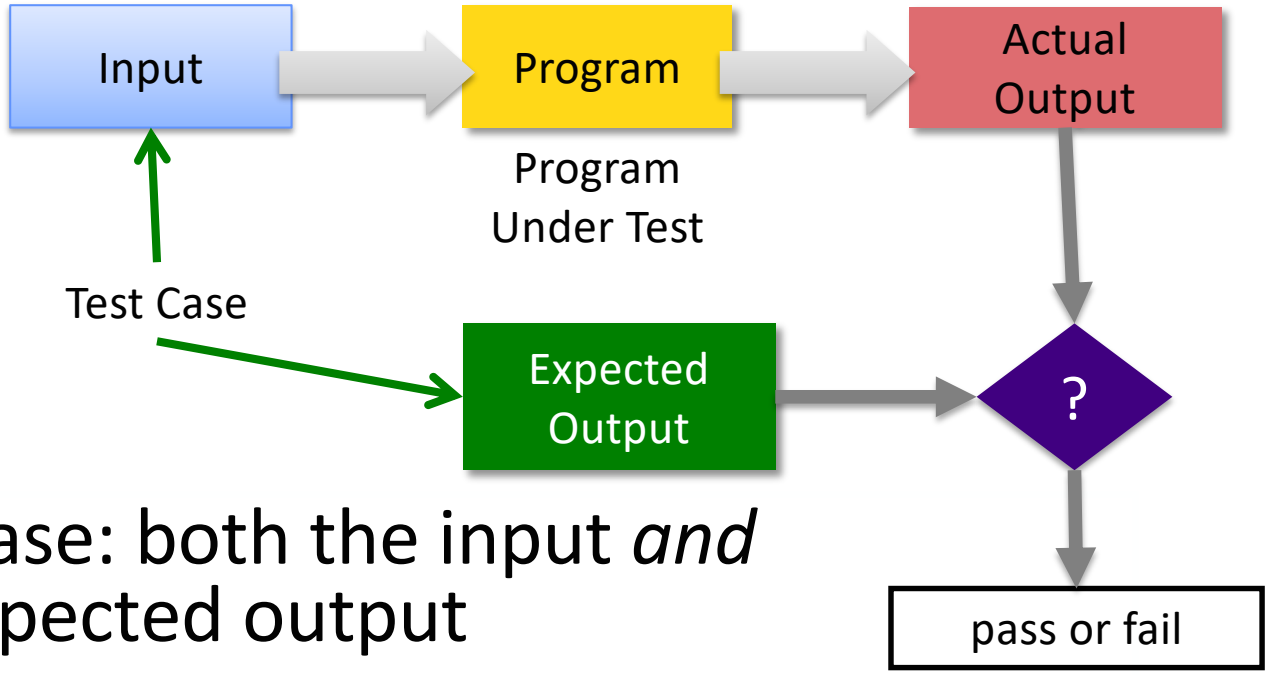
Objectives

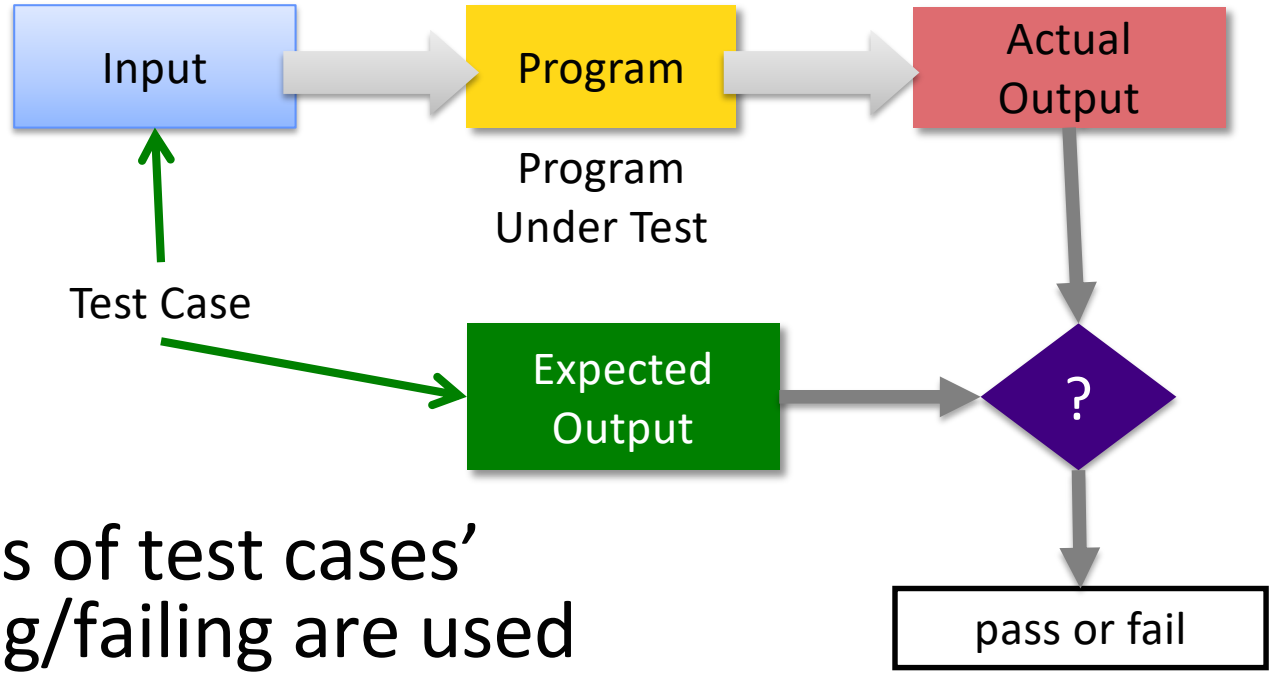
- Testing Overview
- Unit Testing
- JUnit

Review: Software Testing Process



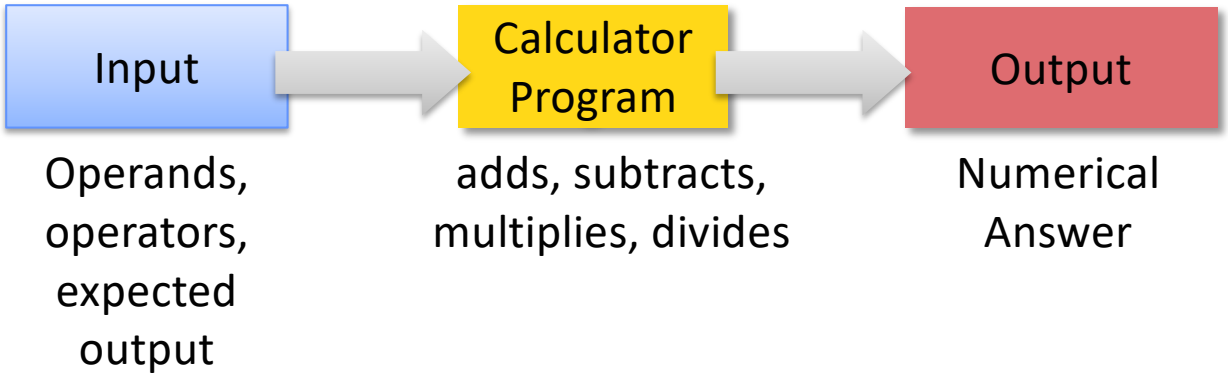
- Test case: both the input *and* the expected output
- Test Suite: set of test cases

Review: Software Testing Process



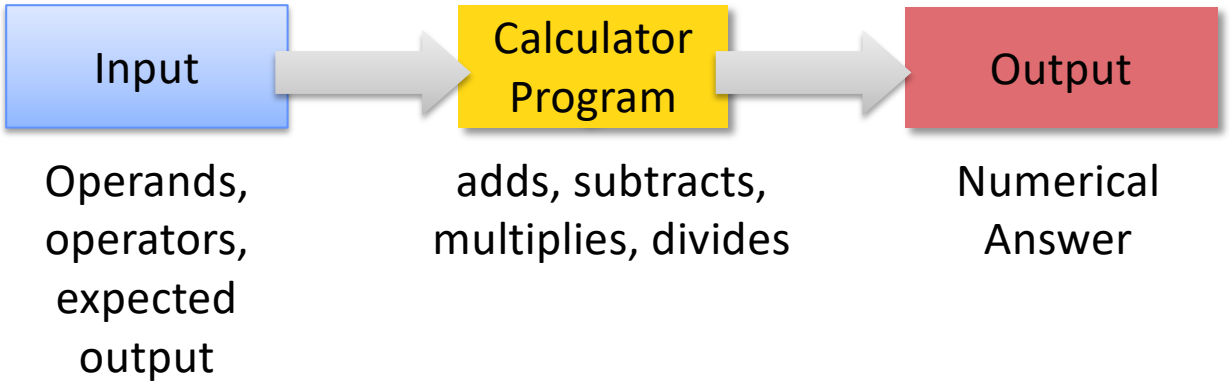
- Results of test cases' passing/failing are used in the subsequent step: ***debugging***

How Would You Test a Calculator Program?



What test cases?
Provide both input and expected output

Example Calculator Test Cases



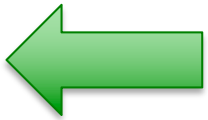
Operation	Input	Expected Output
Add	1, 1	2
Add	1, -1	0
Add	1.5, 0	1.5
…		

Software Testing Questions

- How should you test? How often?
  - Code may change frequently
  - Code may depend on others' code
  - A lot of code to validate
- How do you know that an output is correct?
  - Complex output
  - Human judgment?
- What caused a code failure?

➥ Need a *systematic*, *automated*, *repeatable* approach

Levels of Testing



- Unit
  - Tests minimal software component, in isolation
  - For us, Class-level testing
  - Web: Web pages (Http Request)
- Integration
  - Tests interfaces & interaction of classes
- System
  - Tests that completely integrated system meets requirements
- System Integration
  - Test system works with other systems, e.g., third-party systems

UNIT TESTING

Unit Testing

- Tests minimal software component, in isolation
- For us, Class-level testing
- Web: Web pages (Http Request)

Why Unit Test?

- Verify code works as intended in isolation
- Find defects ***early*** in development
  - Easier to test small pieces
  - Less cost than at later stages (e.g., when integrating)
- Suite of (small) test cases to run after code changes
  - As application evolves, new code is more likely to break existing code
  - Also called **regression** testing

Some Approaches to Testing Methods

- Typical case
  - Test typical values of input/parameters
- Boundary conditions
  - Test at boundaries of input/parameters
  - Many faults live “in corners”
- Parameter validation
  - Verify that parameter and object bounds are documented and checked
  - Example: pre-condition that parameter isn’t null

➥ All black-box testing approaches

Approaches to Testing

Traditional Approach

1. Write code
2. Write tests of code
   - May need to update code to make sure they all pass

Test-Driven Development

1. Write tests that correctly functioning code must pass
2. Write code

Discuss tradeoffs of approaches

- Consider when you'd know you are done in each scenario
- What assumptions are you making?

Another Use of Unit Testing:

Test-Driven Development (TDD)

- A development style, evolved from Extreme Programming
- Idea: write tests first *without code bias*
- The Process:
  1. Write tests that code/new functionality should pass
     - Like a specification for the code (pre/post conditions)
     - All tests will initially *fail*
  2. Write the code and verify that it passes test cases
     - Know you're done coding when you pass **all** tests

How do you know you're "done" in traditional development?

What assumption does this make?

Characteristics of Good Unit Testing

- **Automatic**
- **Thorough**
- **Repeatable**
- **Independent**

STOP: Why are these characteristics of good (unit) testing?

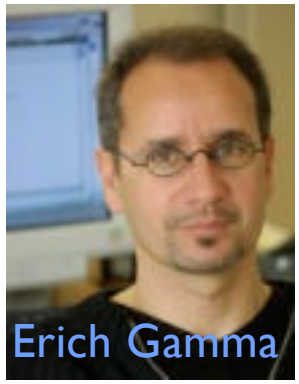
Characteristics of Good Unit Testing

- **Automatic**
  - Since unit testing is done frequently, don't want humans slowing the process down
  - Automate *executing* test cases and *evaluating* results
  - Input: in test itself or from a file
- **Thorough**
  - Covers all code/functionality/cases
- **Repeatable**
  - Reproduce results (correct, failures)
- **Independent**
  - Test cases are independent from each other and from other code
  - Easier to trace failure to code

JUNIT

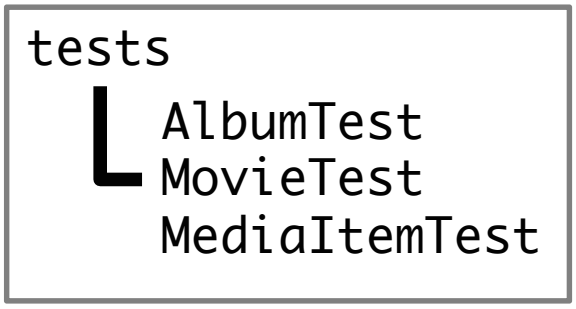
JUnit Framework

- A framework for unit testing Java programs
  - Supported by Eclipse and other IDEs
  - Originally developed by Erich Gamma and Kent Beck
- Functionality
  - Write tests
    - Validate output, automatically
  - Automate execution of test suites
  - Display pass/fail results of test execution
    - Stack trace where fails
  - Organize tests, separate from code
- But, you still need to come up with the tests!


Erich Gamma


Kent Beck

Testing with JUnit



- Typical organization:
  - Set of testing classes
  - Testing classes packaged together in a **`tests`** package
    - Separate package from code testing
- A test class typically
  - Focuses on a specific class
  - Contains methods, each of which represents another test of the class

Structure of a JUnit Test

1. Set up the test case (optional)
   - Example: Creating objects
2. Exercise the code under test
3. Verify the correctness of the results
4. Teardown (optional)
   - Example: reclaim created objects

Annotations

- Testing in JUnit 5: uses ***annotations***
- Provide information about a program that is not part of program itself
- Have no direct effect on operation of the code
  - But compiler or tools may use them
- Example uses of annotations:
  - @Override: method declaration is intended to override a method declaration in parent class
    - If method does not override parent class method, compiler generates error message
  - Information for the compiler to suppress warnings (@SupressWarnings)

Creating Tests

- Tests are contained in *classes*
- The class is named for the functionality you're testing
- Typically located in a separate package named `tests`

```
package edu.wlu.cs.calculator.tests;

public class CalculatorTest {

                This class contains tests for the calculator

}
```

Methods are Test Cases

- Mark your testing method with `@Test`
  - From `org.junit.jupiter.api.Test`

```
public class CalculatorTest {

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

Class for testing the Calculator class

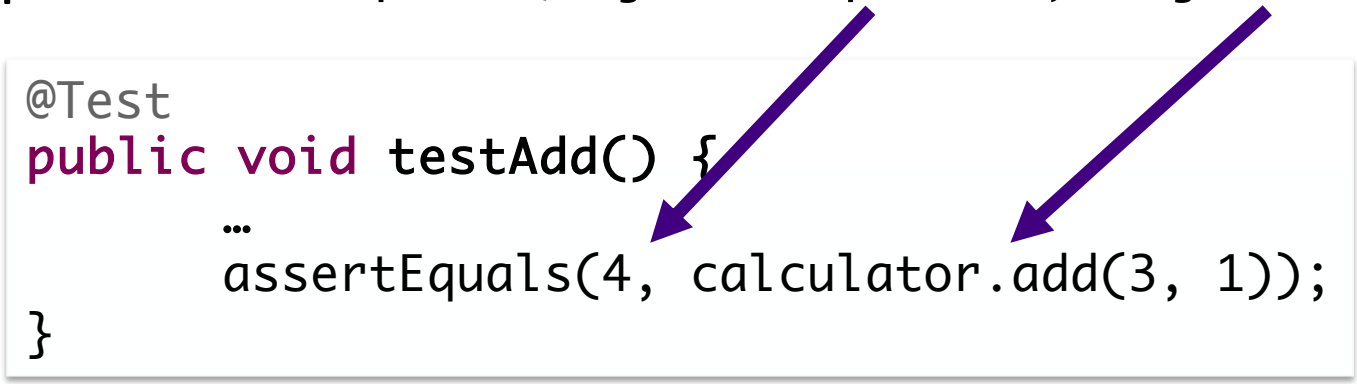
A method to test the "add" functionality

- Convention: Method name describes what you're testing

Assert Methods

Defined in
`org.junit.jupiter.api.Assertions`

- Used to verify that execution results are what you expect
- Variety of assert methods available
- If fail, throw an error
- Otherwise, test keeps executing
- All `static void`
- Example: `assertEquals(Object expected, Object actual)`



Assert Methods

- To use asserts, need *static* import:

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

  - `static` allows us to not have to use classname when calling method

- More examples
  - `assertTrue(boolean condition)`
  - `assertSame(Object expected, Object actual)`
    - Refer to same object
  - `assertEquals(double expected, double actual, double delta)`
    - Doubles are equal within a delta

Example Uses of Assert Methods

```
@Test
public void testEmptyCollection() {
    Collection collection = new ArrayList();
    assertTrue(collection.isEmpty());
}
```

```
assertEquals(double expected, double actual, double delta)
```

```
@Test
public void testPI() {
    final double ERROR_TOLERANCE = .01;
    assertEquals(Math.PI, 3.14, ERROR_TOLERANCE);
}
```

Test will fail if ERROR_TOLERANCE = .001

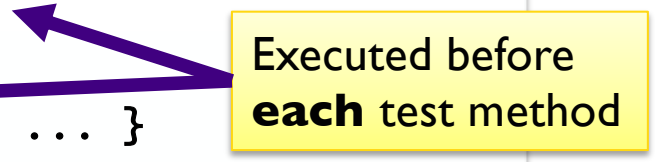
Set Up/Tear Down

- May want methods to set up objects for every test in the class
  - Called **fixtures**
  - If have multiple, no guarantees for order executed

```
@BeforeEach
public void prepareTestData() { ... }

@BeforeEach
public void setupMocks() { ... }

@AfterEach
public void cleanupTestData() { ... }
```



Example Set Up Method

```
private Album testAlbum;

@BeforeEach
public void setUp() {
        testAlbum = new Album("Album title", "Artist",
                        100, 1997, 11);
}
```

Declare the instance variable

`@BeforeEach` Executed before **each** test method

- Can use `testAlbum` object in test methods
- Helps make test methods *independent*
  - Changes to instance variable in one test method don't affect the other test methods

Example: Testing the Album class

```
private Album testAlbum;
```
1. Declare the instance variable

```
@BeforeEach
public void setUp() {
        testAlbum = new Album("Album title", "Artist",
                              100, 1997, 11);
}
```
2. Instantiate the instance variable before every test

```
@Test
public void testDefaultConstructor() {
    // can use testAlbum in here
    assertEquals(11, testAlbum.getNumTracks());
    assertEquals(1997, testAlbum.getCopyrightYear());
    assertTrue(testAlbum.isInCollection());
    …
}
```
3. Use the instance variable in your test methods

Example: Testing the Album class

```
private Album testAlbum;

@BeforeEach
public void setUp() {
        testAlbum = new Album("Album title", "Artist",
                        100, 1997, 11);
}

@Test
public void testInCollection() {
    assertTrue(testAlbum.isInCollection() );
    testAlbum.checkOutOfCollection();
    assertFalse(testAlbum.isInCollection() );
}
```

Exercising the code and verifying its correctness

Expecting an Exception

- Sometimes an exception *is* the expected result

```
@Test
public void testIndexOutOfBoundsException() {
    List emptyList = new ArrayList();

    assertThrows(IndexOutOfBoundsException.class,
        () -> { Object o = emptyList.get(0); }
    );
}
```

Test case passes only if exception is thrown

Expecting an Exception: Breaking It Down

assertThrows(Class<T> expectedType, Executable executable)

```
@Test
public void testIndexOutOfBoundsException() {
    List emptyList = new ArrayList();

    assertThrows(IndexOutOfBoundsException.class,
        () -> { Object o = emptyList.get(0); }
    );

}
```

Example of a *Lambda expression*

How to read assertThrows:
Execute the executable (after the first ,)
and check if it throws an exception of that type (before the ,)

Expecting an Exception: Breaking It Down (2)

assertThrows(Class<T> expectedType, Executable executable)

```
@Test
public void testIndexOutOfBoundsException() {
    List emptyList = new ArrayList();

    assertThrows(IndexOutOfBoundsException.class,
        () -> { Object o = emptyList.get(0); }
    );
}
```

How to read assertThrows:
Execute the highlighted code (in {})
and check if it throws that exception type

A lot more can be said about lambda expressions… but not in CSCI209

Expecting an Exception

- Can also check characteristics of the thrown exception

```
@Test
public void testIndexOutOfBoundsException() {
  List myList = new ArrayList();
  IndexOutOfBoundsException ioobExc =
          assertThrows(IndexOutOfBoundsException.class, () -> {
                  myList.get(0);
          });
  assertEquals("Index 0 out of bounds for length 0",
                  ioobExc.getMessage());
}
```

Test case passes only if exception is thrown *and* message matches

Expecting an Exception: Birthday

```
class BirthdayTest {

    private Birthday bday;

    @BeforeEach
    void setUp() throws Exception {
        bday = new Birthday();
    }

    @Test
    void testSetBirthday() {
        IllegalArgumentException iaEx =
        assertThrows(IllegalArgumentException.class, () -> {
            bday.setBirthday(0, 1);
        });
        assertEquals("Month must be between 1 and 12, inclusive",
            iaEx.getMessage());
    }
}
```

Set Up/Tear Down For Test Class

- May want methods to set up objects for set of tests
  - Executed *once* before any test in class executes

```
@BeforeAll
public static void
setupDatabaseConnection() { ... }

@AfterAll
public static void
teardownDatabaseConnection() { ... }
```

JUnit Examples

- Check out the examples of testing the Chicken and Birthday classes

https://cs.wlu.edu/~sprenkles/cs209/examples/junit_testing/code.html

Writing Good Test Cases

- A test method should focus on one behavior
  - If test case fails, the test case should be helpful in narrowing down where the problem is
- Use assert statements well to verify the results are what you expect
  - May use multiple asserts to verify one result
- Testing isn't typically "creative" and doesn't need to be generalizable
  - Code should be straightforward
- See examples linked from course schedule page

Unit Testing & JUnit Summary

- Unit Testing: testing smallest component of your code
  - For us: class and its methods
- JUnit provides framework to write test cases and run test cases automatically
  - Easy to run again after code changes

JUNIT IN ECLIPSE

Using JUnit in Eclipse

- Eclipse can help make our job easier
  - Automatically execute tests (i.e., methods)
  - We can focus on coming up with tests

Using JUnit in Eclipse: Creating a New Test Class

- In Eclipse, go to your `Assignment5` project
- Create a new JUnit Test Case (under Java)
  - Select **JUnit Jupiter test**
    - When prompted, add JUnit to build path
  - Put in package `edu.wlu.cs.username.tests`
  - Name: `MovieTest`
  - Choose to test `Movie` class
    - Select `setUp` and `tearDown`
    - Select methods to test
- Run the class as a JUnit Test Case

Using JUnit in Eclipse: Creating a New Test Class

- Alternatively…
- Right-click on the class you want to test (e.g., Album)
- Select New → JUnit Test Case
  - Select JUnit Jupiter test
    - When prompted, add JUnit to build path
  - Put in package edu.wlu.cs.username.tests
  - Name: AlbumTest
  - CD should already be selected as "Class under test"
    - Select setUp
    - Select methods to test
- Run the test class as a JUnit Test Case

Example

- Create a test method that tests the method that gets the length of the Movie
  - Revise: Add code to `setUp` method that creates a Movie and use that in your test
- Notes
  - Replaying all the test cases: right click on tests package
  - FastView vs Detached
  - Hint: CTL-Spacebar to get auto-complete options

Got It? Good!

- Take the reading quiz on Canvas!
  - You can/should refer back to the slides