Testing & JUnit
import static org.junit.Assert.*;
import org.junit.*;

public class TestingExamples {

    @Test
    public void testingExampleOne() {
        String inputToTest = "example";
        int otherInputToTest = 4;
        double expected = 14.5;
        double actual = functionToTest(inputToTest, otherInputToTest);
        assertEquals(expected, actual);
    }

    @Test
    public void testingExampleTwo() {
        int[] input = {3, 4, 5};
        int result = countEvens(input);
        assertTrue(result < 3);
    }
}
"Units" of Code

Now that we have functions, we can write programs that consist of individual, atomic units of logic.

In Caesar:

- Encrypting requires converting to symbol array, shifting, and converting back to String
- Each step along the way represented by a function with well-defined inputs and output.
Testing a Unit of Code

How do we test our code to determine if it’s right?
Testing a Unit of Code

How do we test our code to determine if it’s right?

- Identify the **INPUT**, possibly including any state variables
- Generate, manually or through means OUTSIDE of your code an **EXPECTED OUTPUT**
- Execute your code to get an **ACTUAL OUTPUT**
- Compare the expected and actual output
Unit Test Case

Comprised of:

- An **INPUT**
- An **EXPECTED** output (usually manually coded in)
- An **ACTUAL** output (generated by the code we are testing)
- A mechanism of comparing **ACTUAL** and **EXPECTED**

If an expected output doesn’t match the actual output, one of the two is wrong

- Usually, *hopefully*, but not necessarily, the actual output is wrong
A Function to Test

```java
public static int findMax(int a, int b, int c) {
    if (a > b) {
        if (a > c) {
            return a;
        } else {
            return c;
        }
    } else {
        if (b > c) {
            return b;
        } else {
            return a;
        }
    }
}
```
Generating Tests

int findMax(int a, int b, int c) is a function that should return the largest of its three inputs.

- input types: int, int, int
- output type: int

What is the expected output for `findMax` when called on inputs 3, 2, 1?
What is the expected output for `findMax` when called on inputs 1, 2, 3?
Testing a unit of code

Is this a passing or failing test case?
Test Case #1: Input = \{3, 2, 1\}; Expected output = 3; Actual output = 3

Is this a passing or failing test case?
Test Case #2: Input = \{1, 2, 3\}; Expected output = 3; Actual output = 1
Testing a unit of code

Is this a *passing* or *failing* test case? **PASSING!**
Test Case #1: Input = \{3, 2, 1\}; Expected output = 3; Actual output = 3

Is this a *passing* or *failing* test case? **FAILING!**
Test Case #2: Input = \{1, 2, 3\}; Expected output = 3; Actual output = 1
Testing is like potato chips

"They both contribute to my overall poor health. Also, you can’t have just one." – Will McBurney

One test passing may have no bearing on another test passing! One test is not enough to decide if your implementation is bug-free.
Why does Test 1 pass and not Test 2?

Test 1 does not cover/execute the underlying fault in the code. A fault is a particular defect in the code, or bug.

Test Case #1: Input = \{3, 2, 1\}; Expected output = 3; Actual output = 3
Test Case #2: Input = \{1, 2, 3\}; Expected output = 3; Actual output = 1
JUnit

An automatic testing tool that allows you to write tests once and continue to use them again and again.

In this way, if you change something later that breaks code that worked previously, you will immediately know because your tests fail.

Technically not built into Java, so we have a bit of wrangling to do.
Writing a JUnit Test

```java
@Test  // This must be before every test function
public void testFindMax0() {  // Notice – no static keyword
    // inputs
    int a = 3;
    int b = 2;
    int c = 1;
    // expected – generated manually
    int expected = 3;
    // actual – Execute the code with the above input
    int actual = findMax(a, b, c);
    // Assertion – if the two things below aren’t equal, the test fails.
    // Always put expected argument first.
    assertEquals(expected, actual);
}
```
writing a JUnit Test

This is the same as before, but we print an error message now that explains what happens when `assertEquals` does not receive matching inputs.

```java
@Test // This must be before every test function
public void testFindMax0() { // Notice – no static keyword
    // inputs
    int a = 3;
    int b = 2;
    int c = 1;
    String message = "findMax(3, 2, 1) returns the wrong value";
    // expected – generated manually
    int expected = 3;
    // actual – Execute the code with the above input
    int actual = findMax(a, b, c);
    // Assertion – if the two things below aren’t equal, the test fails. // Always put expected argument first.
    assertEquals(message, expected, actual);
}
```
Import Statements

Start all Test files with the two important statements below:

```java
import static org.junit.Assert.*;
import org.junit.*;
```
Writing JUnit (Demo)

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

public class FunctionTest {
    @Test
    public void testMean() {
        double expected = 19;
        double actual = FunctionPractice.mean(a, b);
        assertEquals(expected, actual, 0.001);
    }
}
Testing
Drag Files with Test Cases to "Add test case" Field
Run Tests by Clicking "EXECUTE ALL"
A Failing Test
A Passing Test!

<table>
<thead>
<tr>
<th>FunctionTest</th>
<th>Test</th>
<th>Duration</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>testMean</td>
<td>0.001s</td>
<td>passed</td>
</tr>
</tbody>
</table>
What a test failing means

A test failing doesn’t always mean the code has a bug

- The test could be written wrong (that is, the test writer came up with the wrong expected output)

A test passing doesn’t mean there is no bug

- The test code not execute a buggy statement
- The test could execute a buggy statement in a way that a failure doesn’t manifest
Consider These Test Cases

Test Case #3: Input = {1,1,1}; Expected output = 1; Actual output = 1;
Test Case #4: Input = {4,5,6}; Expected output=4; Actual output = 4;

#3 is an edge case: a set of inputs and output that represent a valid but atypical or unorthodox use case of the function

- at the "edge" of what is a valid way to use the program

#4 is an incorrectly written test that passes but does not reveal the presence of the bug. This is considered a false positive.
**False Negatives**

If your test is erroneous, you could also get a false negative. This test DOESN'T cover the fault, but still fails, due to erroneous testing.

Test Case #5: Input = {9,8,7}; Expected output = 7; Actual output = 9;
Testing Strategies

Exhaustive Testing

- Attempt a test with every possible input
- Not even remotely feasible in most cases

Random Testing

- Select random inputs
- Likely to miss narrow inputs that are special cases (example, dividing by zero)
Testing Strategies

Black-box Testing

- Select inputs based on the specification space
- “Assume the code can’t be seen”
- We focus on this one

White-box Testing

- Select inputs based on the code itself
- Have every line of code covered by at least one test
The need for automatic testing

Automatic testing (such as JUnit) allows for testing rapidly after each update.

If an update breaks a test, a commit can be rejected.

Ensure you don’t break something that already worked.

- Not fool proof