# Unit Testing and Scaffolding

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# Testing Preliminaries



- You're a programmer
  - a coder, a developer, or maybe a hacker!
- As such, it's almost impossible that you haven't had to sit down with a program that you were sure was ready for use
  - or worse yet, a program you knew was not ready
- So, you put together a bunch of test to prove the correctness of your code
  - Let's think about what correctness means

# Testing Preliminaries



- Correctness in Testing ?
  - Which is the point of view ?
- Different points of view means different types of tests (testing)
- Automated tools support

# Outline



- Testing Taxonomy
  - Brief Introduction
- Unit testing with JUnit 4.x
  - Main differences with JUnit 3.x
  - Backward compatibilities
  - JUnit Examples in practice
- Test Scaffolding and Mocking

# 1. Types of testing

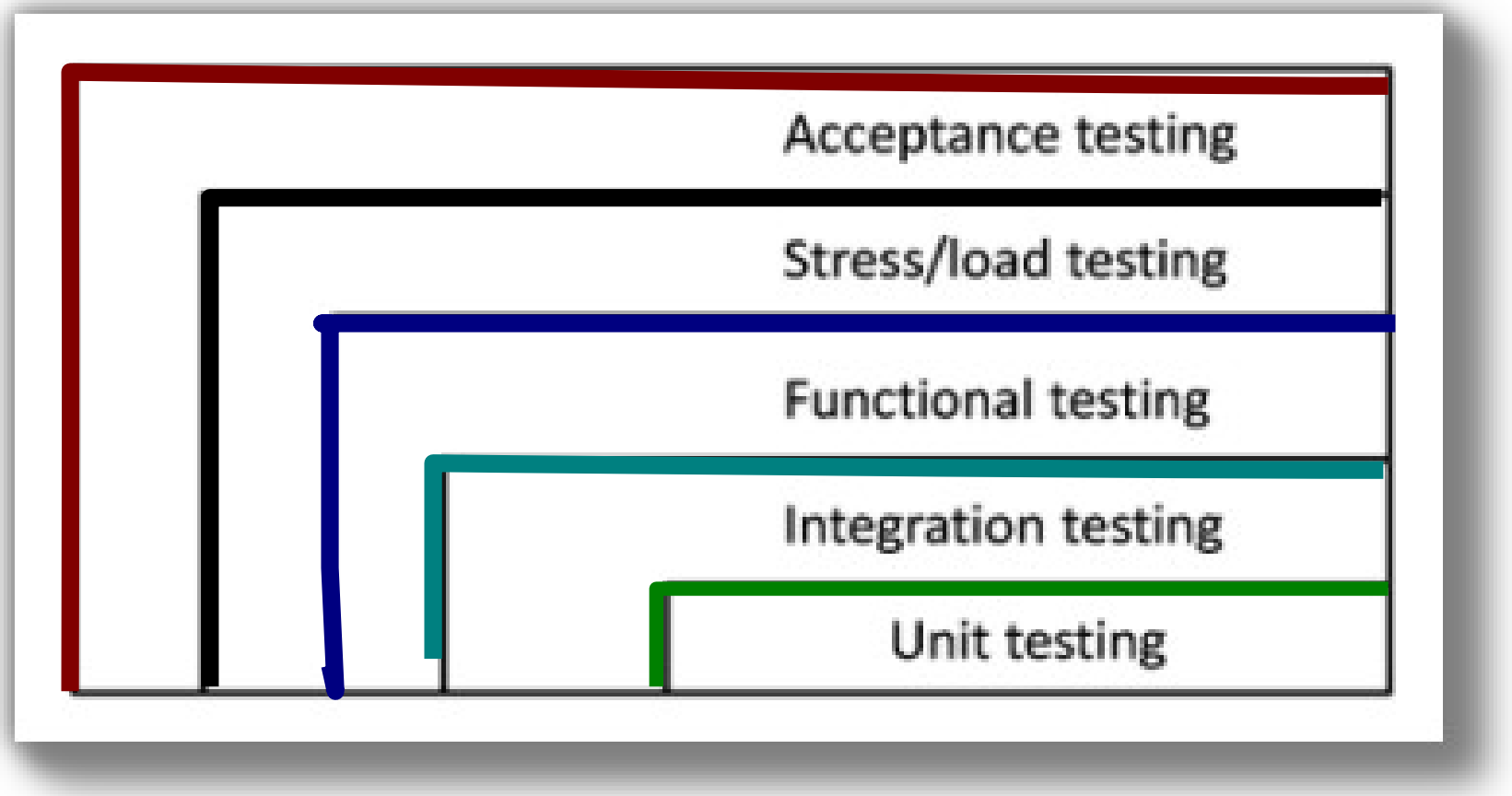
# Example Scenario



- (… not properly related to Computer Science :)
- Please, imagine that you have to test a building
  - Test  if it has been constructed properly
  - Test if it is able to resist to earthquake
  - ….
- What types of “testing” will you do?
  - Make an educated guess

# Five Types of Testing





# Unit Testing



- Testing of the smallest pieces of a program
  - Individual functions or methods
- Keyword: **Unit**
  - **(def) Something is a unit if it there's no meaningful way to divide it up further**
- Buzz Word:
  - **Testing in isolation**

# Unit Testing (cont.)



- Unit test are used to test a single *unit* in isolation
  - Verifying that it works as expected
  - No matter the rest of the program would do
- Possible advantages ?
  - (Possibly) No inheritance of bugs of mistakes from made elsewhere
  - Narrow down on the actual problem

# Unit Testing (cont.)



- Is it enough ?
  - No, by itself, but...
- … it is the foundation upon which everything is based!

- (Back to the example)
  - You can't build a house without solid materials.
  - You can't build a program without units that works as expected.

# Integration Testing



- Aim: Push further back boundaries of isolation
- Tests encompass interactions between related units

- **(Important)**

  **Every test should still run in isolation**
  - To avoid inheriting problems from outside
- Tests check whether the tested unit behave correctly as a group

# Functional Testing



- a.k.a. System Testing
- *Extends boundaries of isolation even further*
  - *To the point they don't even exist.*
- Testing application *Use Cases*

- System tests are very useful, but not so useful without Unit and Integration tests
  - You have to be sure of the pieces before you can be sure of the whole.

# Stress and Acceptance Testing



- **Stress/Load Testing**
  - Test of loadings and performances
    - (Non functional requirements)
  - *Test if the building is able to resist to the earthquake*
- **Acceptance Testing**
  - Last but not least....
  - … does the customer get what he or she expected?

# Before going on...

- Let's take a look at this code, please



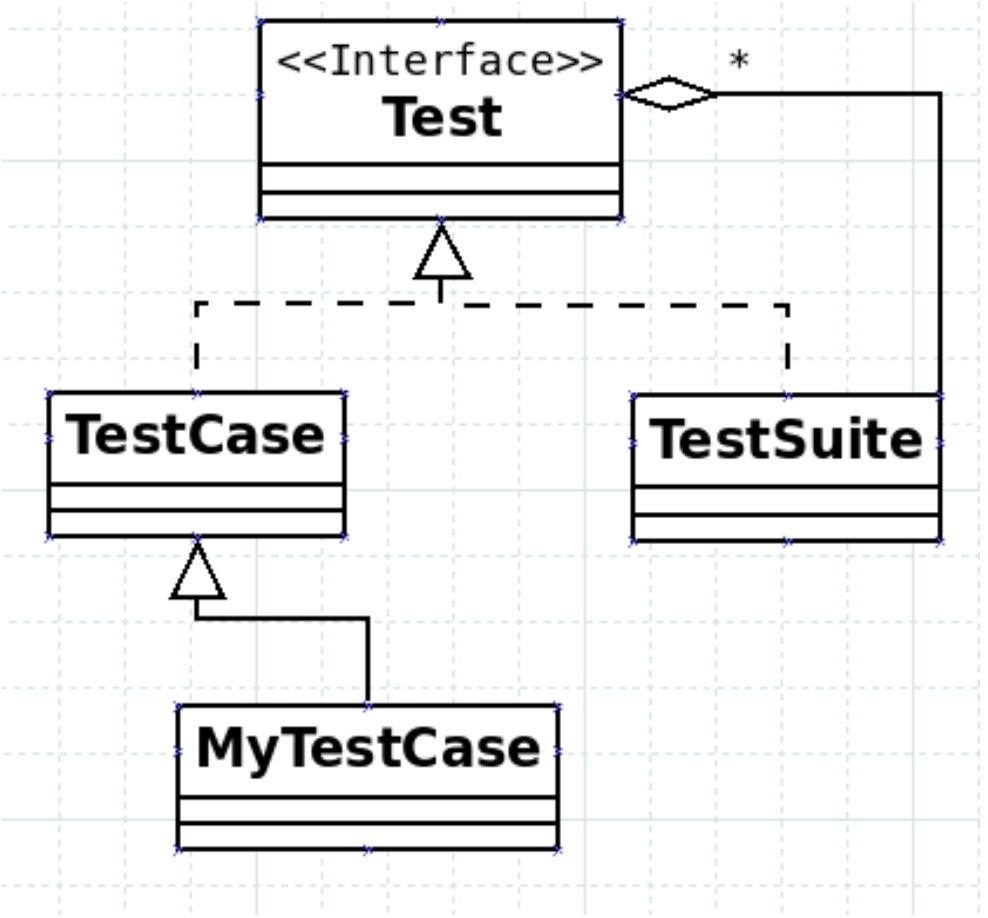
```
class Testable(object):

    def method1(self, number):
        number += 4
        number **= 0.5
        number *= 7
        return number

    def method2(self, number):
        return ((number * 2) ** 1.27) * 0.3

    def method3(self, number):
        return self.method1(number) + self.method2(number)

    def method4(self):
        return 1.713 * self.method3(id(self))
```

# 2. JUnit Testing Framework

# Junit 3.x Design



- Design that is compliant with *xUnit framework* guidelines



# JUnit Assertions



- `assertNotNull`
  - Test passes if Object is not null.
- `assertNull`
  - Test passes if Object is null.
- `assertEquals`
  - Asserts equality of two values
- `assertTrue`
  - Test passes if condition is True
- `assertFalse`
  - Test passes if condition is False
- `assertSame`
  - Test passes if the two Objects are not the same Object

# JUnit 4.x Design



- Main features inspired from other Java Unit Testing Frameworks
  - TestNG
- Test Method **Annotations**
  - Requires Java5+ instead of Java 1.2+
- Main Method Annotations
  - `@Before, @After`
  - `@Test, @Ignore`
  - `@SuiteClasses, @RunWith`

# Java5 Annotations at glance



- Meta Data Tagging
  - `java.lang.annotation`
  - `java.lang.annotation.ElementType`
    - `FIELD`
    - `METHOD`
    - `CLASS`
    - …
- `Target`
  - Specify to which `ElementType` is applied
- `Retention`
  - Specify how long annotation should be available

# JUnit Test Annotation



```
@Retention(RetentionPolicy.RUNTIME)
@Target({ElementType.METHOD})
public @interface Test {

    /**
     * Default empty exception
     */
    static class None extends Throwable {
        private static final long serialVersionUID= 1L;
        private None() {
        }
    }

    /**
     * Optionally specify <code>expected</code>, a Throwable, to cause a test method to succeed iff
     * an exception of the specified class is thrown by the method.
     */
    Class<? extends Throwable> expected() default None.class;

    /**
     * Optionally specify <code>timeout</code> in milliseconds to cause a test method to fail if it
     * takes longer than that number of milliseconds.*/
    long timeout() default 0L;
}
```

# Testing exception handling



- *Test anything that could possibly fail*

```
public class TestDefaultController extends TestCase
{
    [...]
    public void testGetHandlerNotDefined()
    {
        try {
            SampleRequest request = new SampleRequest("testNotDefined");
            //The following line is supposed to throw a RuntimeException
            controller.getHandler(request);
            fail;
        }
        catch (RunTimeException e){
            assert true;
        }
    }
    [...]
}
```

# *New way* of Testing exception handling



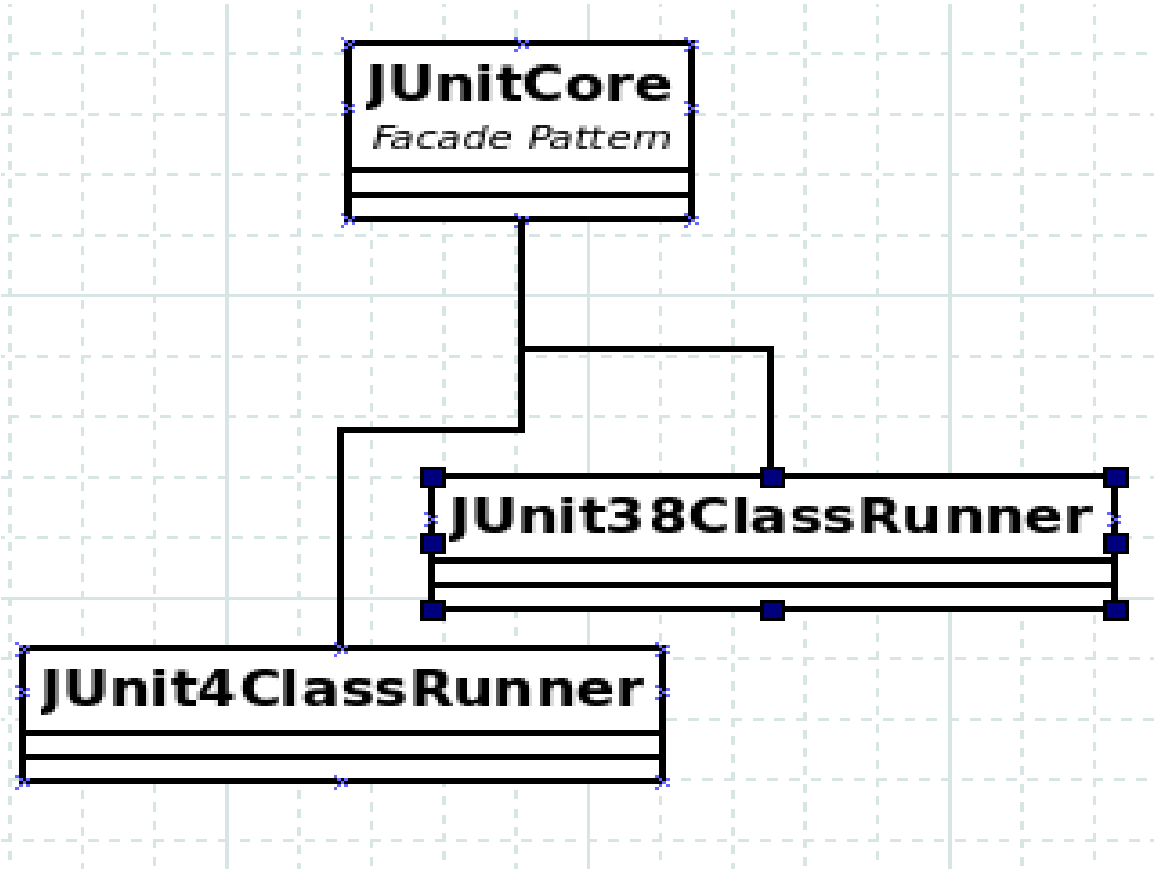
- *Test anything that could possibly fail*

```
public class TestDefaultController
{
    [...]
    @Test(expected=RuntimeException.class)
    public void testGetHandlerNotDefined()
    {
        SampleRequest request = new SampleRequest("testNotDefined");
        //The following line is supposed to throw a RuntimeException
        controller.getHandler(request);
    }
    [...]
}
```

# JUnit 4.x backward compatibility



- JUnit provides a façade class which operates with any of the test runners.
  - `org.junit.runner.JUnitCore`



# JUnit Matchers: Hamcrest



- Junit 4.4+ introduces matchers
  - Imported from **Hamcrest project**
  - http://code.google.com/p/hamcrest/
- Matchers improve testing code refactoring
  - Writing more and more tests assertion became hard to read
  - **Remember:**
    - **Documentation purposes**
- Let's do an example …

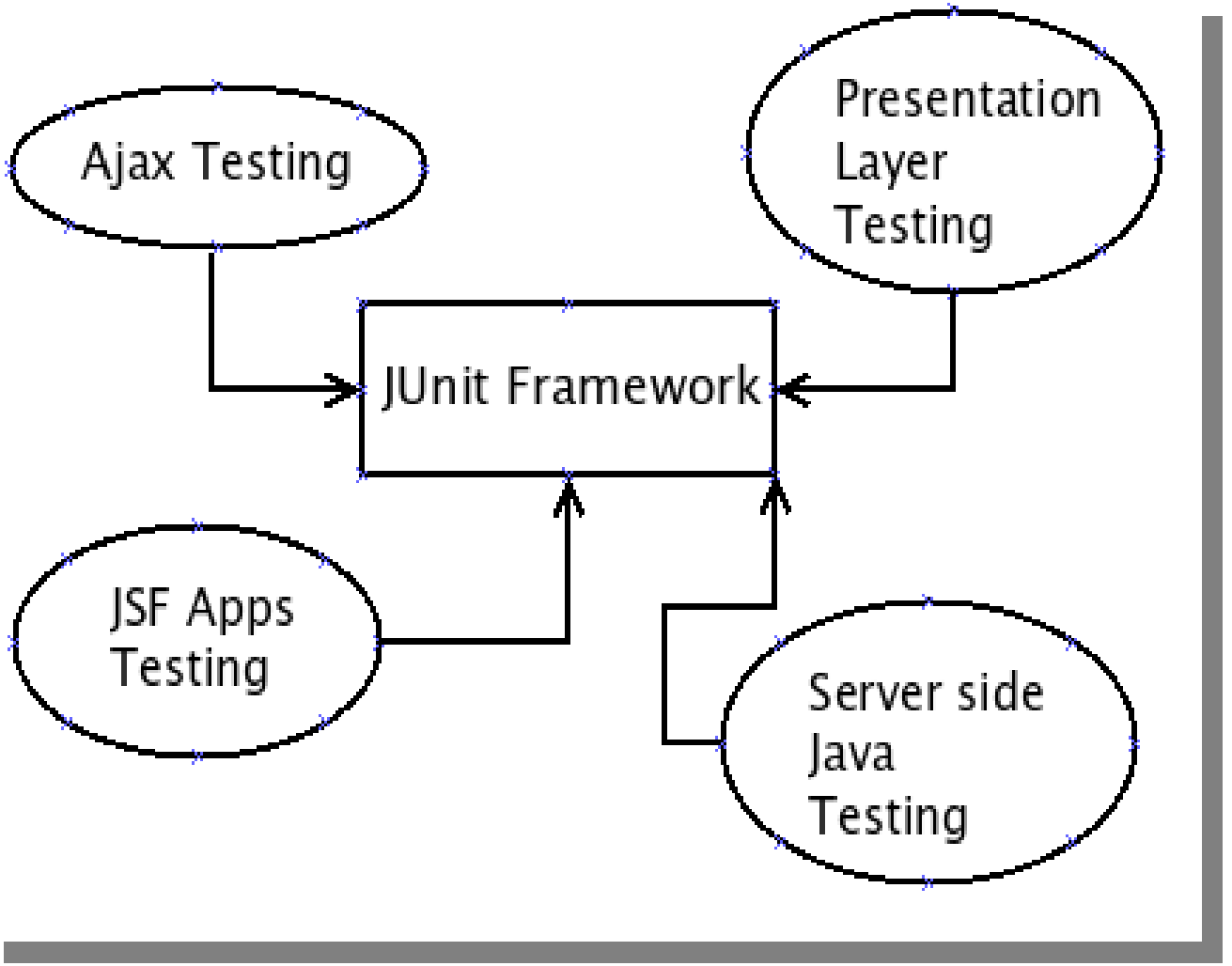
# Matchers Example

```
public class HamcrestTest {
    private List<String> values;
    @Before
    public void setUpList() {
        values = new ArrayList<String>();
        values.add("x");
        values.add("y");
        values.add("z");
    }

    @Test
    public void withoutHamcrest() {
        assertTrue(values.contains("one")
        || values.contains("two")
        || values.contains("three"));
        }
    }
```

```
@Test
public void withHamcrest() {
    assertThat(values, hasItem(anyOf(equalTo("one"), equalTo("two"),
    equalTo("three"))));
}
```

# JUnit 4.x Extensions





# 3. Testing Scaffolding

*Programming today is a race between software engineers striving to build bigger and better idiot-proof programs,*
*and the Universe trying to produce bigger and better idiots. So far, the Universe is winning.*
Cit. Rich Cook

# Integration Testing Example

```
public class TestDB extends TestCase  {
private Connection dbConn;
protected void setUp() {
dbConn = new Connection("oracle", 1521, "fred", "foobar");
dbConn.connect();
}
protected void tearDown() {
dbConn.disconnect();
dbConn = null;
}
public void testAccountAccess()  {
// Uses dbConn
xxx xxx xxxxxx xxx xxxxxxxxx;
}
}
```

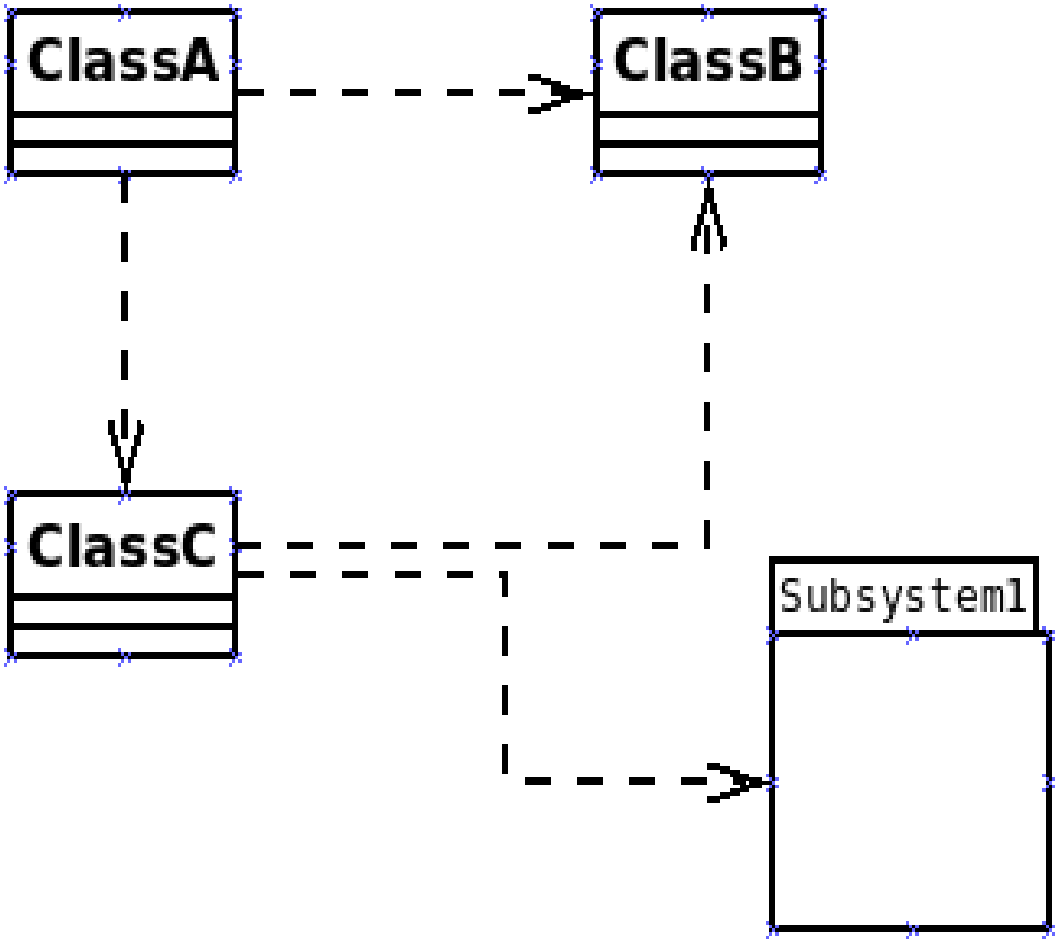
# Integration testing problem



- Integrate multiple components implies to decide in which order classes and subsystems should be integrated and tested
- **CITO** Problem
  - *Class Integration Testing Order* Problem
- Solution:
  - Topological sort of dependency graph

# Integration testing example





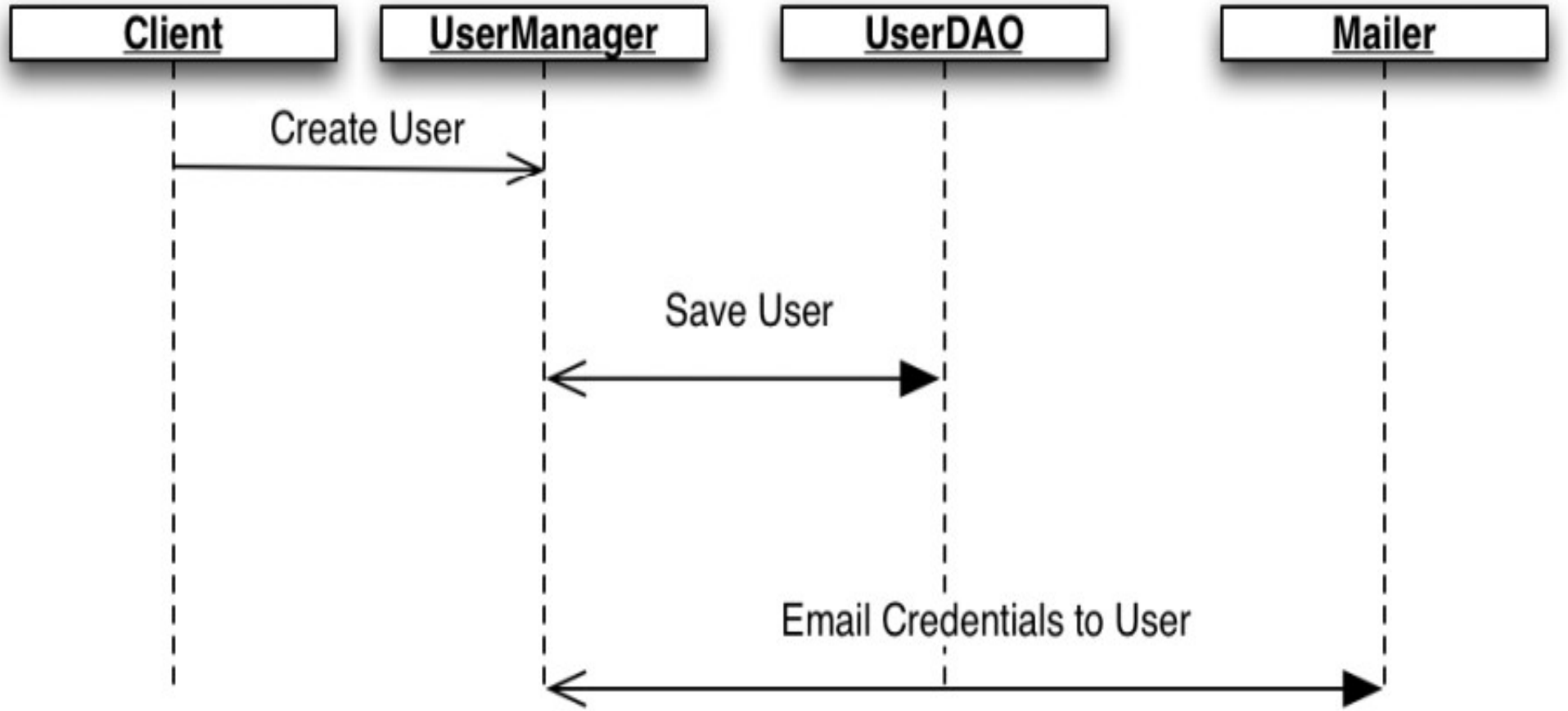
# Testing in isolation



- Testing in isolation offers strong benefits
  - Test code that have not been written
  - Test only a single method (behavior) without side effects from other objects
- *Focused* Integration Testing (!!)
- Solutions ?
  - Stubs
  - Mocks
  - …

# Testing in Isolation: example





# Solution with stubs

```
public class UserDAOStub implements UserDAO {
    public boolean saveUser(String name) {
        return true;
    }
}

public class MailerStub implements Mailer {
    private List<String> mails = new ArrayList<String>();

    public boolean sendMail(String to, String subject,
    String body) {
        mails.add(to);
        return true;
    }

    public List<String> getMails() {
        return mails;
    }
}

[...]

@Test
public void verifyCreateUser() {
    UserManager manager = new UserManagerImpl();
    MailerStub mailer = new MailerStub();
    manager.setMailer(mailer);
    manager.setDAO(new UserDAOStub());
    manager.createUser("tester");
    assert mailer.getMails().size() == 1;
}
```

# Solution with Mocks

```
@Test
public void createUser() {
    // create the instance we'd like to test
    UserManager manager = new UserManagerImpl();
    // create the dependencies we'd like mocked
    Mock mailer = mock(Mailer.class);
    Mock dao = mock(UserDAO.class);
    // wire them up to our primary component, the user manager
    manager.setMailer((Mailer)mailer.proxy());
    manager.setDAO((UserDAO)dao.proxy());
    // specify expectations
    dao.saveUser() must return true;
    expect invocation dao.saveUser() with parameter "tester";
    dao.sendMail must return true;
    expect invocation dao.sendMail with parameter "tester"
    // invoke our method
    manager.createUser("tester");
    // verify that expectations have been met
    verifyExpectations();
}
```

# Key Ideas



(Ignoring the specifics of codes)

- Mocks do not provide our own implementation of the components we'd like to swap in

- Main Difference:
  - Mocks test behavior and interactions between components
  - Stubs replace heavyweight process that are not relevant to a particular test with simple implementations

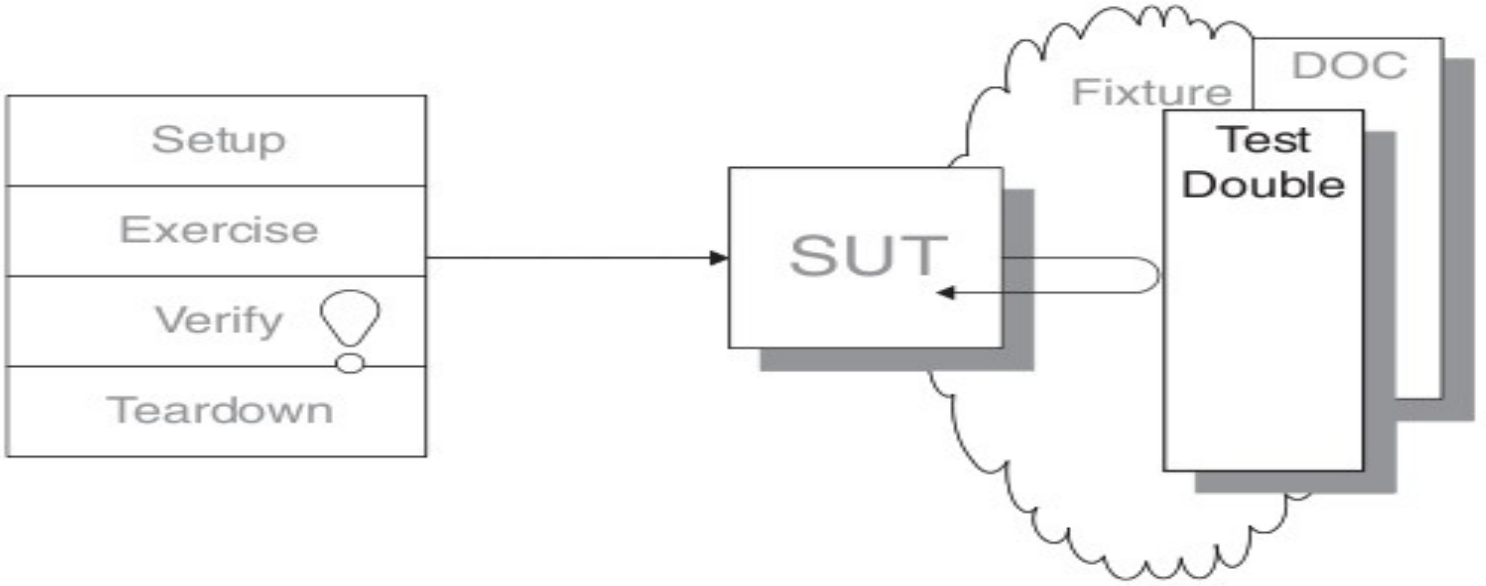
# Naming Problems and Buzz Worlds



- Unfortunately, while two components are quite distinct, they're used interchangeably.
  - Example: `spring-mock package`
- If we want to be stricter in terms of naming, stub objects defined previously are
  - **test doubles**
- Test Doubles, Stubs, Mocks, Fake Objects... *how can we work it out ?*

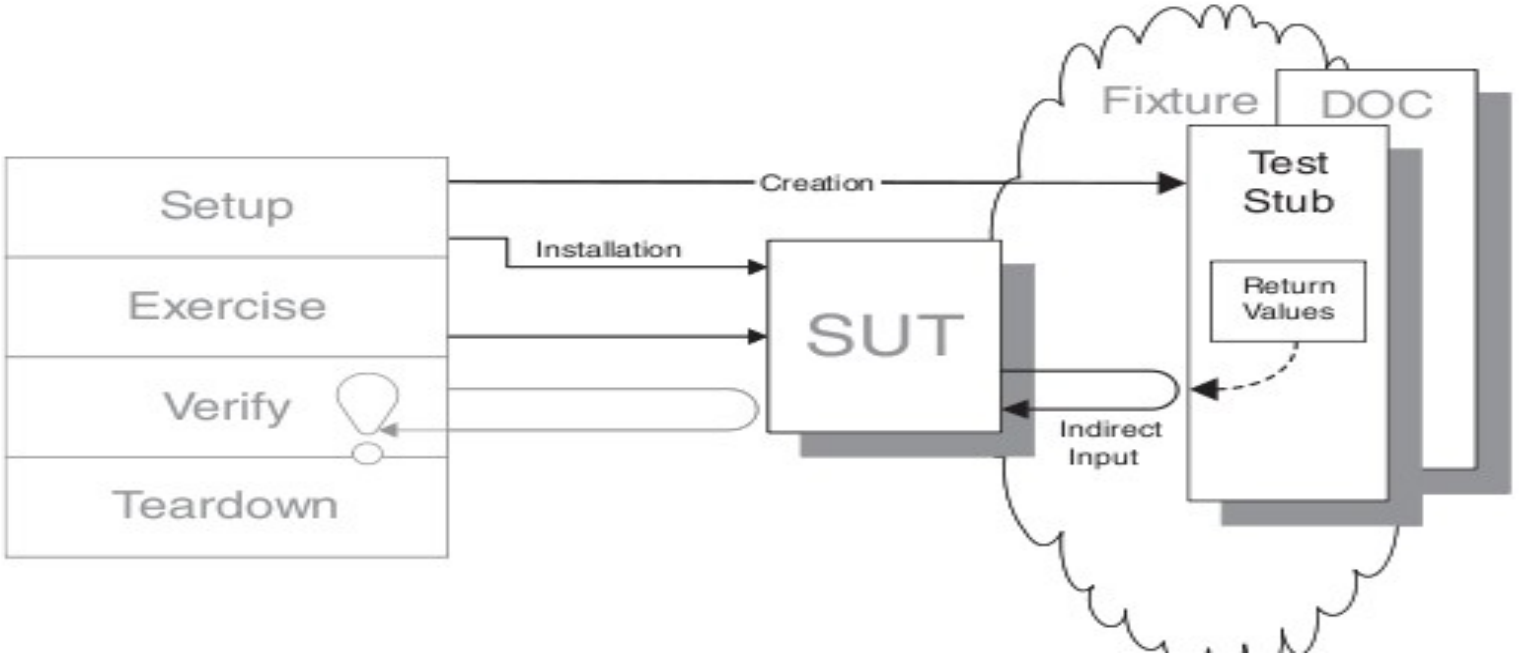
# Test Double Pattern (a.k.a. Imposter)






- Q: How can we verify logic independently when code it depends on is unusable?
  - Q1: How we can avoid slow tests ?
- A: We replace a component on which the SUT depends with a “test-specific equivalent.”

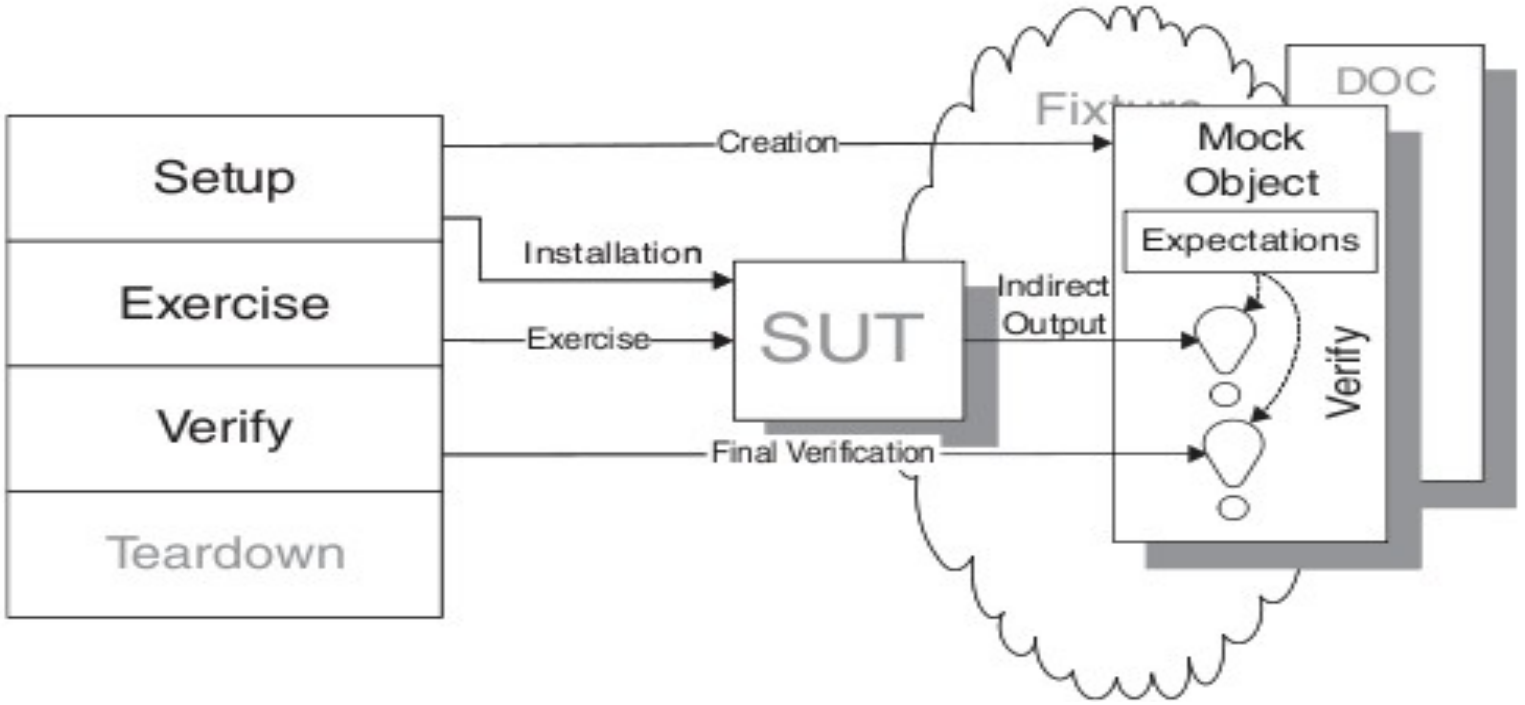
# Test Stub Pattern




- Q: How can we verify logic independently when it depends on indirect inputs from other software components ?
- A: We replace a real objects with a test-specific object that feeds the desired inputs into the SUT

# Mocks Objects






- Q: How can we implement Behavior Verification for indirect outputs of the SUT ?
- A: We replace an object on which the SUT depends on with a test-specific object that verifies it is being used correctly by the SUT.

# Mock Objects Observations



- Powerful way to implement Behavior Verification
  - while avoiding Test Code Duplication between similar tests.
- It works by delegating the job of verifying the indirect outputs of the SUT entirely to a Test Double.
- Important Note: **Design for Mockability**
  - **Dependency Injection Pattern**

# Design for Mockability



- Dependency Injection

```
public void doWork1() {
  B b = B.getInstance();
  b.doSomething();
}
```

```
private B b;

public void setB(B b) {
  this.b = b;
}
```

# Design for Mockability



- **Q: How much are the directions in which we could slice functionalities of the system under test?**
- **A:**
  - **Vertical Slicing**
  - **Horizontal Slicing**
-

# Mock Libraries



- Two main design philosphy:
  - DSL Libraries
  - Record/Replay Models Libraries
- Record Replay Frameworks
  - First train mocks and then verify expectations
- DSL Frameworks
  - Domain Specific Languages
  - Specifications embedded in “Java” Code

# Mocking with EasyMock

```
import static org.easymock.EasyMock.*;

public class EasyMockUserManagerTest {
    @Test
    public void createUser() {
        // create the instance we'd like to test
        UserManager manager = new UserManagerImpl();
        UserDAO dao = createMock(UserDAO.class);
        Mailer mailer = createMock(Mailer.class);
        manager.setDAO(dao);
        manager.setMailer(mailer);
        // record expectations
        expect(dao.saveUser("tester")).andReturn(true);
        expect(mailer.sendMail(eq("tester"), (String)notNull(),
        (String)notNull())).andReturn(true);
        replay(dao, mailer);
        // invoke our method
        manager.createUser("tester");
        // verify that expectations have been met
        verify(mailer, dao);
    }
}
```

# EasyMock Test



- Create Mock objects
  - Java Reflections API
- Record Expectation
  - `expect methods`
- Invoke Primary Test
  - `replay method`
- Verify Expectation
  - `verify method`

# JMock Example



```
import org.jmock.Mockery;
import org.jmock.integration.junit4.JMock;
import org.jmock.integration.junit4.JUnit4Mockery;
import org.jmock.Expectations;

@RunWith( JMock.class )
public class TestAccountServiceJMock
{
    private Mockery context = new JUnit4Mockery();
    private AccountManager mockAccountManager;
        @Before
        public void setUp()
        {
            UserDAO dao = context.mock(UserDAO.class);
            Mailer mailer = context.mock(Mailer.class);
        }
    @Test
    public void createUser()
    {
        UserManager manager = new UserManagerImpl();
        // Set Mocks
        UserDAO dao = createMock(UserDAO.class);
        Mailer mailer = createMock(Mailer.class);
        manager.setDAO(dao);
        manager.setMailer(mailer);
         // invoke our method
        manager.createUser("tester");
        context.checking( new Expectations() {
            {
                oneOf(dao).saveUser("tester");
                will(returnValue(true));
                oneOf(mailer).sendMail("tester",(String)notNull(),(String)notNull());
                will( returnValue(true) );
            } } }}
```

# JMock features



- JMock syntax relies heavily on chained method calls
  - Sometimes difficult to decipher and debbuger

- **Common Pattern:**

```
invocation-count (mockobject).method(arguments);
inSequence(sequence-name);
when(state-machine.is(state-name));
will(action);
then(state-machine.is(new-state name));
```

# JMock Working Example

# JMock features (intro)



- JMock previsous versions required subclassing
  - Not so smart in testing
  - Now directly integrated with Junit4
  - JMock tests requires more typing
- JMock API is extensible

# JMock Example

```
import org.jmock.Expectations;
import org.jmock.Mockery;
import org.jmock.integration.junit4.jMock;
import org.jmock.integration.junit4.JUnit4Mockery;

@RunWith(JMock.class)
public class TurtleDriverTest {
  private final Mockery context = new JUnit4Mockery() ;
  private final Turtle turtle = context. mock(Turtle. class);

  @Test public void
  goesAMinimumDistance() {
    final Turtle turtle2 = context.mock(Turtle.class, "turtle2");
    final TurtleDriver driver = new TurtleDriver(turtle1, turtle2) ; // set up
    context. checking(new Expectations() {{ // expectations
      ignoring (turtle2);
      allowing (turtle). flashLEDs();
      oneOf (turtle). turn(45);
      oneOf (turtle). forward(with(greaterThan(20)));
      atLeast(1).of (turtle).stop();
    }});
    driver. goNext(45); // call the code
    assertTrue("driver has moved", driver. hasMoved() ) ; // further assertions
  }
}
```

# 1. Test Fixture

```
import org.jmock.Expectations;
import org.jmock.Mockery;
import org.jmock.integration.junit4.jMock;
import org.jmock.integration.junit4.JUnit4Mockery;

@RunWith(JMock.class)
public class TurtleDriverTest {
  private final Mockery context = new JUnit4Mockery() ;
```

- Mockery represents the *context*
  - Neighboring objects it will communicate with
  - By convention the mockery is stored in an istance variable named `context`
- `@RunWith(JMock.class)` annotation
- `JUnit4Mockery` reports expectation failures as JUnit4 test failures

# 2. Create Mock Objects

```
private final Turtle turtle = context. mock(Turtle. class);

final Turtle turtle2 = context.mock(Turtle.class, "turtle2");
```

- The tests has two mock turtles
  - The first is a field in the test class
  - The second is local to the test
- References (fields and Vars) have to be **`final`**
  - Accessible from Anonymous `Expectations`
- The second mock has a specified name
  - JMock enforces usage of names except for the first (default)
  - This makes failures reporting more clear

# 3. Tests with Expectations

```
context. checking(new Expectations() {{ // expectations
  ignoring (turtle2);
  allowing (turtle). flashLEDs();
  oneOf (turtle). turn(45);
  oneOf (turtle). forward(with(greaterThan(20)));
  atLeast(1).of (turtle).stop();
}});
```

- A test sets up it expectations in one or more *expectation blocks*
  - An expectation block can contain any number of expectations
  - Expectation blocks can be interleaved with calls to the code under test.

# 3. Tests with Expectations

```
context. checking(new Expectations() {{ // expectations
  ignoring (turtle2);
  allowing (turtle). flashLEDs();
  oneOf (turtle). turn(45);
  oneOf (turtle). forward(with(greaterThan(20)));
  atLeast(1).of (turtle).stop();
}});
```

- Expectations have the following structure:

```
invocation-count
(mockobject).method(arguments);

inSequence(sequence-name);

when(state-machine.is(state-name));

will(action);

then(state-machine.is(new-state name));
```

# What's with the double braces?



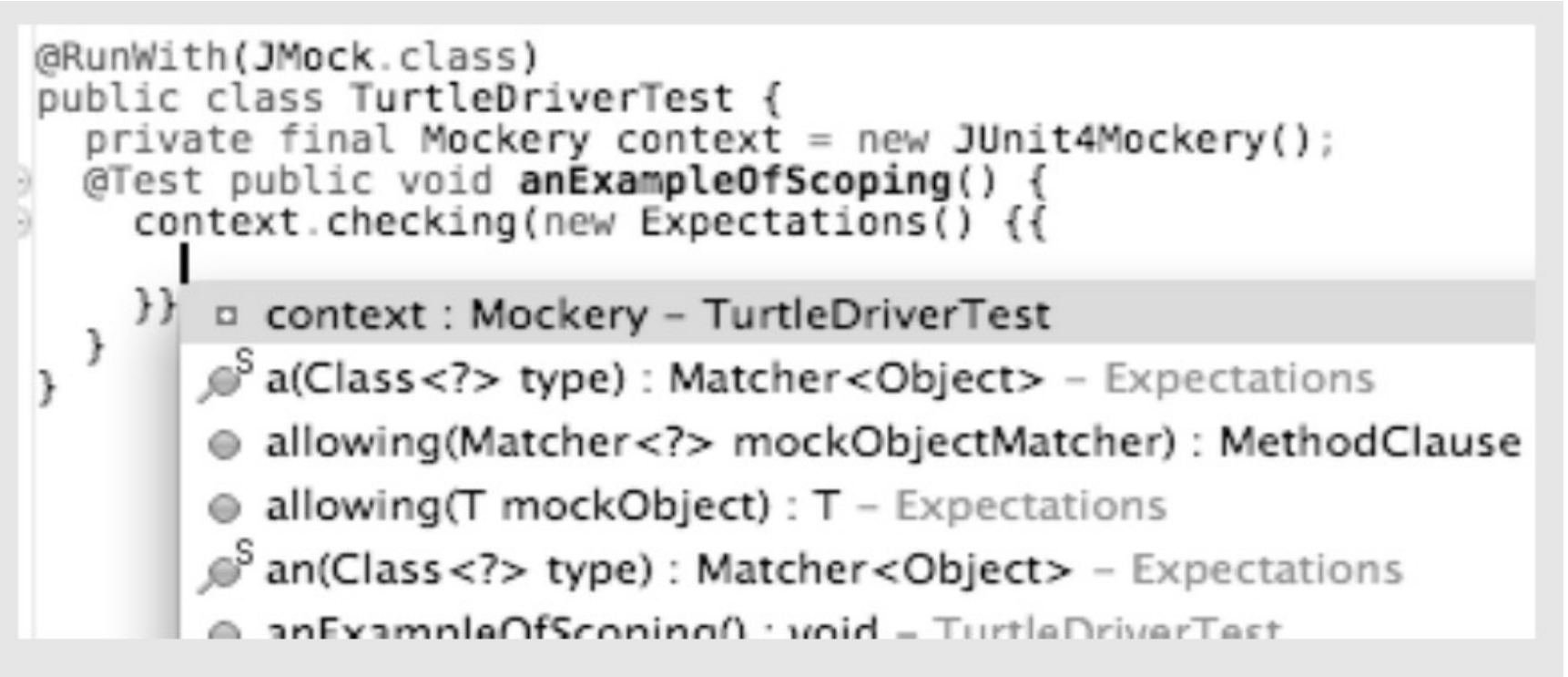
```
context.checking(new Expectations(){{
        oneOf(turtle).turn(45);
   }});
```

- Anonymous subclass of `Expectations`
- Baroque structure to provide a scope for building up expectations
  - Collection of expectation components
  - Is an example of **Builder Pattern**
  - Improves code completion

# What's with the double braces?



```
context.checking(new Expectations(){{
        oneOf(turtle).turn(45);
   }});
```



# Allowances and Expectations



```
context.checking(new Expectations(){{
   ignoring (turtle2);
   allowing (turtle).flashLEDs();
   oneOf(turtle).turn(45);
}});
```

- *Expectations* describe the interactions that are **essential** to the protocol we're testing
- *Allowances* **support** the interaction we're testing
  - `ignoring()` clause says that we don't care about messages sent to `turtle2`
  - `allowing()` clause matches any call to `flashLEDs` of `turtle`

# Allowances and Expectations



```
context.checking(new Expectations(){{
   ignoring (turtle2);
   allowing (turtle).flashLEDs();
   oneOf(turtle).turn(45);
}});
```

- Distintion between *allowances* and *expectations* is not rigid
- **Rule of Thumb:**
  - ***Allow queries; Expect Commands***
- **Why?**
  - Commands could have side effects;
  - Queries don't change the world.

# Dependency injection issues?

- **Too Many Dependencies**
  - Ideas??

```
public class RacingCar {
    private final Track track;
    private Tyres tyres;
    private Suspension suspension;
    private Wing frontWing;
    private Wing backWing;
    private double fuelLoad;
    private CarListener listener;
    private DrivingStrategy driver;

    public RacingCar(Track track, DrivingStrategy driver, Tyres tyres,
                     Suspension suspension, Wing frontWing, Wing backWing,
                     double fuelLoad, CarListener listener)
    {
        this.track = track;
        this.driver = driver;
        this.tyres = tyres;
        this.suspension = suspension;
        this.frontWing = frontWing;
        this.backWing = backWing;
        this.fuelLoad = fuelLoad;
        this.listener = listener;
    }
}
```

# Dependency injection issues?

- Dependency injection for mockability



```
public class RacingCar {
    private final Track track;
    private DrivingStrategy driver = DriverTypes.borderlineAggressiveDriving();
    private Tyres tyres = TyreTypes.mediumSlicks();
    private Suspension suspension = SuspensionTypes.mediumStiffness();
    private Wing frontWing = WingTypes.mediumDownforce();
    private Wing backWing = WingTypes.mediumDownforce();
    private double fuelLoad = 0.5;
    private CarListener listener = CarListener.NONE;

    public RacingCar(Track track) {
        this.track = track;
    }

    public void setSuspension(Suspension suspension) { [...]
    public void setTyres(Tyres tyres) { [...]
    public void setEngine(Engine engine) { [...]
    public void setListener(CarListener listener) { [...]
}
```

# Expectations or … ?

- **Too Many Expectations**
  - Ideas??

```
//Production code
public void adjudicateIfReady(ThirdParty thirdParty, Issue issue) {
    if (firstParty.isReady()) {
        Adjudicator adjudicator = organization.getAdjudicator(); //getter
        Case acase = adjudicator.findCase(firstParty, issue); // Lookup
        thirdParty.proceedWith(acase);
    }
    else
        thirdParty.adjourn();
}
```

```
//Test Code
@Test public void decidesCasesWhenFirstPartyIsReady() {
    context.checking(new Expectations(){{
        one(firstPart).isReady(); will(returnValue(true));
        one(organizer).getAdjudicator(); will(returnValue(adjudicator));
        one(adjudicator).findCase(firstParty, issue); will(returnValue(acase));
        one(thirdParty).proceedWith(acase);
    }});

    claimsProcessor.adjudicateIfReady(thirdParty, issue);
}
```

# Expectations or … ?

- **Too Many Expectations**
  - Ideas??

```
//Production code
public void adjudicateIfReady(ThirdParty thirdParty, Issue issue) {
    if (firstParty.isReady()) {
        Adjudicator adjudicator = organization.getAdjudicator(); //getter
        Case acase = adjudicator.findCase(firstParty, issue); // Lookup
        thirdParty.proceedWith(acase);
    }
    else
        thirdParty.adjourn();
}
```

```
//Refactored Test Code
@Test public void decidesCasesWhenFirstPartyIsReady() {
    context.checking(new Expectations(){{
        allowing(firstPart).isReady(); will(returnValue(true));
        allowing(organizer).getAdjudicator(); will(returnValue(adjudicator));
        allowing(adjudicator).findCase(firstParty, issue); will(returnValue(acase));

        one(thirdParty).proceedWith(acase);
    }});

    claimsProcessor.adjudicateIfReady(thirdParty, issue);
}
```

# Expectations or … ?

- **Too Many Expectations**
  - Ideas??



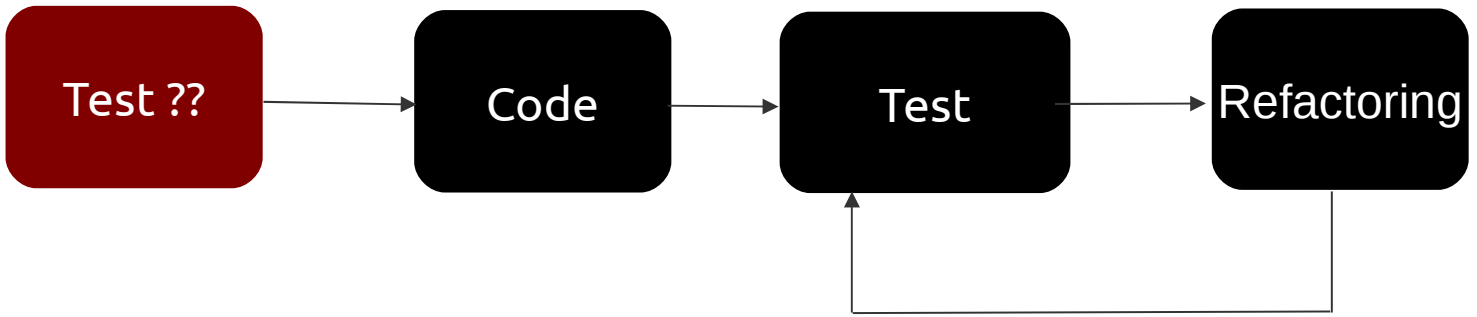
```
//Refactored Production Code
public void adjudicateIfReady(ThirdParty thirdParty, Issue issue) {
    if (firstParty.isReady())
        thirdParty.startAdjudication(organization, firstParty, issue);
    else
        thirdParty.adjourn();
}
```

```
//Refactored Test Code
@Test public void decidesCasesWhenFirstPartyIsReady() {
    context.checking(new Expectations(){{
        allowing(firstPart).isReady(); will(returnValue(true));
        allowing(organizer).getAdjudicator(); will(returnValue(adjudicator));
        allowing(adjudicator).findCase(firstParty, issue); will(returnValue(acase));

        one(thirdParty).proceedWith(acase);
    }});

    claimsProcessor.adjudicateIfReady(thirdParty, issue);
}
```

# Development process



- Let's think about the development process of this example:




- **Q: Does make sense to write tests before writing production code?**
- **A: Two Keywords**
  - **TDD:** Test Driven Development
  - **Test-first Programming**

# Mocks and Stubs Pitfall



- False sense of security
- Maintenance Overhead
  - Keep mocks up2date with test and producton code
  - *Example:*
    - *UserManager won't send mail no more*
  - Maintenance headaches in making test code to run

# References

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