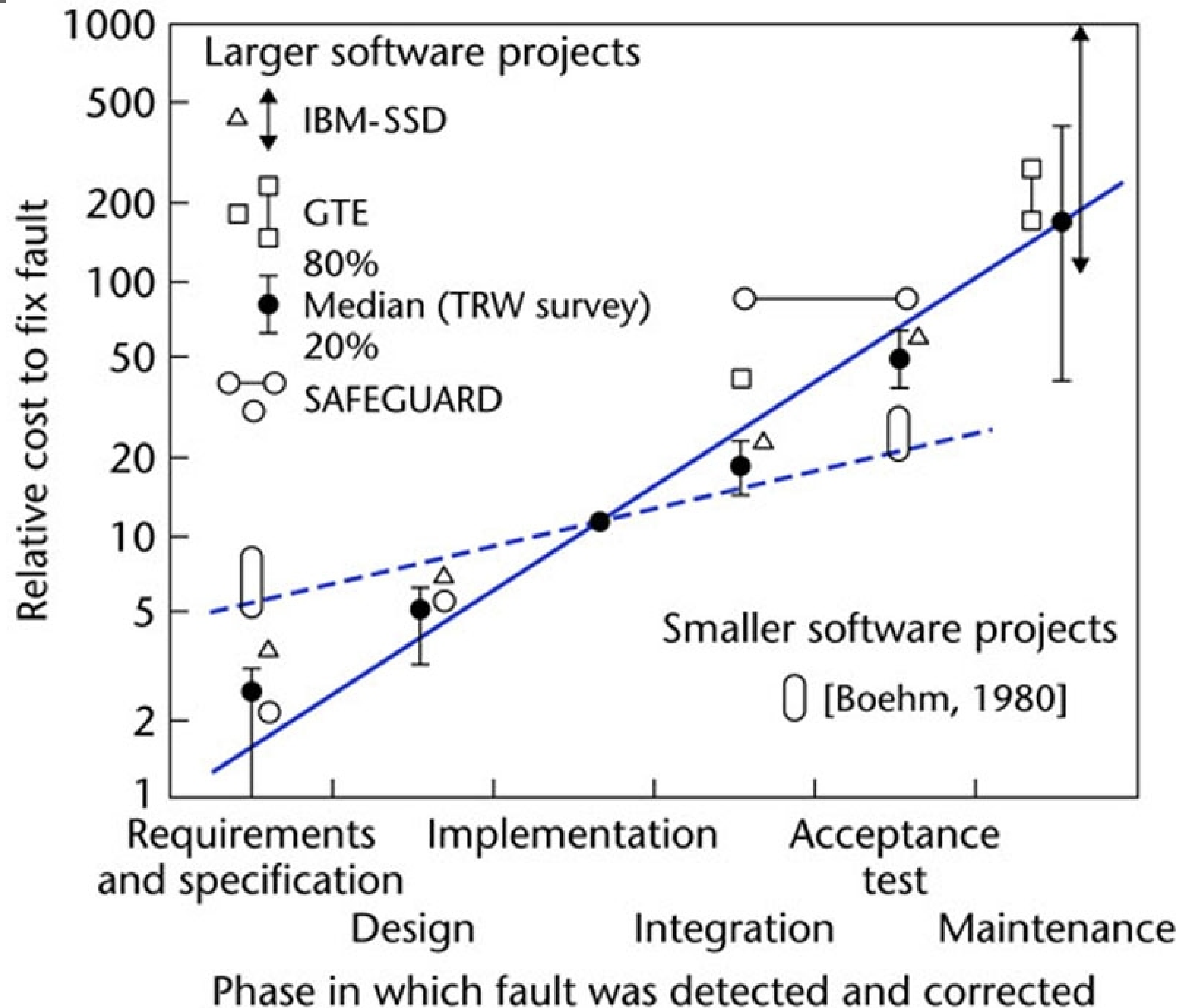


Figure 1.5

An Example

- A Coin Purse holds coins.
- It has a capacity that is fixed when the purse is created.
  - capacity is the number of coins (any type) that purse can hold
- You can insert and withdraw coins within capacity.

Purse
+ Purse(capacity)
+ getCapacity( ) : int
+ getBalance( ) : int
+ isFull( ) : boolean
+ insert(Coin) : boolean
+ withdraw(amount) : Coin[*]
+ count( ) : int

Writing Test Code from Scratch

```
Purse purse = new Purse(2); // can hold 2 coins
// test insert and isFull methods
boolean result = purse.insert( new Coin( 10 ) );
if ( ! result ) out.println("ERROR: insert failed");
if ( purse.isFull() )
   out.println("ERROR: full");
balance = purse.getBalance( );
if ( balance != 10 )
   out.println("ERROR: balance is wrong" );
if ( purse.withdraw(5) != null )
   out.println("ERROR: withdraw is wrong");
if ( purse.withdraw(10) == null )
   out.println("ERROR: couldn't withdraw 10 Baht");
```

Too Much Coding!

- A **lot of code** for a simple test.
- Would you write these tests for a real application?

  No way.

Insight: Factor out Common Code

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

- *Automate the redundant code.*
- *Create a tool to perform tests and manage output.*

JUnit does it!

```
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)

Some Simple Tests

```
import org.junit.Test;
import org.junit.Assert;
public class SimpleTest {
  @Test
  public void testAddition( ) {
      Assert.assertEquals( 2, 1+1 );
  }
  @Test
  public void testSqrt() {
     Assert.assertEquals(5.0, Math.sqrt(25),1.0E-12);
  }
  @Test
  public void testPi() {
      Assert.assertTrue( Math.PI < 3.15 );
  }
```

Structure of a Test Class

Class in Your Project

```
public class Purse {
    /** create coin purse */
    public Purse(int capacity) {
        ...
    }
    /** insert coins */
    public boolean insert(
        int tens, int fives, int ones){
        ...
    }
    /** get value of purse */
    public int getBalance( ) {
        ...
    }
```

Test Class

```
public class PurseTest {
    @Test
    public void testPurse( ) {
        // test the constructor
    }
    @Test
    public void testInsert() {
        // test insert method
    }
    @Test
    public void testGetBalance( ) {
        // test balance method
    }
```

Example: test the Math class

```
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

Example: test the Purse constructor

```
import org.junit.*;
public PurseTest  {
    /** test the constructor */
    @Test
    public void testPurseConstructor( ) {
        Purse p = new Purse( 10 );    // capacity 10
        Assert.assertEquals("Purse should be empty", 0, p.count() );
        Assert.assertEquals("Capacity should be 10", 10, p.getCapacity() );
        Assert.assertFalse(  p.isFull() );
    }
```

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 );
```

Floating Point Tests have a tolerance

```
static final double TOL = 1.0E-8; // tolerance
@Test
public void testMath( ) {
    Assert.assertEquals(
                1.414213562, Math.sqrt(2), TOL );
  }
```

tolerance for floating point comparison

Comparison of floating point values should include a *tolerance* for comparison. Test passes if

| expected - actual | <= tolerance

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 StupidTest {
    @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

assertEquals can compare any values. It uses the class's `equals( )` method.

```
assertEquals( 10, 2*5 );
assertEquals( "YES", "yes".toUpperCase() );
assertArrayEquals( int[]{1,2,3}, array );
```

assertEquals and assertSame

assertSame tests if two values refer to the same object.

Like writing a == b in Java.

```
Object x = "test";
list.add( x );
assertSame( x, list.get(list.size()-1) );
```

test insertCoin method

```
import org.junit.*;
import static org.junit.Assert.* ;
public PurseTest  {
   @Test
   public void insertCoins() {
      Purse purse = new Purse( 2 );
      assertTrue("Couldn't add coin!", p.insertCoin( new Coin( 2 ) );
      assertEquals( 2, purse.getBalance( ) );
      assertFalse( purse.isFull( ) );
      assertTrue("Couldn't add note!", p.insertCoin(new BankNote(50) );
      assertEquals( 52, purse.getBalance( ) );
      assertTrue( purse.isFull( ) );
```

Import all static methods from the Assert class.

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() );
    }
```

Create Test fixture before each test.

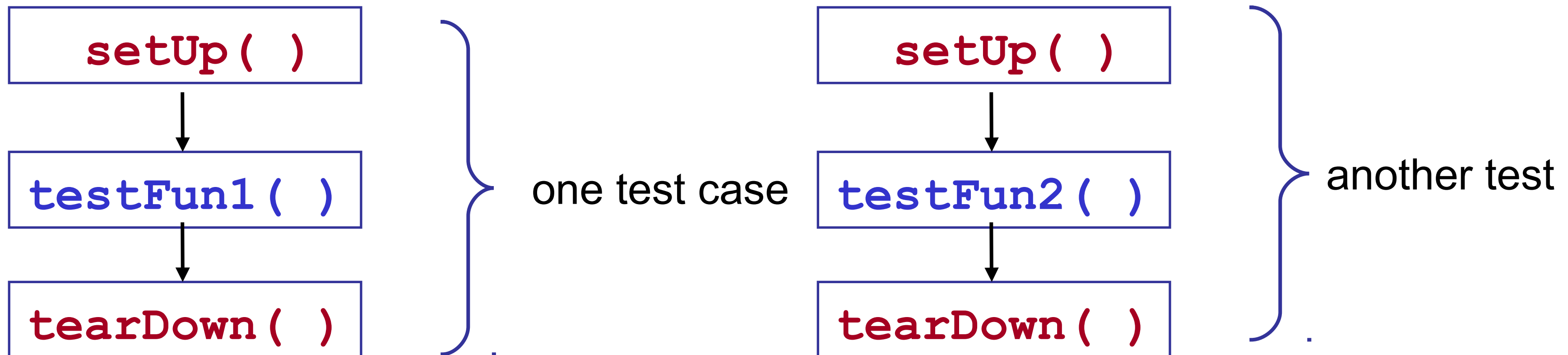
@Before (setUp) and @After (tearDown)

- `@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.



Why use @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.

```
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.

```
// 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!
}
```

Valid Arguments

- If an argument is invalid, Coin throws InvalidArgument Exception

```
// this test should throw an Exception
@Test( expected=InvalidArgumentException.class )
public void testRejectBadCoins() {
    Coin coin = new Coin(-1);
}
```

Limit the Execution Time

- specify a time limit (milliseconds) for a test
- this test fails if it takes more than 500 milliseconds

```
// 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-1 ) );
}
```

fail!

- Signal that a test has failed:

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

What to Test?

- Test BEHAVIOR not just methods.
- May have MANY TESTS for one method.
- One test may involve several methods.

Designing Tests

"edge" cases:

- a Purse with capacity 0 or 1
- if capacity is 2, can you insert 1, 2, or 3 coins?

typical cases:

- some withdraw that should succeed: 1 Baht
- can you withdraw *exactly* the amount in the purse?
- some withdraws that should fail.

Designing Tests

- impossible cases:
  - can you withdraw negative amount?
  - can you withdraw balance+1 ?
  - can you withdraw Double.INFINITY ?

Organize Your Test Code

- Create a separate source tree named "test" for tests
  - avoid mixing application classes and test classes

```
coinpurse/
     src/purse/
              Purse.java
              Coin.java
     test/purse/
              PurseTest.java
              CoinTest.java
```

Designing Tests

- typical cases
  - Purse capacity 5. Insert many different coins.
  - When you withdraw, do coins match what you inserted?

Example: Purse

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

- "can I insert same coin twice?"
- "can I withdraw *all* the money?"
- "does withdraw always *exactly match* what I requested?"

Questions about JUnit 4

- Why use:

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

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

assertEquals(1.0, Math.sin(Math.PI/2), 1.0E-14);

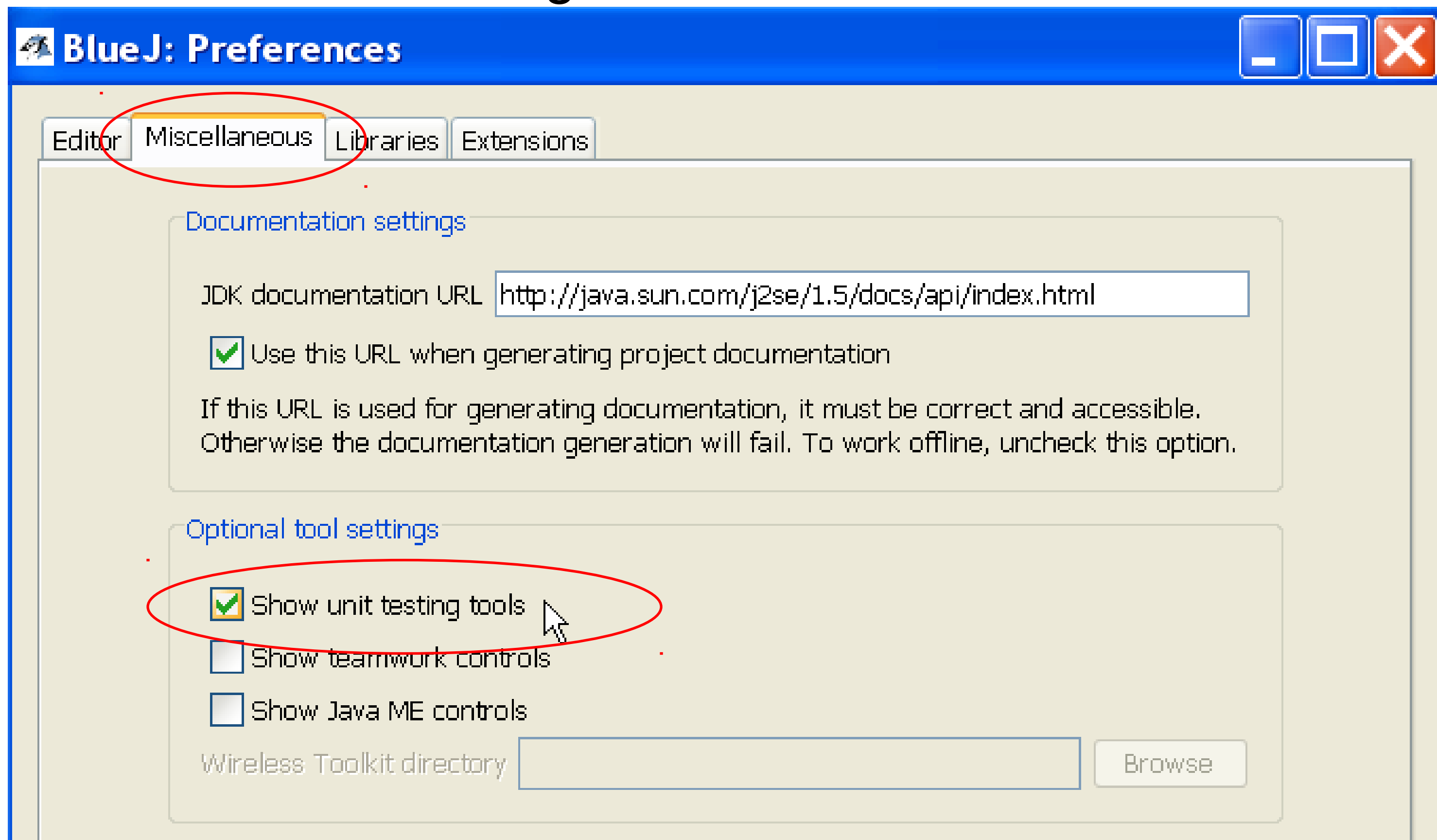
- How do you test if a String named `str` is null ???

String str;

assertNotNull(str); or assertTrue(str == null);

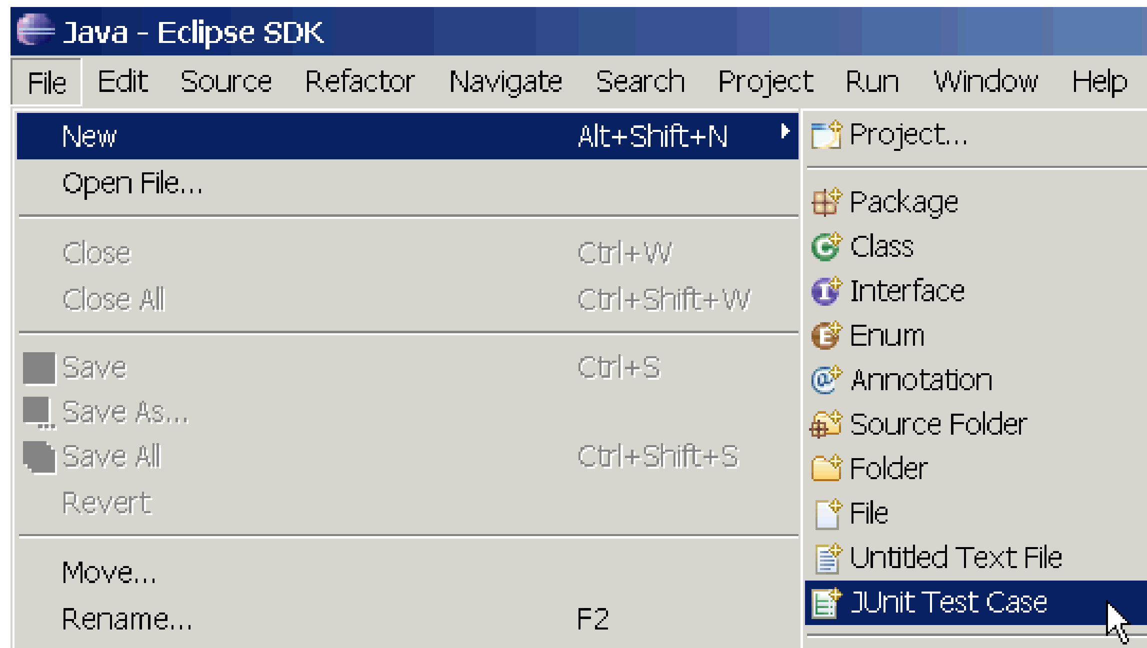
Using JUnit in BlueJ

1. From "Tools" menu select "Preferences..."
2. Select "Miscellaneous" tab.
3. Select "Show unit testing tools".



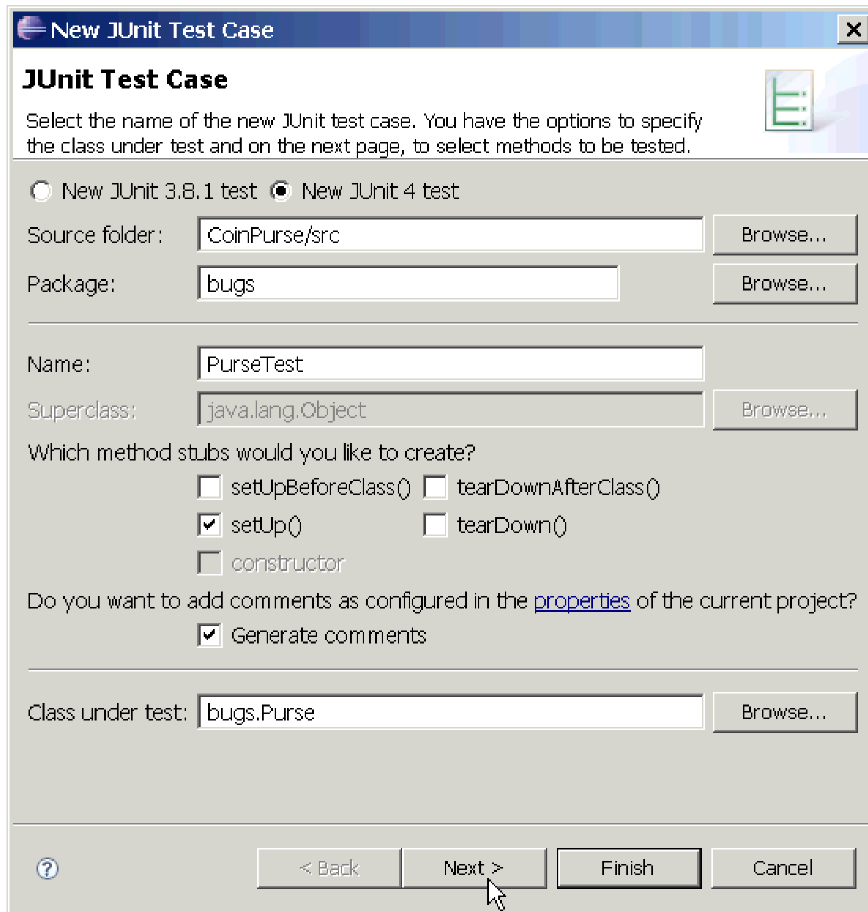
Using JUnit in Eclipse

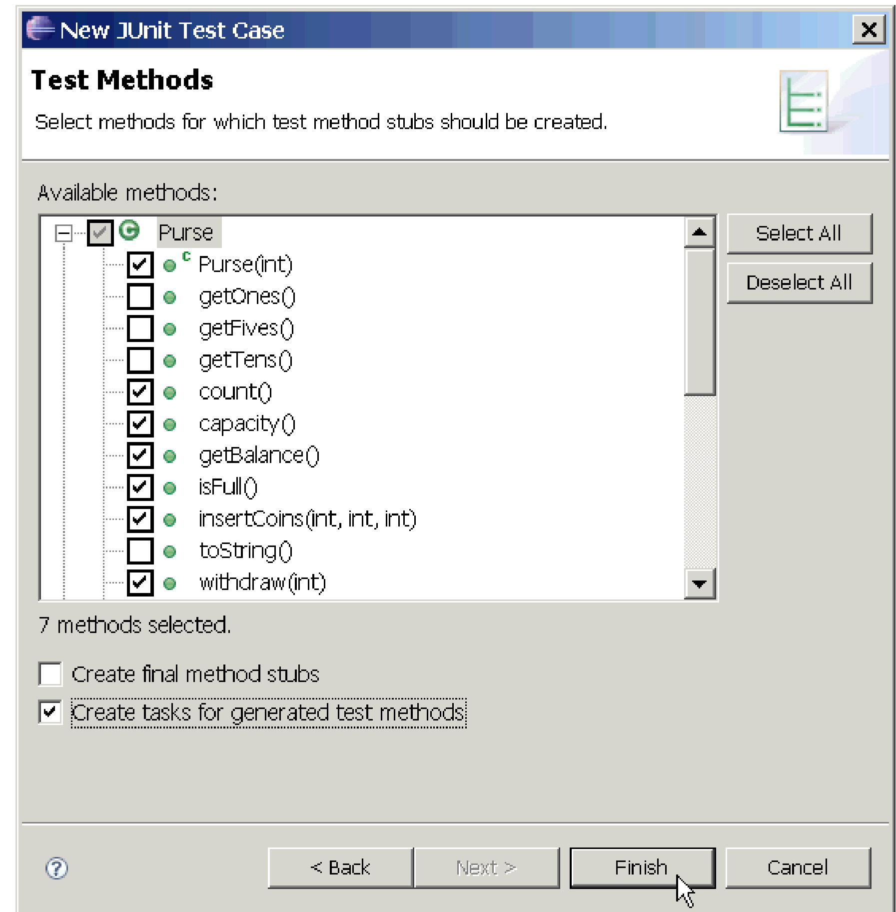
- Eclipse includes JUnit 3.8 and 4.x libraries
  - you should use Junit 4 on your projects
- eclipse will manage running of tests.
  - *but,* you can write your own test running in the main method
- Select a source file to test and then...



Using JUnit in Eclipse (2)

- Select test options and methods to test.



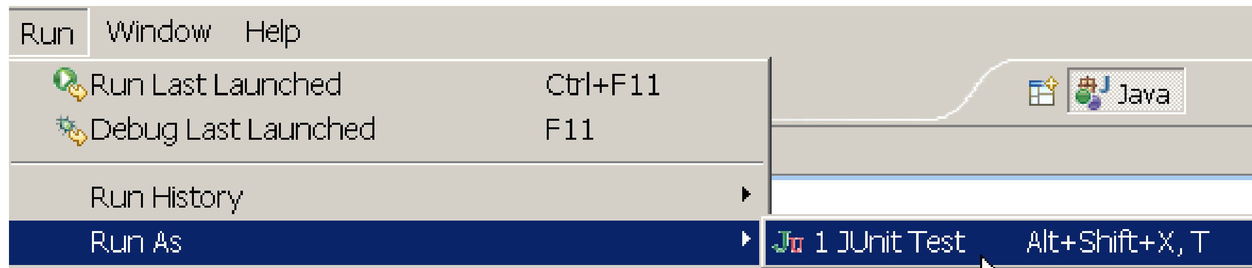


Using JUnit in Eclipse (3)

```
/** 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)

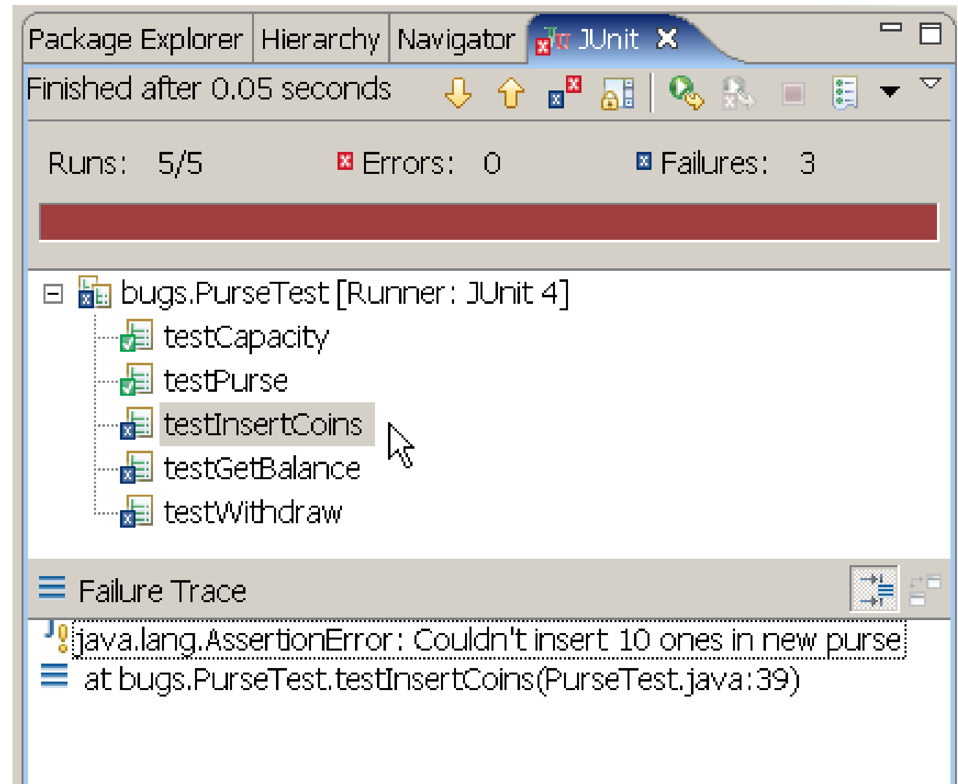


Select the JUnit test case file and choose

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.



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

TestNG - a better JUnit

`http://www.testng.org`

`NUnit` - Unit testing for .Net Applications

`http://www.nunit.org`

JUnit 3.x is obsolete

But existing software still uses JUnit 3.x, so it is useful to know how to read JUnit 3 tests.

For new code, use the current version of JUnit.

Structure of a JUnit 4 Test Class

```
import org.junit.*;                    // package org.junit
import static org.junit.Assert.*;
public PurseTest  {                    // don't extend TestCase
    Purse purse;
    /**test insert coins */
    @Test                              // use @Test annotation for tests
    public void testInsertCoins() {     // any method name is OK
        Purse p = new Purse( 1 );
        boolean result = p.insertCoin( new Coin( 5 ) );
        assertTrue("Couldn't insert coins!", result );
        assertFalse( p.insertCoin( new Coin(1) ); // should be full
        assertEquals( 5.0, p.getBalance( ), 0.001 );
    }
    @Before
    public void initialize( ) {        // any method name is OK
        purse = new Purse( 10 ); // capacity 10
    }
```

Structure of a JUnit 3 Test Class

```
import junit.framework.*;       // package junit.framework
import static junit.framework.Assert.*;
public PurseTest  extends TestCase {  // must extend TestCase
    Purse purse;
                                          // No annotations
    public void testInsertCoins() {       // names must begin with "test"
        Purse p = new Purse( 1 );
        boolean result = p.insertCoin( new Coin( 5 ) );
        assertTrue("Couldn't insert coins!", result );
        assertFalse( p.insertCoin( new Coin(1) );
        assertEquals( 5.0, p.getBalance(), 0.001 );
    }
                                          // no @Before annotation
    protected void setUp( ) {             // setUp method must use this name
        purse = new Purse( 10 ); // capacity 10
    }
```

Key Points in Using JUnit 3.x

1. Test class "`extends TestCase`"
2. JUnit package is `junit.framework`

```
import junit.framework.*;
```

3. Import static methods:

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

4. Must use the naming convention:

```
public void testGetBalance( ) { ... }
protected void setUp( ) { ... }
protected void tearDown( ) { ... }
```

5. no annotations (@Before, @After, @Test ...)

JUnit 3 Test Suite

- For JUnit 3.x your need a method & a constructor:
  - PurseTest(string) constructor calls super(string)
  - suite( ) creates a test suite

```
import junit.framework.*;
public PurseTest extends TestCase {
    public PurseTest( String testmethod ) {
        super( testmethod );
    }
    /** create a test suite automatically */
    public static Test suite( ) {
        TestSuite suite = new TestSuite( PurseTest.class );
        return suite;
    }
}
```

This is standard form of the constructor; just copy it

Compiling and Running Tests

You invoke a JUnit **`TestRunner`** to run your test suite. JUnit 3.8 provides 3 test runners:

- junit.textui.TestRunner - console test runner
- junit.awtui.TestRunner - graphical using AWT
- junit.swingui.TestRunnger - graphical using Swing

```
> set CLASSPATH = /java/junit3.8.2/junit.jar;.
> javac PurseTest.java
> java junit.swingui.TestRunner PurseTest
```

Name of your test class as arg.

Another Way to Run Tests

Call test runner from your class's main method

- don't need to invoke junit.*.TestRunner on cmd line

```
public PurseTest extends TestCase {
   ...
   public static void main( String [] args ) {
      junit.swingui.TestRunner.run( PurseTest.class );
   }
```

```
> set CLASSPATH = /java/junit3.8.2/junit.jar;.
> javac PurseTest.java
> java PurseTest
```

Name of your test class as arg.

Selecting Tests to Run: `TestSuite`

- In the example we created a TestSuite using:

```
public static Test suite( ) {
    TestSuite suite = new TestSuite( PurseTest.class );
    return suite;
}
```

JUnit uses *reflection* to locate all methods named "`test*`".

- or can specify only the tests you want to run

```
/** create a custom test suite */
public static Test suite( ) {
    TestSuite suite = new TestSuite(  );
    suite.addTest( new PurseTest( "testPurse" ) );   // test the constructor
    suite.addTest( new PurseTest( "testInsertCoins") ); // insert coins
    return suite;
}
```

only run these test methods

JUnit 3 Adaptor for JUnit 4 test class

- You can run JUnit 3 test cases using JUnit 4 ...

```
import org.junit.Test;
import static org.junit.Assert.*;
             // import adaptor for JUnit 3
import junit.framework.JUnit4TestAdaptor;
public PurseTest  {     // don't extend TestCase

     /* JUnit 3 calls suite( ) to get a test suite */
     public static junit.framework.Test suite( ) {
        return new JUnit4TestAdaptor( PurseTest.class );
     }

     @Test
     ... rest of the JUnit 4 tests ...
```

Questions about JUnit 3

- What are the 2 forms of every **`assert( )`**?

- Why use:

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

- What is the name of ...
  - the test class for "**`class LineItem`**"?
  - your test class **`extends`** what other class?
  - the test method for the **`LineItem`** constructor?
  - the test method for the **`getItemID()`** method?