CS1632:
Unit Testing, part 1

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Unit Testing

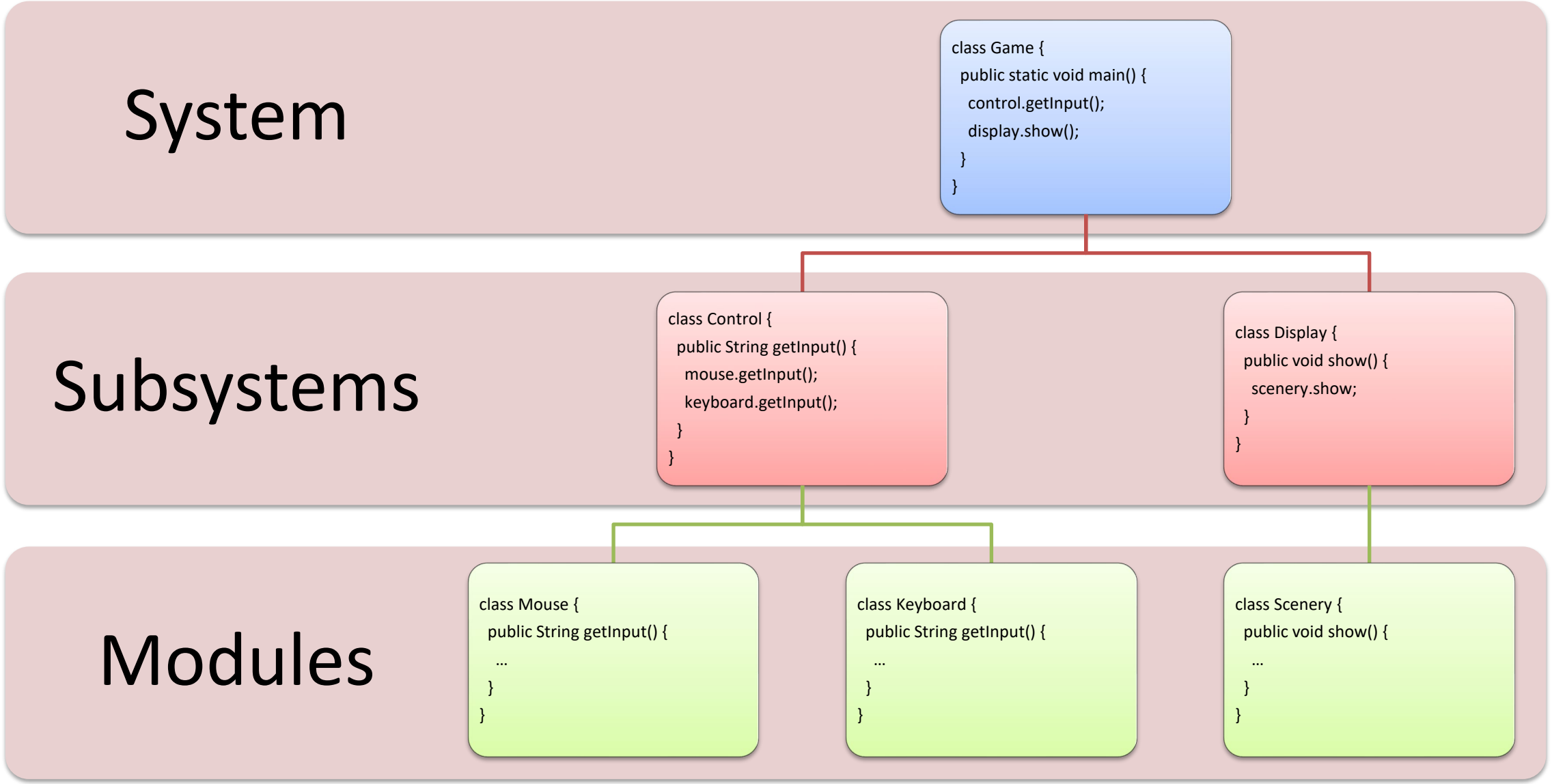
The what and why

What is unit testing?

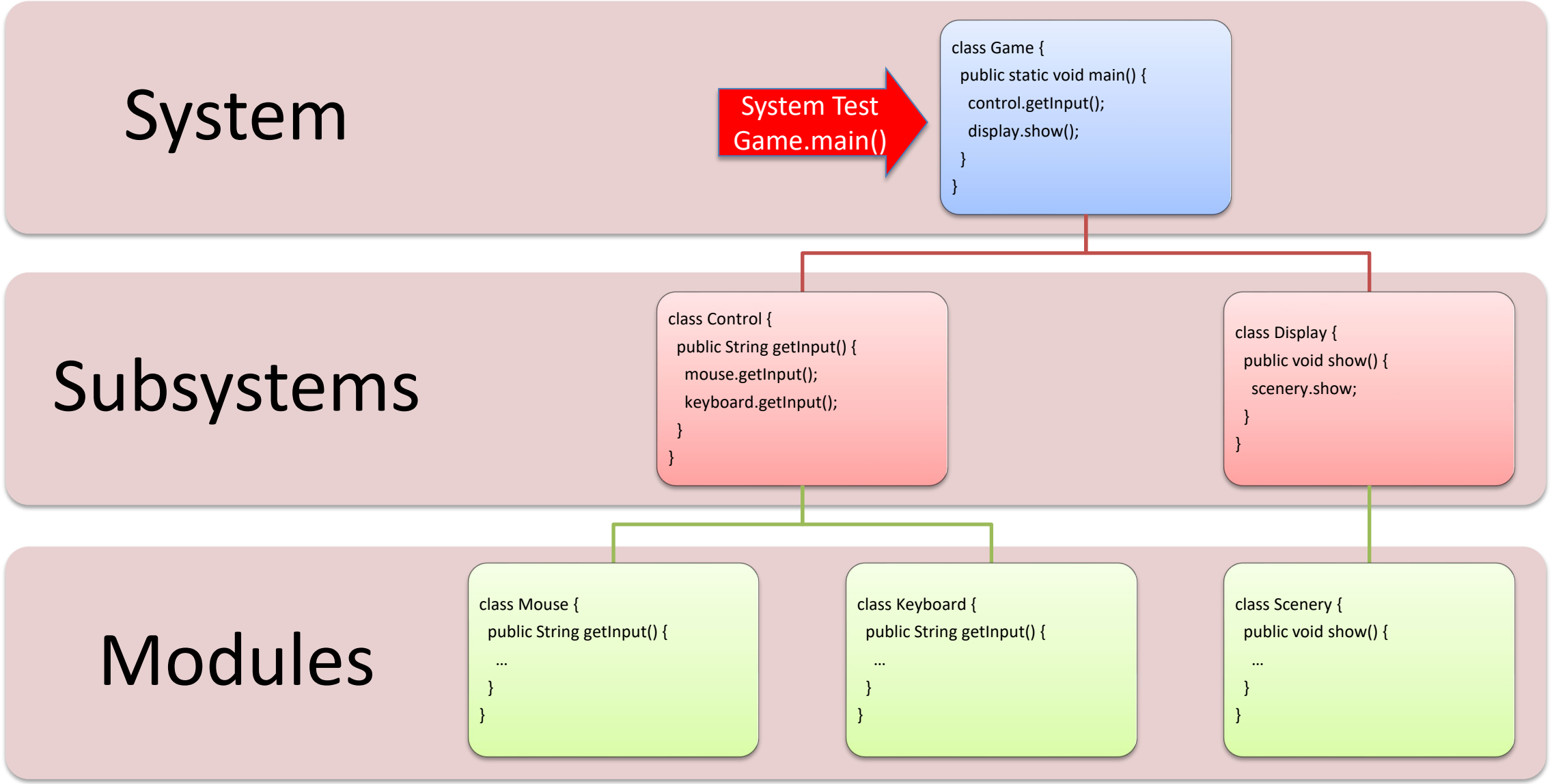
- **Unit testing**: testing small "units" of code instead of whole system
  - Units can be subsystems, modules, all the way down to individual methods
  - Most commonly refers to testing methods by directly invoking them
  - White-box testing, typically automated by a testing script

- 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 Test tests Everything. What's the point?



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

System

Subsystems

Modules

System Test
Game.main()

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

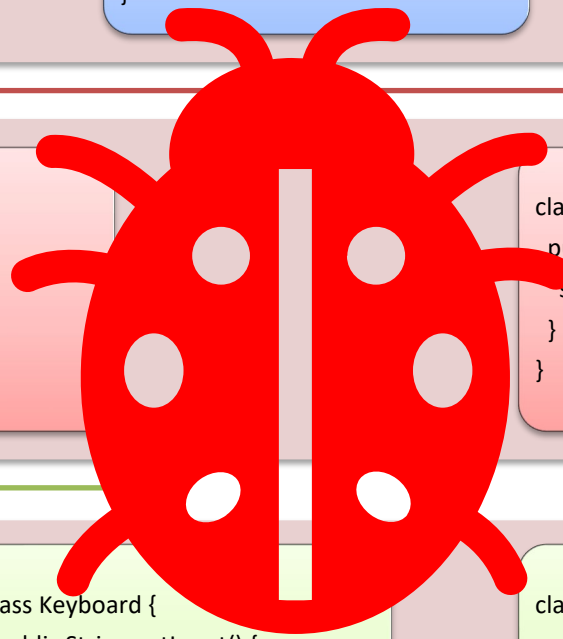
```
class Control {
  public String getInput() {
    mouse.getInput();
    keyboard.getInput();
  }
}
```

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

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

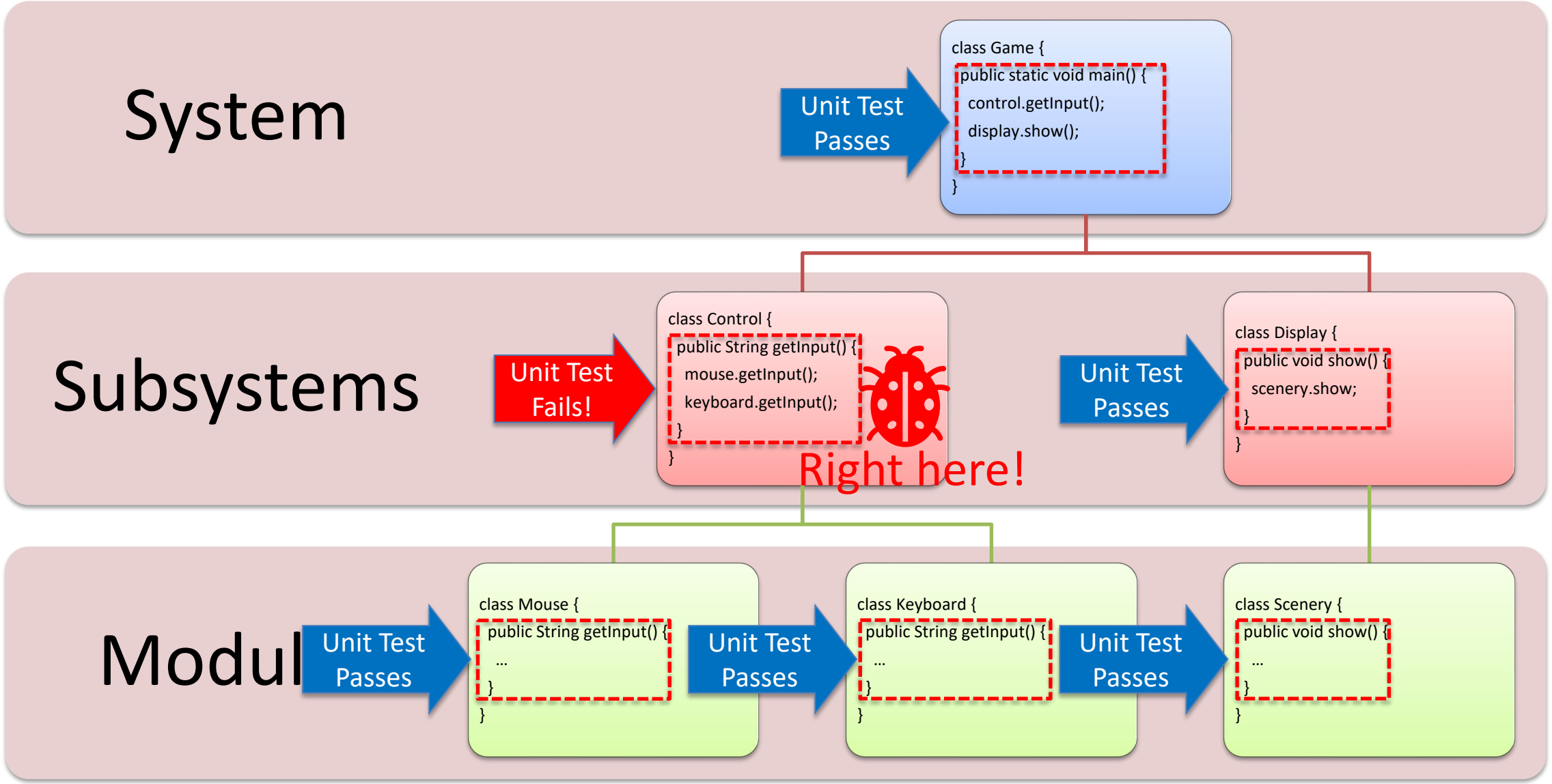
```
class Keyboard {
  public String getInput() {
    …
  }
}
```

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

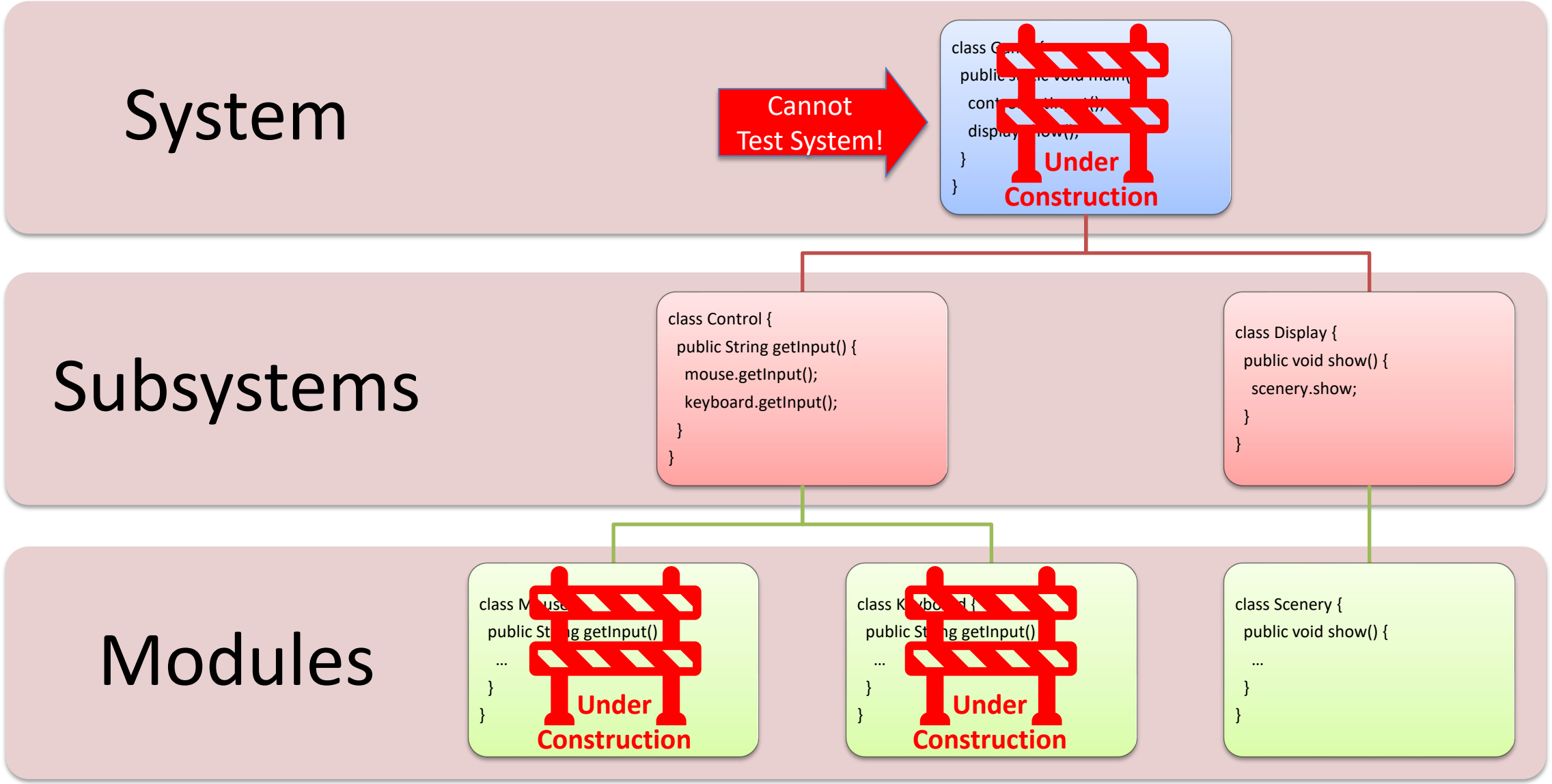


Could be anywhere!

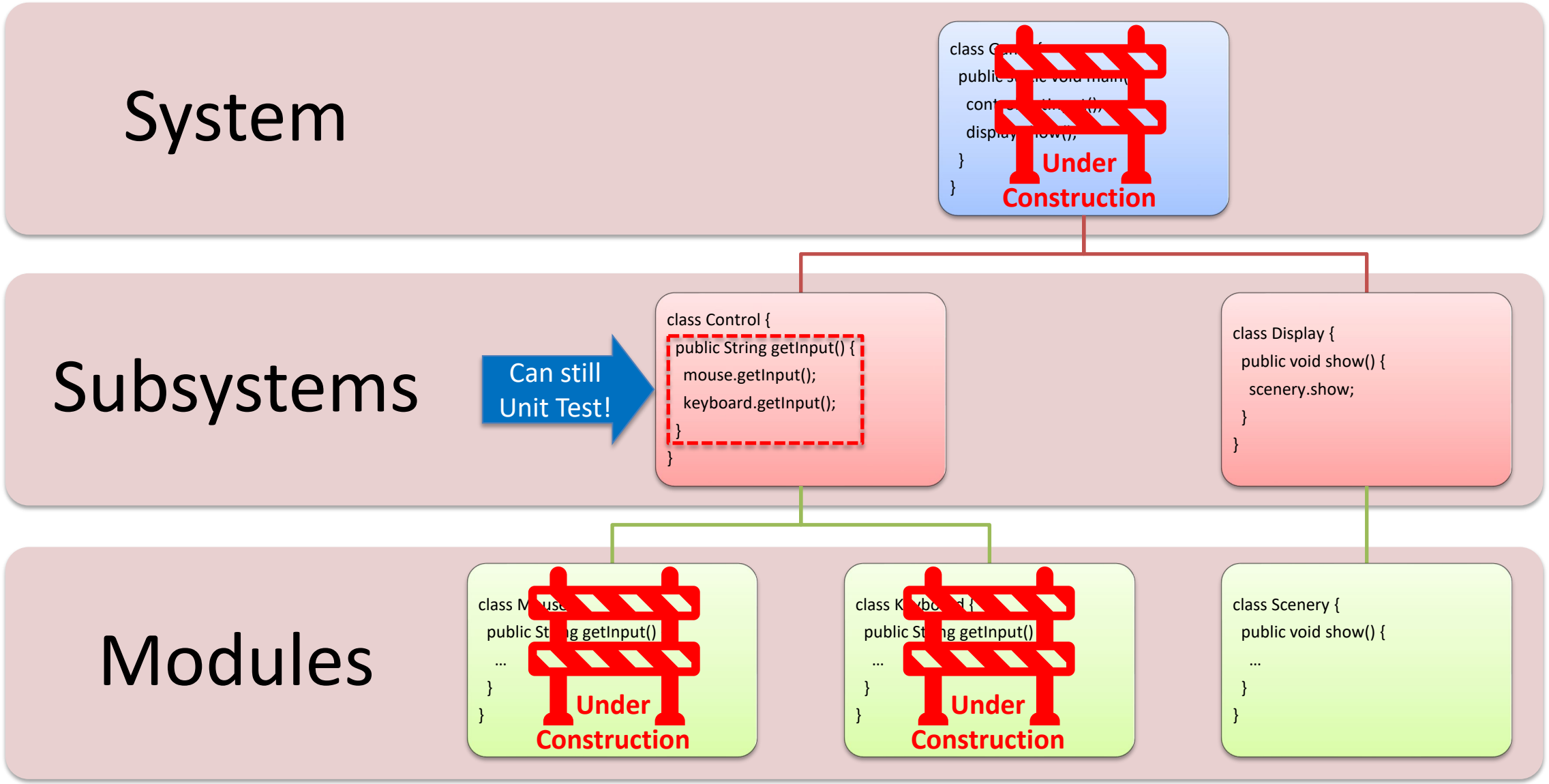
1. Unit Testing Localizes the Bug



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



2. Unit Testing Allows Testing Early On



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**)
   - Shift-left testing makes sure technical debt does not accumulate

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

A popular framework for Java unit testing

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`: Methods run as **test cases** when JUnit test class 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 test fixture set up by `@Before` (if it needs clean up such as open files, databases)
- Typically, one JUnit test class tests one Java class
  - Consists of `@Test` methods and optionally a `@Before` and `@After`

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";
    }
  }
}
```

JUnit Assertions

- Assertions are used to check **postconditions**:
  - `assertEquals, assertArrayEquals, assertSame, assertNotSame, assertTrue, assertFalse, assertNull, assertNotNull, assertThrows, fail(), ...`
  - `assertEquals(Object expected, Object actual)`:
    Asserts that two objects are equal in value.
  - `assertSame(Object expected, Object actual)`:
    Asserts that two references refer to the same object.
  - `fail()`:
    Always fails. Useful to indicate tests that are yet to be implemented.
- Refer to JUnit reference for more details:
  - https://junit.org/junit4/javadoc/latest/org/junit/Assert.html

JUnit is not the only unit test framework out there

- xUnit frameworks for each programming language
  - C++: CPPunit
  - JavaScript: JSUnit
  - PHP: PHPUnit
  - Python: PyUnit

- Ideas we learned apply to other testing frameworks

Unit Testing Private Methods

Should you do it? If so, how?

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…

Private methods cannot be called directly

```
class Bird {
  private int flapLeft(int n) { … }
}
class BirdTest {
  @Test public void testFlapLeft3Times() {
    // Precondition: Create a new bird.
    Bird bird = new Bird();
    // Execution Step: Flap 3 times.
    int ret = bird.flapLeft(3);  // Compiler error!
    // Postcondition: Return value is 3.
    assertEquals(3, ret);
  }
}
```

Private methods must be called via Java Reflection

```
class BirdTest {
  @Test public void testFlapLeft3Times() throws Exception {
    // Precondition: Create a new bird.
    Bird bird = new Bird();
    // Execution Step: Flap 3 times.
    Method m = Bird.class.getDeclaredMethod("flapLeft", int.class);
    m.setAccessible(true); // Change method from private to public.
    Object ret = m.invoke(bird, 3); // Invoke flapLeft on bird.
    // Postcondition: Return value is 3.
    assertEquals(3, (int) ret);
  }
}
```

Integration Testing

Unit testing should always be followed by integration testing.

Unit Testing cannot replace Integration Testing

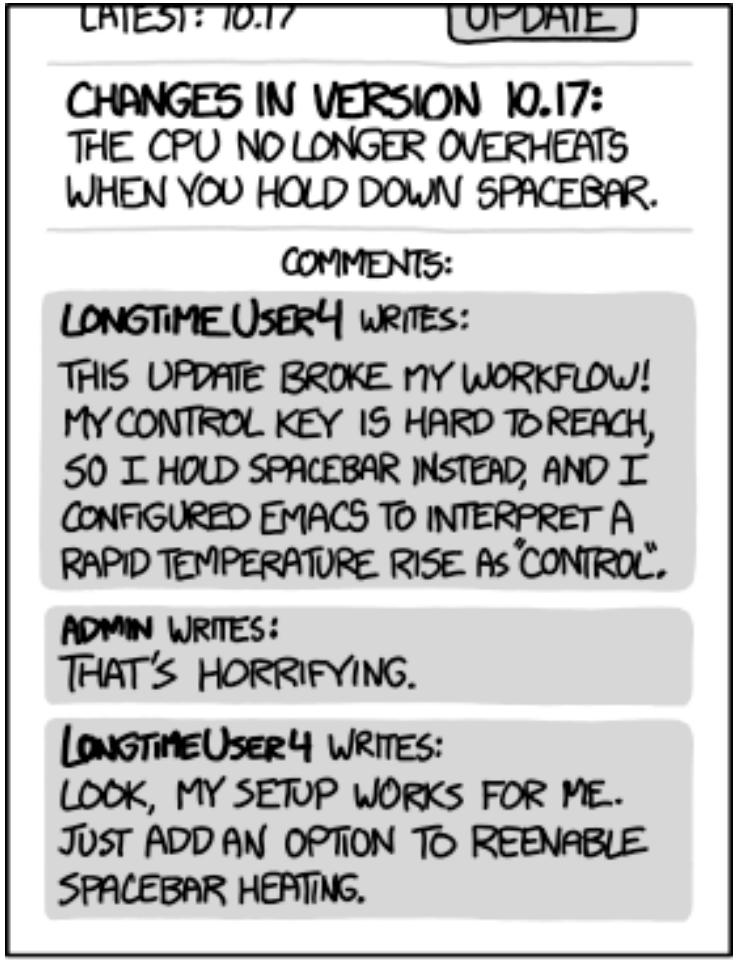
- A proper testing process includes both:
  - Unit tests to detect local errors within units of code
  - Integration tests to check that units work together correctly

- Units often have hidden undocumented dependencies between them
  - Since they are undocumented, they are not unit tested
  - Defects arising from these dependencies only surface when units are integrated

Hyrum's Law

"With a sufficient number of users of an API, it does not matter what you promise in the contract: all observable behaviors of your system will be depended on by somebody."

--- Hyrum Wright



Courtesy https://www.hyrumslaw.com/

Courtesy https://xkcd.com/1172/

Now Please Read Textbook Chapter 13

- Read Textbook Chapter 24 for details about Java Reflection
- Also see sample_code/junit_example
  - Do “mvn test” to run all unit and integration tests
  - Or, you can open the folder in VSCode and use the Testing extension
- JUnit 4 User Manual:
  - https://github.com/junit-team/junit4/wiki
- Junit 4 User Reference:
  - https://junit.org/junit4/javadoc/latest/