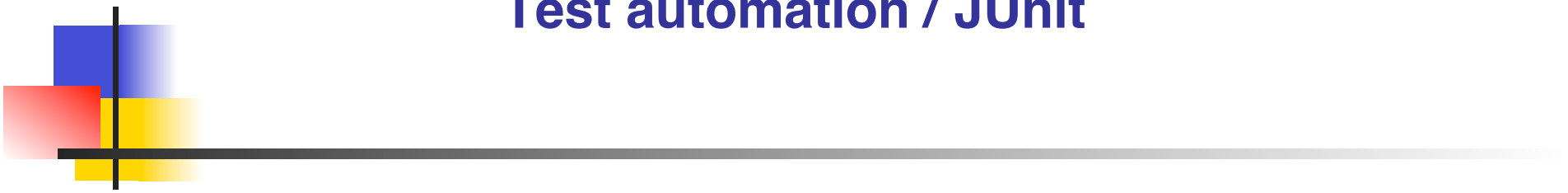
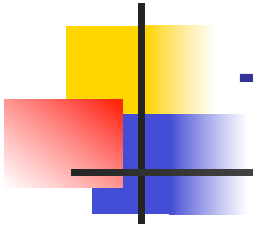


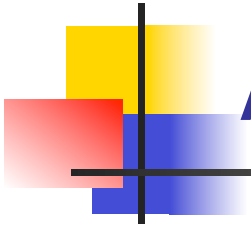
Test automation / JUnit

Building automatically repeatable test suites



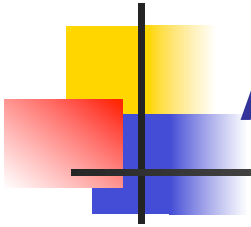
Test automation

- 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



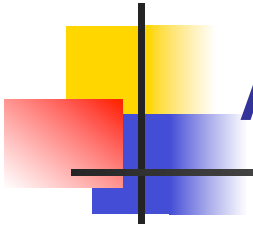
Automated testing steps

- 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



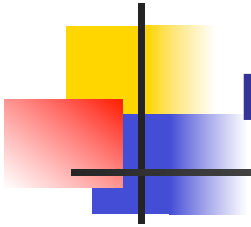
Automated testing advantages

- 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



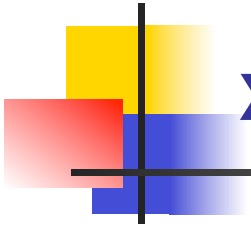
Automated testing advantages

- 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



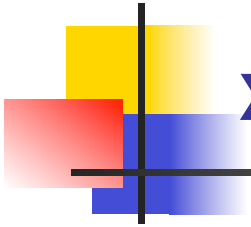
Limitations and caveats

- 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
- If the implementation is changing frequently, maintaining the test suite might be difficult



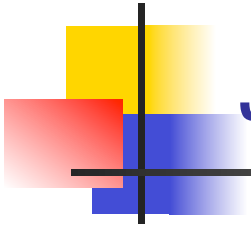
XP approach to testing

- 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**



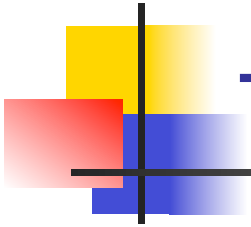
XP consequences

- 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**



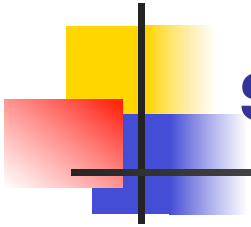
JUnit

- 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

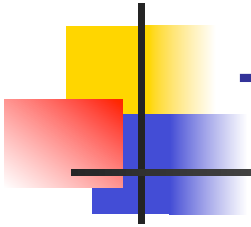
- A **test fixture** sets up the data (both objects and primitives) that are needed for every test
  - **Example: If you are testing code that updates an employee record, you need an employee record to test it on**
- A **unit test** is a test of a *single* class
- A **test case** tests the response of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



Structure of a JUnit test class

- The next sequence of slides deal with JUnit when compiling and running Java at the operating system level
  - **A later sequence of slides describes how to use JUnit within Eclipse**
- To test a class named **Fraction**
- Create a test class **FractionTest**

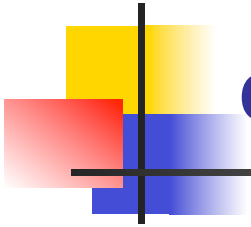
```
import org.junit.*;
import static org.junit.Assert.*;
public class FractionTest
{
            …
}
```



Test fixtures

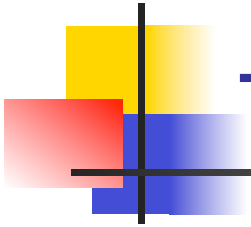
- Methods annotated with **@Before** will execute before every test case
- Methods annotated with **@After** will execute after every test case

```
@Before
public void setUp() {…}

@After
public void tearDown() {…}
```



Class Test fixtures

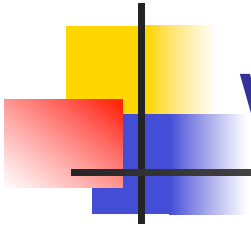
- Methods annotated with **@BeforeClass** will execute once before all test cases
- Methods annotated with **@AfterClass** will execute once after all test cases
- These are useful if you need to allocate and release expensive resources once



Test cases

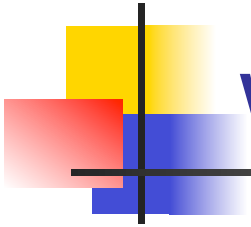
- Methods annotated with **@Test** are considered to be test cases

```
@Test
public void testadd() {…}

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



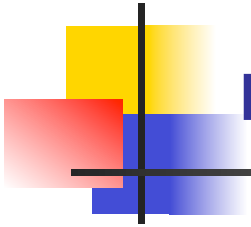
What JUnit does

- For *each* test case **aTestCase**
  - **JUnit executes all @Before methods**
    - **Their order of execution is not specified**
  - **JUnit executes aTestCase**
    - **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

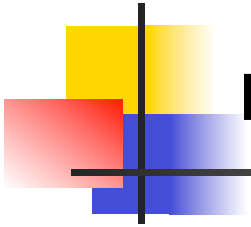
- Call the methods of the class being tested
- Assert what the correct result should be with one of the provided **assert methods**
- These steps can be repeated as many times as necessary
- An assert method is a JUnit method that performs a test, and throws an **AssertionError** if the test fails
 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



List of assert methods 1

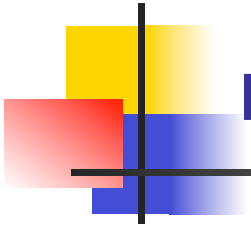
- `assertTrue(boolean b)`
  `assertTrue(String s, boolean b)`
  - Throws an AssertionError if *b* is False
  - The optional message *s* is included in the Error

- `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

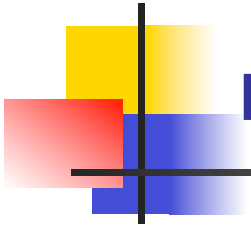
- Consider a trivial "counter" class
  - **The constructor creates a counter and sets it to zero**
  - **The increment method adds one to the counter and returns the new value**
  - **The decrement method subtracts one from the counter and returns the new value**
  - **The corresponding JUnit test class is on the next slide**



Example JUnit test class for counter program

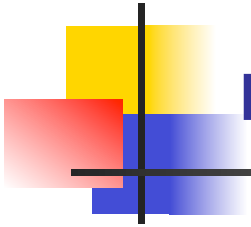
```
public class CounterTest {
    Counter counter1;

    @Before

    public void setUp() {          // create a 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);
    }

}
```

Each test begins with a *brand new* counter. No need consider the order in which the tests are run.



List of assert methods 2

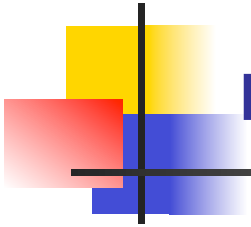
- `assertEquals(Object` ***`expected`***`,`
  `Object` ***`actual`***`)`
  - Uses the equals method to compare the two objects
  - Casting may be required when passing primitives, although autoboxing may be done
  - There is also a version to compare arrays



List of assert methods 3

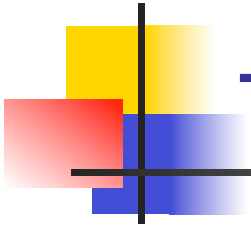
- `assertSame(Object expected, Object actual)`
  - Asserts that two references are attached to the same object (using ==)

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



List of assert methods 4

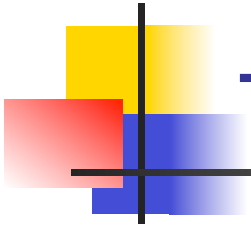
- `assertNull(Object object)`
  - Asserts that a reference is null
- `assertNotNull(Object object)`
  - Asserts that a reference is not null
- `fail()`
  - Causes the test to fail and throw an AssertionError
  - Useful as a result of a complex test, or when testing for exceptions



Testing for exceptions

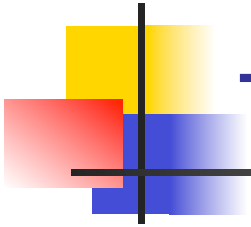
- If a test case is expected to raise an exception, it can be noted as follows and on the next slide

```
@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
  }
}
```



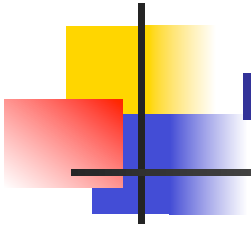
The assert statement

- A statement such as

  assert *boolean_condition*;

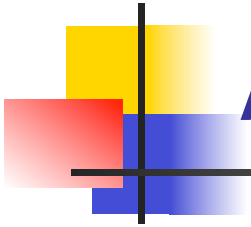
  will also throw an **AssertionError** if the ***boolean_condition*** is false

- Can be used instead of the JUnit **assertTrue** method



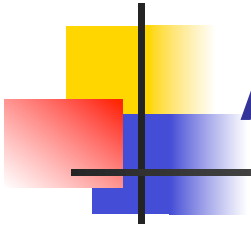
Ignoring test cases

- 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



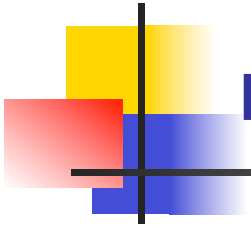
Automated testing issues

- It isn't 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

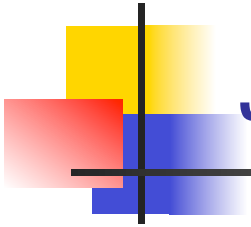
- To test methods that do output, you have to capture the output
  - **It's possible to capture output, but it's an unpleasant coding chore**
- To test methods that change the state of the object, you have to have code that checks the state
  - **It's a good idea to have methods that test state invariants**



First steps toward solutions

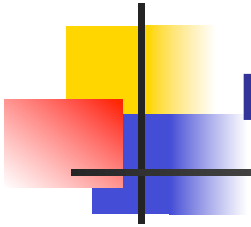
- You can redefine `System.out` to use a different `PrintStream` with `System.setOut(PrintStream)`

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



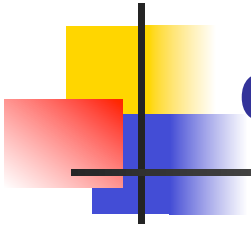
JUnit in Eclipse

- JUnit can be downloaded from **www.junit.org**
- For this course, we will use it as part of Eclipse
- Eclipse contains wizards to help with the development of test suites with JUnit
- JUnit results are presented in an Eclipse window



Hello World demo

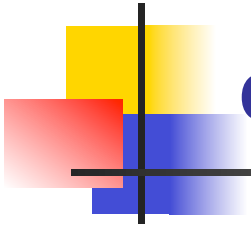
- Run Eclipse
- File -> New -> Project, choose Java Project, and click Next
- Type in a project name, e.g. ProjectWithJUnit, click Finish
- Project -> Properties, select Java Build Path, Libraries, click Add External JARs.
- Browse to directory where JUnit is stored
- Pick junit.jar and click Open
- JUnit will appear in the list of libraries. Click OK



Create a class

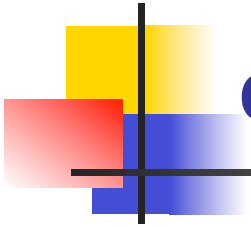
- Right-click on ProjectWithJUnit
  Select New -> Package
  Enter package name, e.g. **code**
  Click Finish

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



Create a class - 2

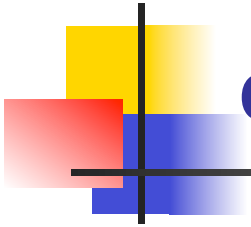
- Add a dummy method such as
  public String say() { return null; }
- Right-click in the editor window and select Save



Create a test class

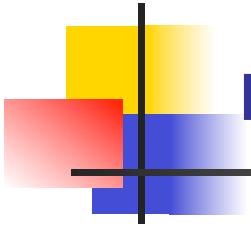
- Right-click on ProjectWithJUnit
  Select New -> Package
  Enter package name, e.g. **test**
  Click Finish

- Right-click on test
  Select New -> Junit Test Case
  Enter test class name, e.g. **HelloWorldTest**
  Enter class under test: **code**.**HelloWorld**



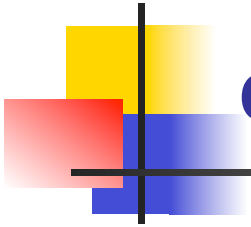
Create a test class

- Check to create a setup method
- Click Next
- Check the checkbox for the say method
  - **This will create a stub for a test case for this method**
- Click Finish
- The HelloWorldTest class is created
- The first version of the test suite is ready



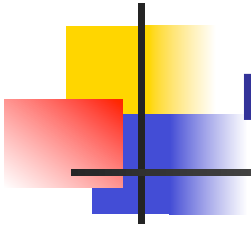
Run the test class - 1st try

- Run -> Run as -> JUnit Test
- The results appear in the left window (you may have to click the JUnit tab)
- The automatically created test case fails



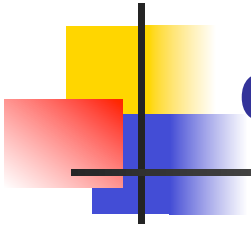
Create a better test case

- 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());
```



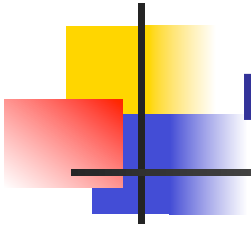
Run the test class - 2nd try

- 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



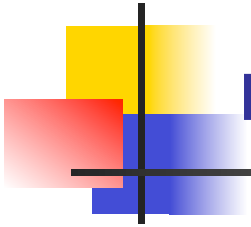
Create a test suite

- Right-click on the test package, select New -> Class. Name the class **AllTests**.
- Modify the class text so it looks like the next slide
- Run with Run -> Run As -> JUnit Test
- You can easily add more test classes



Example Currency program

```
package currency;
public class Currency {

protected int amount;
protected String type;

Currency(int amount, String type) {
   this.amount = amount;    this.type = type;  }

public boolean equals(Object obj) {
  return amount == ((Currency) obj).amount
          && type == ((Currency) obj).type;  }

protected Currency times(int multiplier) {
  return new Currency(amount * multiplier, type);  }

static Currency dollar(int amount) {
  return new Currency(amount, "Dollar");  }

static Currency franc(int amount){
  return new Currency(amount, "Franc");  }
}
```

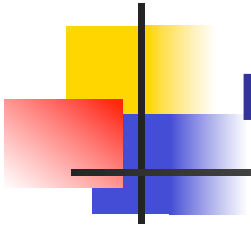


Example Currency test program – 1 of 2

```
package currency;
import junit.framework.*;

public class TestMoney extends TestCase{

public static void main (String[] args) {
  junit.textui.TestRunner.run(suite());
}

public static Test suite() {
  return new TestSuite(TestMoney.class);
}

public void testEquality(){
  assertTrue(new Currency(5, "Currency").equals(new Currency(5, "Currency")));
  assertFalse(new Currency(5, "Currency").equals(new Currency(6, "Currency")));
  assertTrue(new Currency(5, "Franc").equals(new Currency(5, "Franc")));
  assertFalse(new Currency(5, "Franc").equals(new Currency(6, "Franc")));
  assertFalse(new Currency(5, "Franc").equals(new Currency(5, "Currency")));
}

…
```

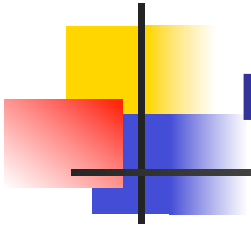
Example Currency test program – 2 of 2

```
...
public void testMultiplication() {
  Currency five = new Currency(5, "Dollar");
  assertEquals(new Currency(15, "Dollar"), five.times
(3));  }
public void testCurrencyType( )
  assertEquals("Dollar", Currency.dollar(1).type);
  assertEquals("Franc", Currency.franc(1).type);
}

}
```



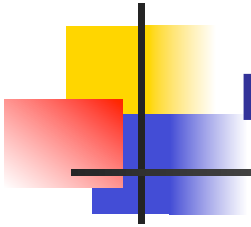
No tool?

- What do you do if there is no equivalent to JUnit for the language or system in which you have to write test cases?



Minimal output testing – 1

- What to do if no tool exists?
  - **Use minimal output testing**
    - **Works for any programming language**
    - **Works for any system**
  - **Successful test outputs only the briefest of messages**
    - **test started**
      test ended



Minimal output testing – 2

- Basic structure
  - **Test program is a sequence of if-statements with the following structure**
    - **Note use of msg_id to identify which test failed**
  - **Rest of test program consists of set up and support routines to simplify programming the condition and then-phrase**

```
if expected_output ≠ actual output
then print_message(msg_id, … )
fi
```