

# CS1632: Unit Testing, part 1

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# What is unit testing?

- **Unit testing:** testing small "units" of code instead of whole system
  - Units can be subsystems, modules, all the way down to individual methods
  - Most commonly refers to testing methods by directly invoking them
  - White-box testing, typically automated by a testing script
- Goal: Ensure unit works independent of rest of the system
  - Does NOT ensure that units work together well when integrated
  - Need **integration testing** for that purpose

# Why Unit Test?

System

```
class Game {  
    public static void main() {  
        control.getInput();  
        display.show();  
    }  
}
```

Subsystems

```
class Control {  
    public String getInput() {  
        mouse.getInput();  
        keyboard.getInput();  
    }  
}
```

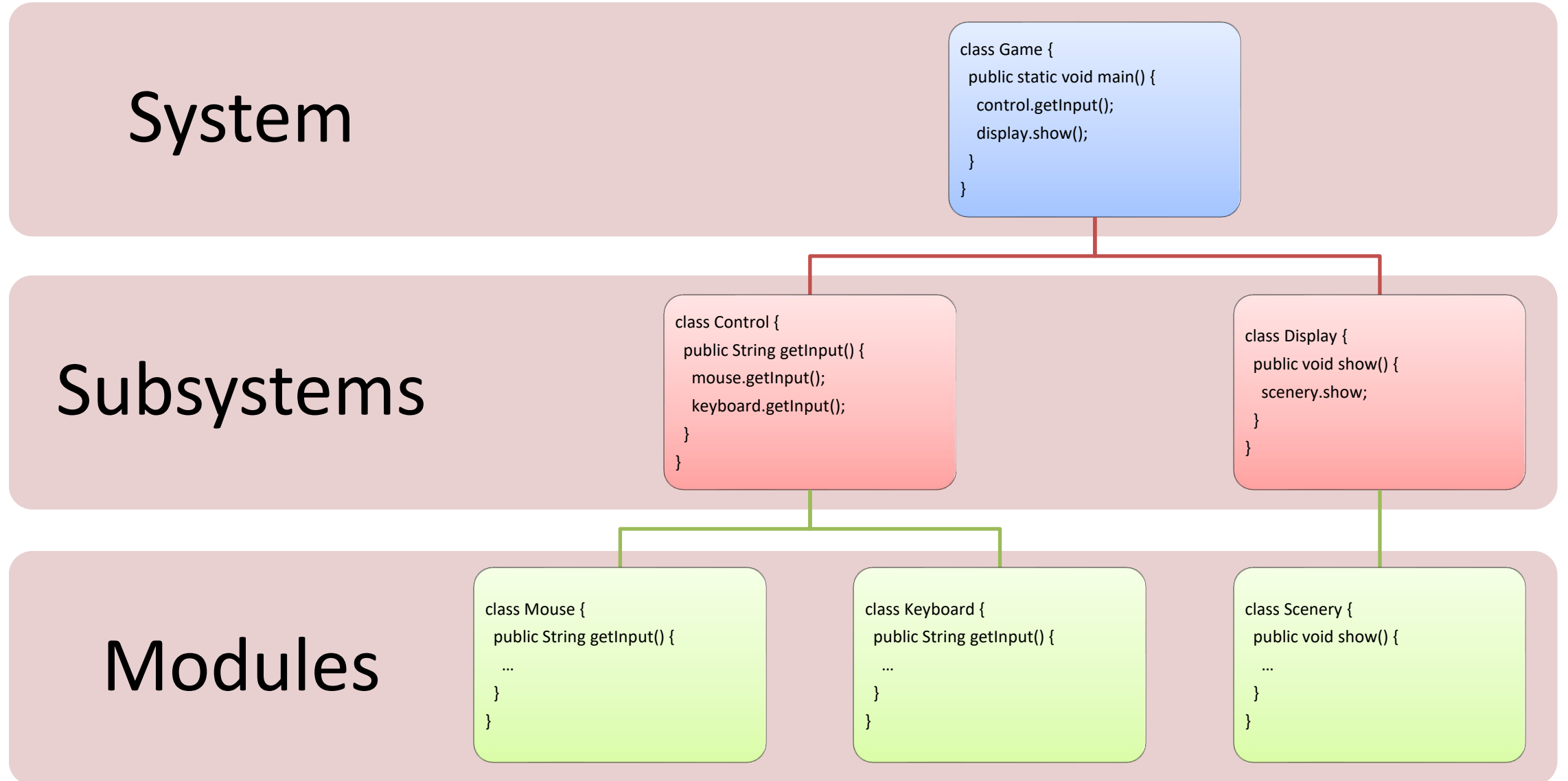
```
class Display {  
    public void show() {  
        scenery.show;  
    }  
}
```

Modules

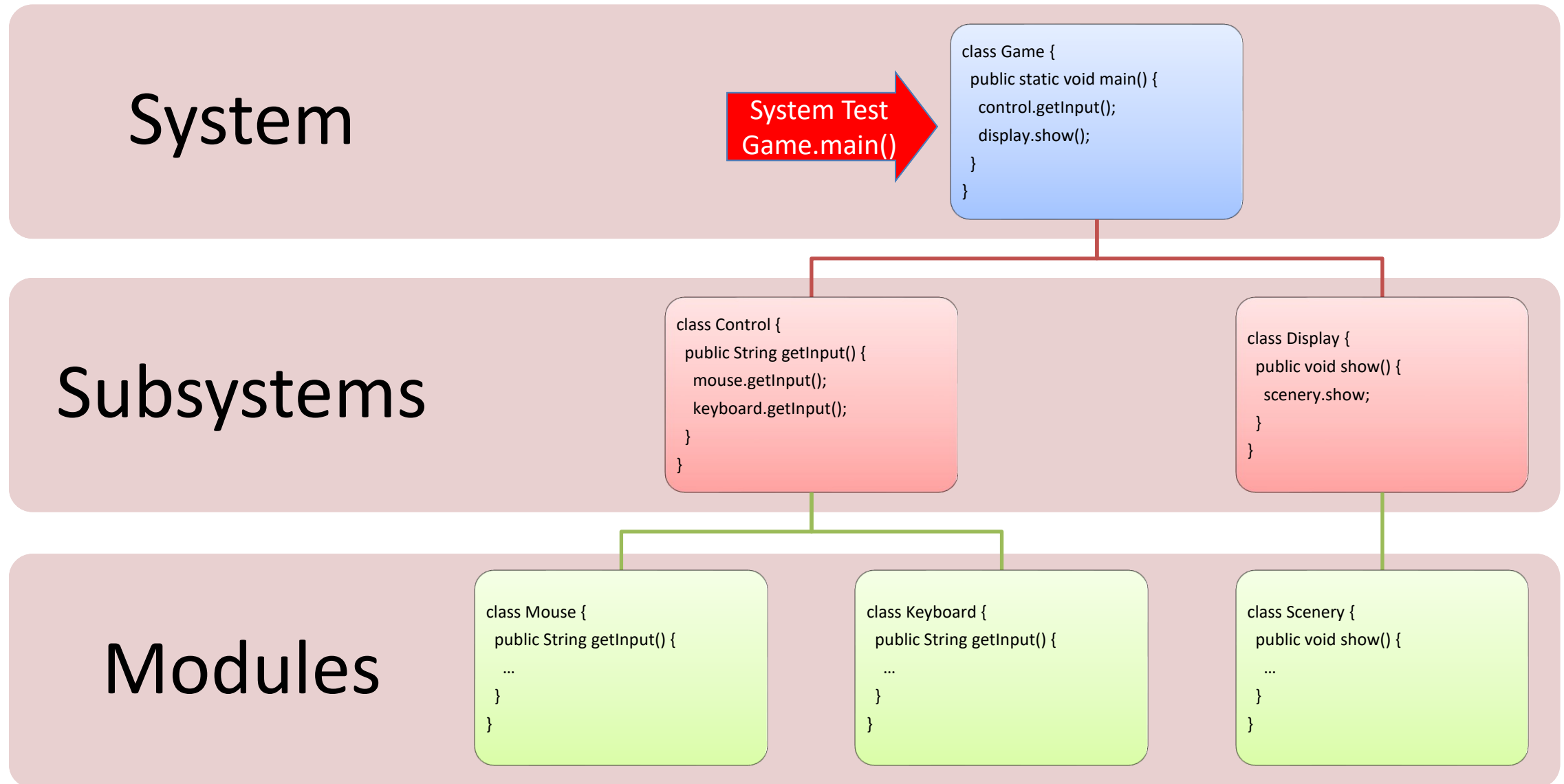
```
class Mouse {  
    public String getInput() {  
        ...  
    }  
}
```

```
class Keyboard {  
    public String getInput() {  
        ...  
    }  
}
```

```
class Scenery {  
    public void show() {  
        ...  
    }  
}
```



# System Test tests Everything. What's the point?



# What if System Test Fails? Where's the Bug?

System

System Test  
Game.main()

```
class Game {  
    public static void main() {  
        control.getInput();  
        display.show();  
    }  
}
```

Subsystems

```
class Control {  
    public String getInput() {  
        mouse.getInput();  
        keyboard.getInput();  
    }  
}
```

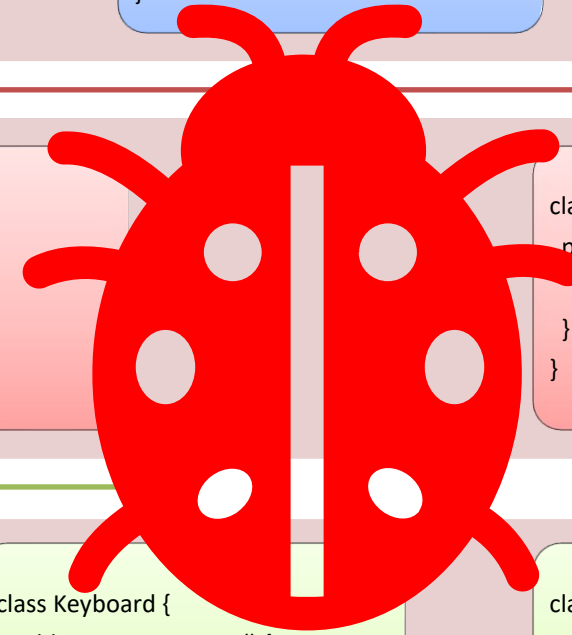
```
class Display {  
    public void show() {  
        scenery.show;  
    }  
}
```

Modules

```
class Mouse {  
    public String getInput() {  
        ...  
    }  
}
```

```
class Keyboard {  
    public String getInput() {  
        ...  
    }  
}
```

```
class Scenery {  
    public void show() {  
        ...  
    }  
}
```



Could be anywhere!

# 1. Unit Testing Localizes the Bug

System

Unit Test  
Passes

```
class Game {  
    public static void main() {  
        control.getInput();  
        display.show();  
    }  
}
```

Subsystems

Unit Test  
Fails!

```
class Control {  
    public String getInput() {  
        mouse.getInput();  
        keyboard.getInput();  
    }  
}
```



Right here!

Unit Test  
Passes

```
class Display {  
    public void show() {  
        scenery.show;  
    }  
}
```

Module

Unit Test  
Passes

```
class Mouse {  
    public String getInput() {  
        ...  
    }  
}
```

Unit Test  
Passes

```
class Keyboard {  
    public String getInput() {  
        ...  
    }  
}
```

Unit Test  
Passes

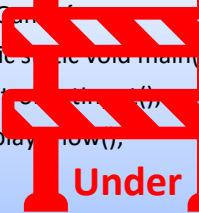
```
class Scenery {  
    public void show() {  
        ...  
    }  
}
```

# What if System is Being Built? Can it be Tested?

System

Cannot  
Test System!

```
class Control {  
    public static void main()  
    {  
        control.getInput();  
        display.show();  
    }  
}
```



Under  
Construction

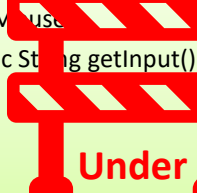
Subsystems

```
class Control {  
    public String getInput() {  
        mouse.getInput();  
        keyboard.getInput();  
    }  
}
```

```
class Display {  
    public void show() {  
        scenery.show;  
    }  
}
```

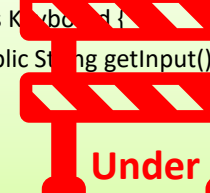
Modules

```
class Mouse {  
    public String getInput()  
    ...  
}
```



Under  
Construction

```
class Keyboard {  
    public String getInput()  
    ...  
}
```

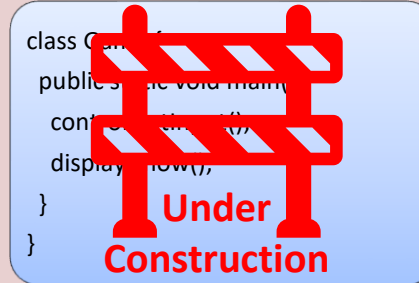


Under  
Construction

```
class Scenery {  
    public void show() {  
        ...  
    }  
}
```

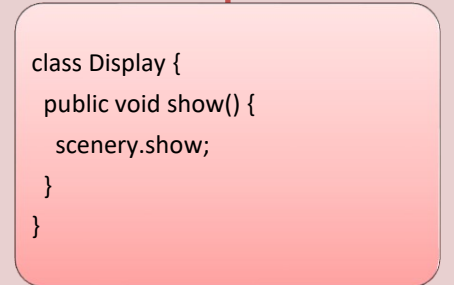
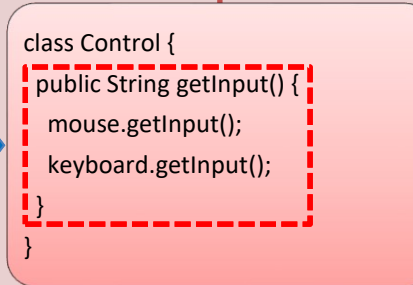
## 2. Unit Testing Allows Testing Early On

System

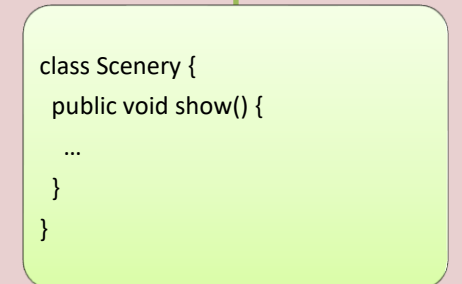
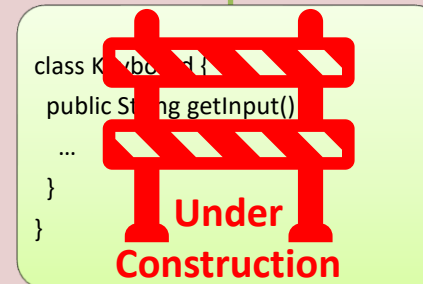
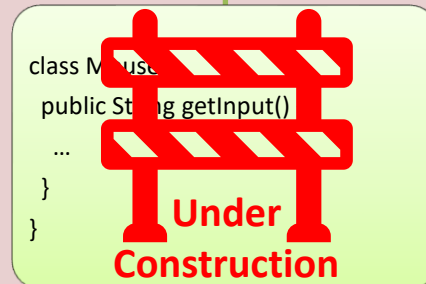


Subsystems

Can still  
Unit Test!



Modules





# Unit Testing is Done by Developers

## Unit Test Code

```
class ControlTest {  
    @Test  
    public void testGetInput() {  
        String str = control.getInput();  
        // Do postcondition checks on str  
    }  
}
```

## Unit Implementation Code

```
class Control {  
    public String getInput() {  
        String str = mouse.getInput();  
        str += keyboard.getInput();  
        return str;  
    }  
}
```

- Unit test code is developed in concert with implementation code
  - In Test Driven Development (TDD), test code is written before implementation
- Developers know best about the behavior of individual methods
- Allows immediate testing without waiting for other units to complete

# Why do Unit Testing?

1. Can localize defects to a small unit of code
  - Easier to locate bug compared having to scan entire code base
2. Can perform testing early on during development (a.k.a. **shift left**)
  - Unit tests can be made into a regression test suite with good coverage
3. Unit tests serve as “living documentation”
  - Unit tests can be viewed as a documentation of expected behavior
  - Documentation is living because tests will fail if they become stale

# JUnit Framework

- **JUnit**: A framework for automated unit testing of Java programs
- Composed of **annotations + assertions**

# JUnit Annotations

- Annotations are used to indicate special methods to JUnit:
  - `@Test`: A method that is run as a **test case** when JUnit is invoked
  - `@Before`: A method that sets up a common set of **preconditions** before running each test case (a.k.a. **test fixture**)
  - `@After`: A method that tears down the test fixture set up by `@Before` (if it involves external resources such as files, databases)
- A JUnit test class has multiple `@Test` methods but only one set of `@Before` and `@After` methods.
  - Typically, one JUnit test class tests all methods of an implementation class

# JUnit Assertions

- Assertions are used to check **postconditions**:
  - `assertEquals`, `assertArrayEquals`, `assertSame`, `assertNotSame`, `assertTrue`, `assertFalse`, `assertNull`, `assertNotNull`, `fail()`, ...
  - `assertSame(Object expected, Object actual)`:  
Asserts that two references refer to the same object
  - `assertEquals(Object expected, Object actual)`:  
Asserts that two objects are equal
  - `fail()`:  
Always fails. Indicates code location that should not be reached.
- Refer to JUnit reference for more assertions:
  - <http://junit.sourceforge.net/javadoc/org/junit/Assert.html>

# Example JUnit Test Class

## JUnit Test Class

```
class CatTest {  
    @Test void testIsRented() {  
        // Precondition setup  
        Cat cat = new Cat();  
        cat.rent();  
        // Execution step  
        boolean ret = cat.IsRented();  
        // Postcondition check  
        assertTrue(ret);  
    }  
    @Test void testToString() {  
        Cat cat = new Cat();  
        String ret = cat.toString();  
        assertEquals("available cat", ret);  
    }  
}
```

## Implementation Class

```
class Cat {  
    boolean rented = false;  
    public void rent() {  
        rented = true;  
    }  
    public boolean isRented() {  
        return rented;  
    }  
    public String toString() {  
        if (rented) {  
            return "rented cat";  
        } else {  
            return "available cat";  
        }  
    }  
}
```

# Example JUnit Test Class – Using a Test Fixture

## JUnit Test Class

```
class CatTest {  
    Cat cat;  
    @Before void setUp() {  
        // Test fixture setup  
        cat = new Cat();  
    }  
    @Test void testIsRented() {  
        cat.rent();  
        boolean ret = cat.IsRented();  
        assertTrue(ret);  
    }  
    @Test void testToString() {  
        String ret = cat.toString();  
        assertEquals("available cat", ret);  
    }  
}
```

## Implementation Class

```
class Cat {  
    boolean rented = false;  
    public void rent() {  
        rented = true;  
    }  
    public boolean isRented() {  
        return rented;  
    }  
    public String toString() {  
        if (rented) {  
            return "rented cat";  
        } else {  
            return "available cat";  
        }  
    }  
}
```

# Wrong JUnit Test Class – Can you see why?

## JUnit Test Class

```
class CatTest {  
    // Initialize cat  
    Cat cat = new Cat();  
  
    @Test void testIsRented() {  
        cat.rent();  
        boolean ret = cat.IsRented();  
        assertTrue(ret);  
    }  
    @Test void testToString() {  
        String ret = cat.toString();  
        assertEquals("available cat", ret);  
    }  
}
```

## Implementation Class

```
class Cat {  
    boolean rented = false;  
    public void rent() {  
        rented = true;  
    }  
    public boolean isRented() {  
        return rented;  
    }  
    public String toString() {  
        if (rented) {  
            return "rented cat";  
        } else {  
            return "available cat";  
        }  
    }  
}
```



# A JUnit Test Class with Expensive Test Fixture

## JUnit Test Class

```
class DatabaseTest {  
    @Before void setUp() {  
        populateDB(A);  
    }  
    @Test void test1() {  
        // Reads A only.  
    }  
    @Test void test2() {  
        // Reads A only.  
    }  
    @After void tearDown() {  
        emptyDB(A);  
    }  
}
```

- Note **@After** is needed this time.
  - Need to empty database before repopulating for next test case.
- Having to repeatedly populate a DB is computationally expensive.
- Is there a way to optimize?

# Two More JUnit Annotations

- `@BeforeClass`: Called at start of each JUnit test class
  - Used to set up part of test fixture that is computationally expensive
  - If there is a part that is read-only, wasteful to set up repeatedly
- `@AfterClass`: Called at end of each JUnit test class
  - Used to tear down part of test fixture set up in `@BeforeClass`

# The JUnit Test Class – Optimized

## JUnit Test Class

```
class DatabaseTest {  
    @BeforeClass void setUp() {  
        populateDB(A);  
    }  
    @Test void test1() {  
        // Reads A only.  
    }  
    @Test void test2() {  
        // Reads A only.  
    }  
    @AfterClass void tearDown() {  
        emptyDB(A);  
    }  
}
```

- Note database A is read-only.
- **@Before** or **@BeforeClass** is functionally equivalent, in this case.
- But **@BeforeClass** is faster!

# The JUnit Test Class – Wrongly Optimized

## JUnit Test Class

```
class DatabaseTest {  
    @BeforeClass void setUp() {  
        populatedDB(B);  
    }  
    @Test void test1() {  
        // Reads and writes B.  
    }  
    @Test void test2() {  
        // Reads and writes B.  
    }  
    @AfterClass void tearDown() {  
        emptyDB(B);  
    }  
}
```

- Note database B is now read-write.
- Do you see the problem?

# Using fail() to Test Exception Postcondition

## JUnit Test Class

```
class CatTest {  
    @Test public void testRentTwice() {  
        Cat cat = new Cat();  
        cat.rent();  
        try {  
            cat.rent();  
            fail("No exception even when  
renting twice in a row.");  
        } catch (Exception e) {  
            // Success!  
        }  
    }  
}
```

## Implementation Class

```
class Cat {  
    boolean rented = false;  
  
    public void rent() throws Exception {  
        if (rented) {  
            throw new Exception(  
                "already rented");  
        }  
        rented = true;  
    }  
    ...  
}
```

# Public vs. Private Methods

- Java classes have two types of methods:
  - Public methods: comprises the public interface of the class
  - Private methods: “helper” methods used for internal implementation
- Q: Should we test private methods as well?
- Two approaches:
  - Test public methods only
  - Test every method – public and private

# Argument for testing public methods only

- Private methods may be inaccessible from external test classes
  - Fortunately, Java allows access through Java reflection
- Private methods get added/removed/changed all the time
  - Because they are merely helpers and not part of the public interface
  - If we test them, we may need to modify the test code frequently
- Private methods are tested as part of public methods anyway

# Private methods are tested as part of public methods

```
class Bird {  
    public int fly(int n) {  
        return flapLeft(n) + flapRight(n);  
    }  
    // Tested as part of fly call.  
    private int flapLeft(int n) { ... }  
    private int flapRight(int n) { ... }  
    // Dead code! So, no need to test anyway.  
    private void urinate(double f) { ... }  
}
```

- A test of `fly` always tests `flapLeft` and `flapRight`
- Any private method not called in `fly` is in effect *dead code*



# Argument for testing every method

- Public/private distinction is arbitrary
  - They are all methods that deserve to be unit tested
- Testing private methods helps localize a bug further
  - Able to tell exactly which private method has the bug
  - If testing only public methods, can localize only up to public methods

# Testing private methods helps localize a bug further

// Assume all the called methods are private

```
public boolean foo(boolean n) {  
    if (bar(n) && baz(n) && beta(n)) {  
        return true;  
    } else if (baz(n) ^ (thud(n) || baa(n)) {  
        return false;  
    } else if (meow(n) || chew(n) || chirp(n)) {  
        return true;  
    } else {  
        return false;  
    }  
}
```

- If `foo` fails, hard to tell which private method has the defect, or `foo` itself

# So, should we test private methods or not?

- As everything in software QA, it depends on the context.
  - Depends on the complexity of the public and private methods.
  - Depends on whether you expect private methods to change often.
- If you decide to test them, here is how...

# Testing private methods using Java Reflection

```
class Bird {  
    private int flapLeft(int n) { ... }  
}  
  
class BirdTest {  
    @Test public int testFlapLeft(int n) {  
        // Get method flapLeft which has one argument of int type.  
        Method m = Bird.class.getDeclaredMethod("flapLeft", int.class);  
        // Change method from private to public.  
        m.setAccessible(true);  
        // Pass arguments to invoke. 1st argument is always the instance.  
        Object ret = m.invoke(new Bird(), 5);  
    }  
}
```

# Now Please Read Textbook Chapter 13

- Read Textbook Chapter 24 for details about Java Reflection
- Also see `sample_code/junit_example/LinkedListTest.java`
  - For Mac/Linux: you can run all JUnit tests by “`bash runTests.sh`”
  - For Windows: you can run all JUnit tests by “`runTests.bat`”
  - Above script will invoke TestRunner to run test suite
- User manual:
  - <https://junit.org/junit5/docs/current/user-guide/>
- Reference Javadoc:
  - <http://junit.sourceforge.net/javadoc/>