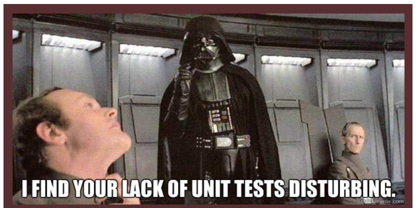


The Absolute Beginner's Guide to JUnit in the Classroom

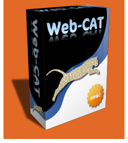
http://web-cat.org/sigcse2014

SIGCSE ATLANTA 2014

Stephen Edwards

Manuel Pérez-Quiñones

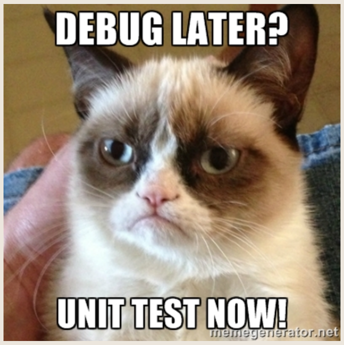
Virginia Tech



What is unit testing?

- "Software test" == a check on the **behavior** of some piece of code
- "Unit test" == a test on a single **unit** (usually a single class, or a single method)
- Key ideas:
  - Write test in the form of **program code**
  - So it can be **automatically repeated**

Why?



Is it more work?

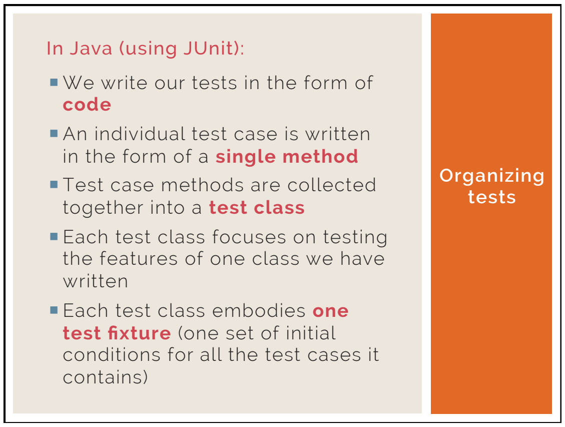
You betcha!

- More work up front in **writing** an assignment (you have to be more careful)
- You have to write a **solid solution**, too!
- But this work **buys you advantages** in the long run
  - Better, more carefully thought out assignment writeups
  - Ability to automatically check behavior of student solutions

Basic Steps to Create a Test Class

Testing terms

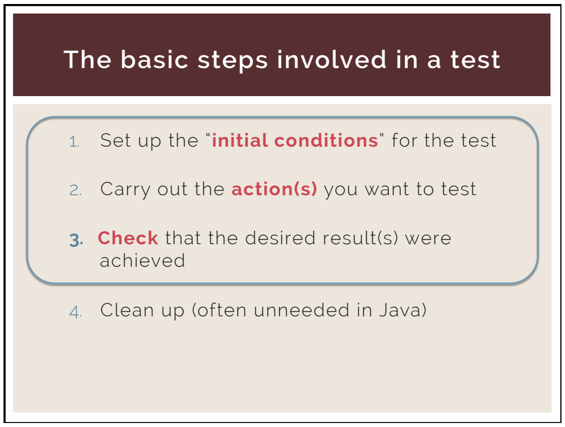
- A **test case** is an individual test for a specific behavior in a unit
- A **claim** or **assertion** is a statement expressing the behavior or outcome we expect in a test case
- A **test fixture** is the name for the initial conditions used in one or more test cases
- A **test suite** is a collection of test cases



Organizing tests

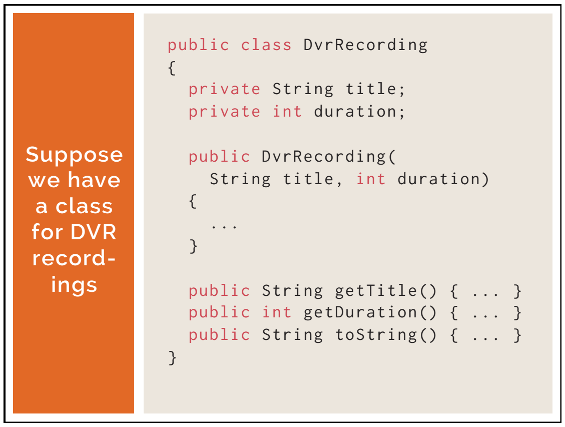
In Java (using JUnit):

- We write our tests in the form of **code**
- An individual test case is written in the form of a **single method**
- Test case methods are collected together into a **test class**
- Each test class focuses on testing the features of one class we have written
- Each test class embodies **one test fixture** (one set of initial conditions for all the test cases it contains)



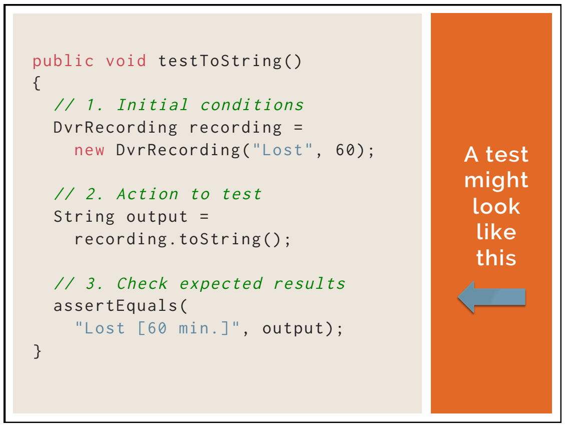
The basic steps involved in a test

1. Set up the "**initial conditions**" for the test
2. Carry out the **action(s)** you want to test
3. **Check** that the desired result(s) were achieved
4. Clean up (often unneeded in Java)



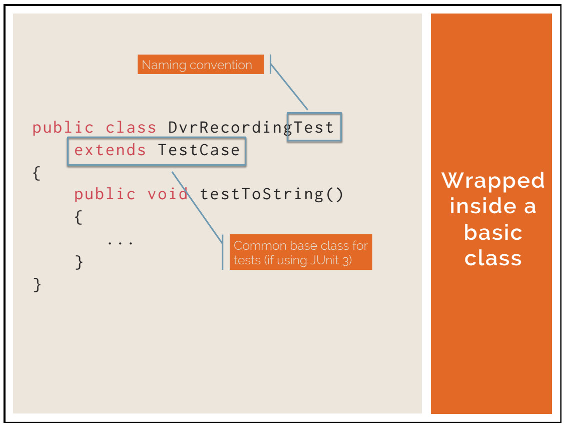
Suppose we have a class for DVR recordings

```
public class DvrRecording
{
  private String title;
  private int duration;

  public DvrRecording(
    String title, int duration)
  {
    ...
  }

  public String getTitle() { ... }
  public int getDuration() { ... }
  public String toString() { ... }
}
```



A test might look like this

```
public void testToString()
{
  // 1. Initial conditions
  DvrRecording recording =
    new DvrRecording("Lost", 60);

  // 2. Action to test
  String output =
    recording.toString();

  // 3. Check expected results
  assertEquals(
    "Lost [60 min.]", output);
}
```

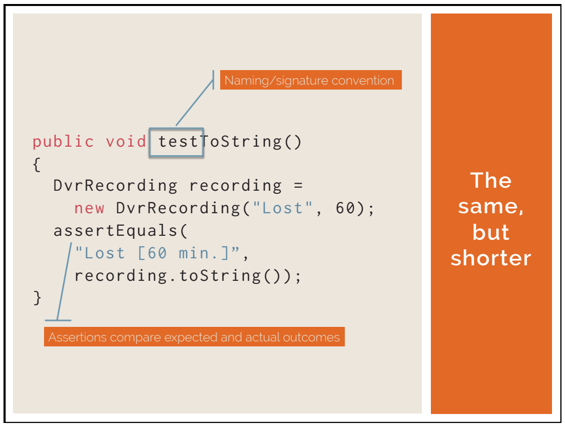


Wrapped inside a basic class

Naming convention

```
public class DvrRecordingTest
    extends TestCase
{
    public void testToString()
    {
       ...
    }
}
```

Common base class for tests (if using JUnit 3)

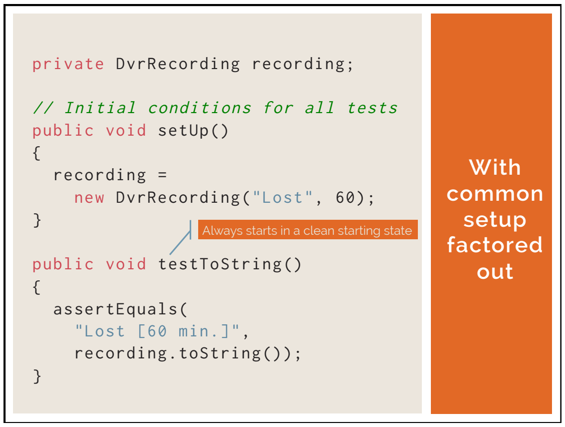


The same, but shorter

Naming/signature convention

```
public void testToString()
{
  DvrRecording recording =
    new DvrRecording("Lost", 60);
  assertEquals(
    "Lost [60 min.]",
    recording.toString());
}
```

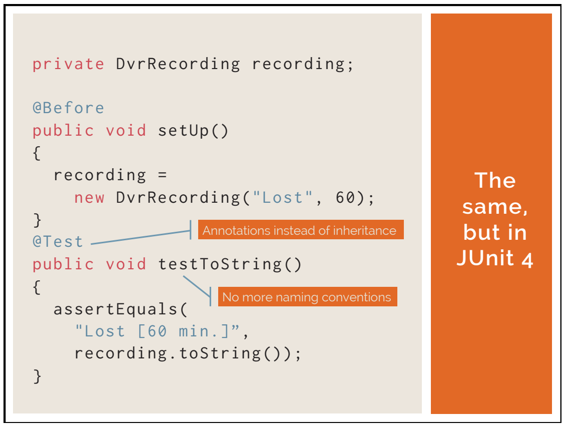
Assertions compare expected and actual outcomes



With common setup factored out

```
private DvrRecording recording;

// Initial conditions for all tests
public void setUp()
{
  recording =
    new DvrRecording("Lost", 60);
}

public void testToString()
{
  assertEquals(
    "Lost [60 min.]",
    recording.toString());
}
```

Always starts in a clean starting state

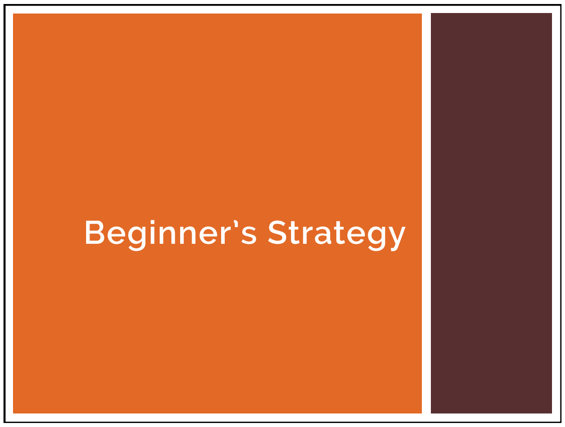


The same, but in JUnit 4

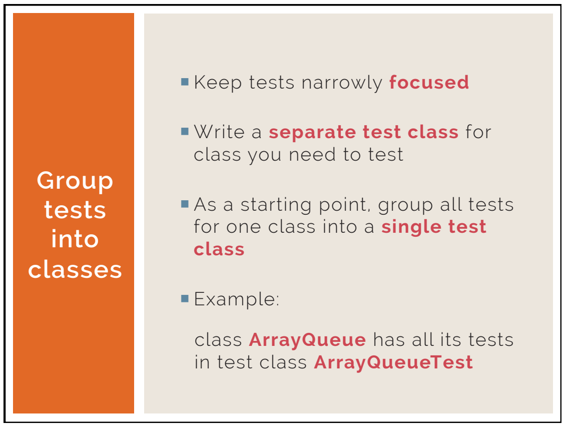
```
private DvrRecording recording;

@Before
public void setUp()
{
  recording =
    new DvrRecording("Lost", 60);
}
@Test
public void testToString()
{
  assertEquals(
    "Lost [60 min.]”,
    recording.toString());
}
```

Annotations instead of inheritance

No more naming conventions



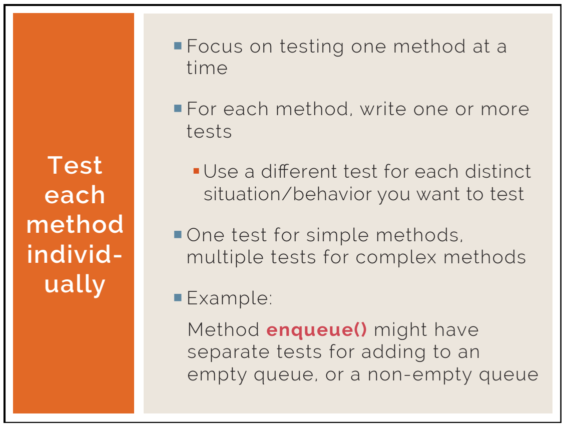
Beginner’s Strategy



Group tests into classes

- Keep tests narrowly **focused**
- Write a **separate test class** for class you need to test
- As a starting point, group all tests for one class into a **single test class**
- Example:

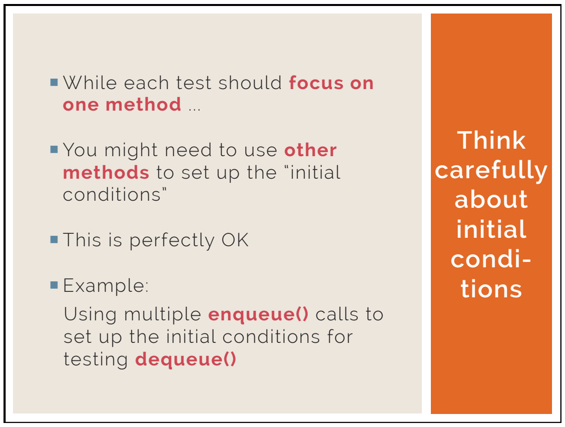
  class **ArrayQueue** has all its tests in test class **ArrayQueueTest**



Test each method individually

- Focus on testing one method at a time
- For each method, write one or more tests
  - Use a different test for each distinct situation/behavior you want to test
- One test for simple methods, multiple tests for complex methods
- Example:

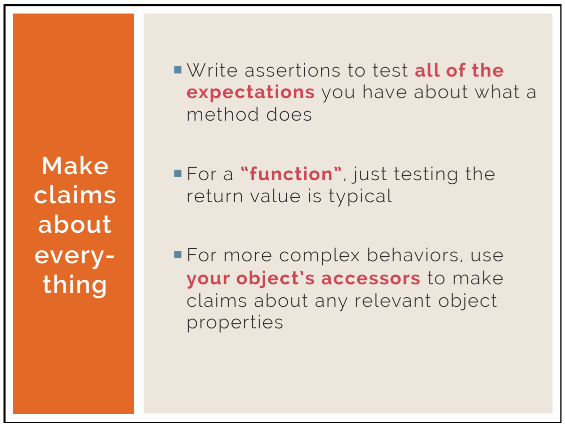
  Method **enqueue()** might have separate tests for adding to an empty queue, or a non-empty queue



Think carefully about initial conditions

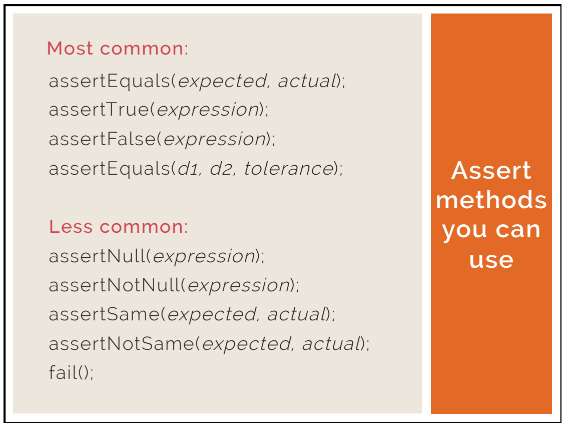
- While each test should **focus on one method** …
- You might need to use **other methods** to set up the "initial conditions"
- This is perfectly OK
- Example:

  Using multiple **enqueue()** calls to set up the initial conditions for testing **dequeue()**



Make claims about every-thing

- Write assertions to test **all of the expectations** you have about what a method does
- For a **"function"**, just testing the return value is typical
- For more complex behaviors, use **your object's accessors** to make claims about any relevant object properties



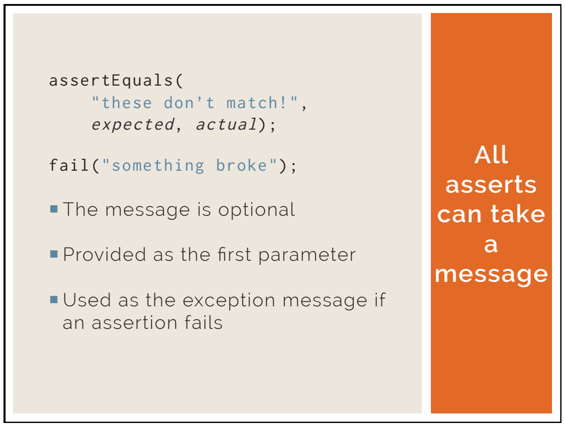
Assert methods you can use

Most common:

assertEquals(*expected, actual*);
assertTrue(*expression*);
assertFalse(*expression*);
assertEquals(*d1, d2, tolerance*);

Less common:

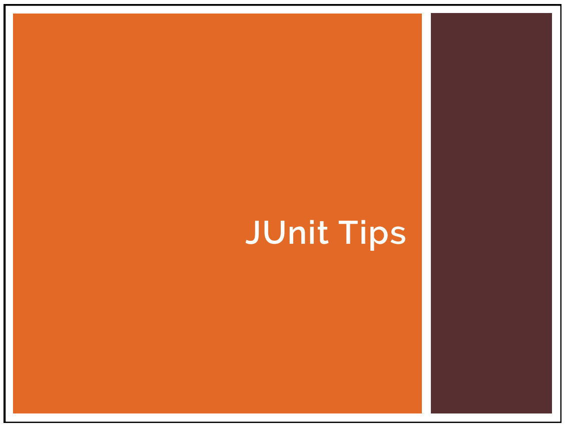
assertNull(*expression*);
assertNotNull(*expression*);
assertSame(*expected, actual*);
assertNotSame(*expected, actual*);
fail();



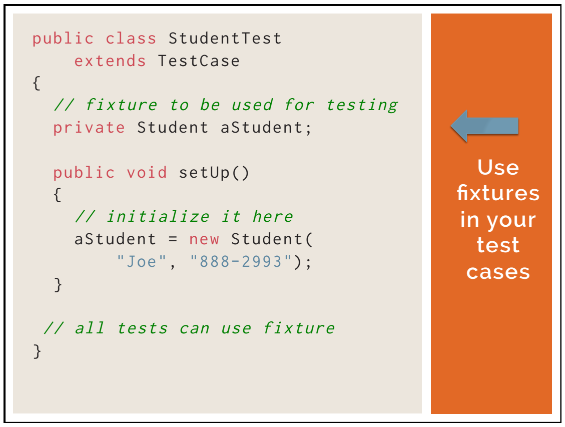
All asserts can take a message

```
assertEquals(
    "these don't match!",
    expected, actual);

fail("something broke");
```

- The message is optional
- Provided as the first parameter
- Used as the exception message if an assertion fails

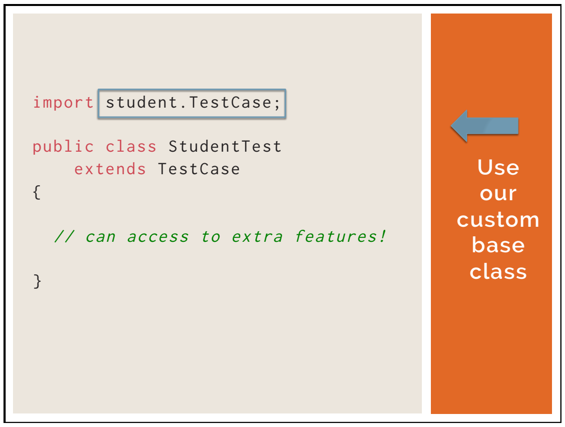


JUnit Tips



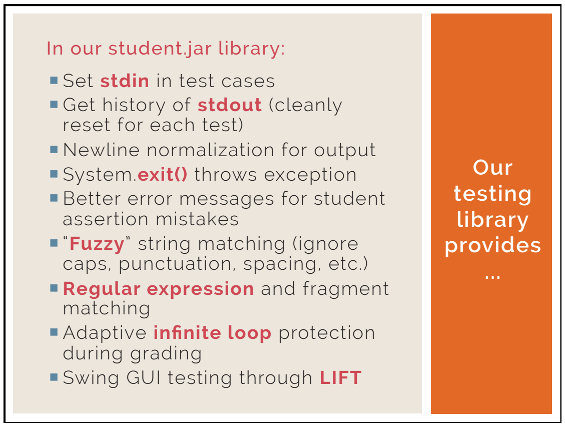
Use fixtures in your test cases

```
public class StudentTest
    extends TestCase
{
  // fixture to be used for testing
  private Student aStudent;

  public void setUp()
  {
    // initialize it here
    aStudent = new Student(
        "Joe", "888-2993");
  }

 // all tests can use fixture
}
```



Use our custom base class

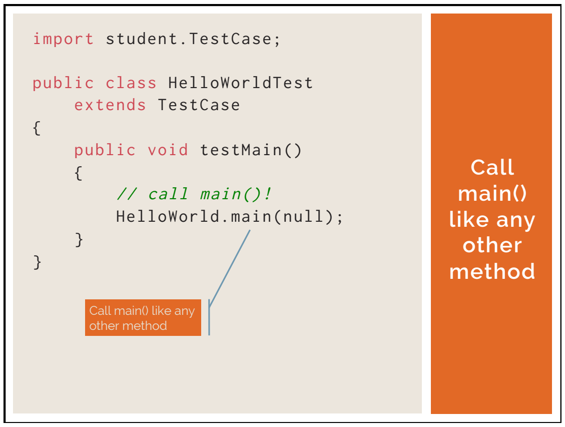
```
import student.TestCase;

public class StudentTest
    extends TestCase
{

  // can access to extra features!

}
```



Our testing library provides …

In our student.jar library:

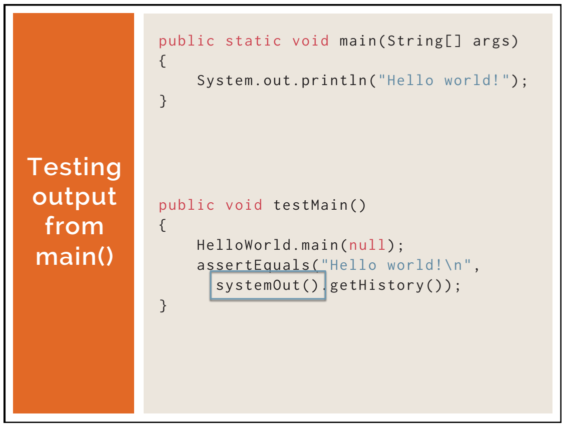
- Set **stdin** in test cases
- Get history of **stdout** (cleanly reset for each test)
- Newline normalization for output
- System.**exit()** throws exception
- Better error messages for student assertion mistakes
- "**Fuzzy**" string matching (ignore caps, punctuation, spacing, etc.)
- **Regular expression** and fragment matching
- Adaptive **infinite loop** protection during grading
- Swing GUI testing through **LIFT**



Call main() like any other method

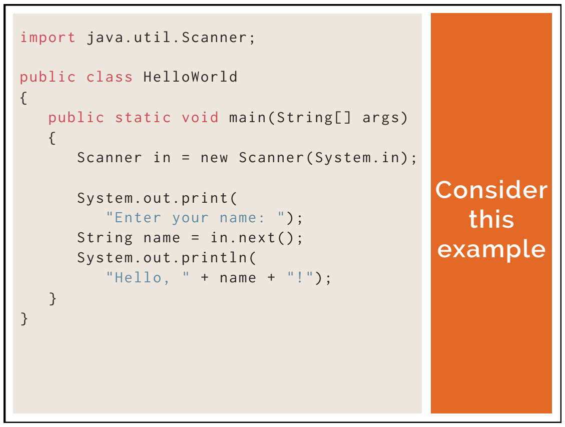
```java
import student.TestCase;

public class HelloWorldTest
    extends TestCase
{
    public void testMain()
    {
        // call main()!
        HelloWorld.main(null);
    }
}
```

Call main() like any other method



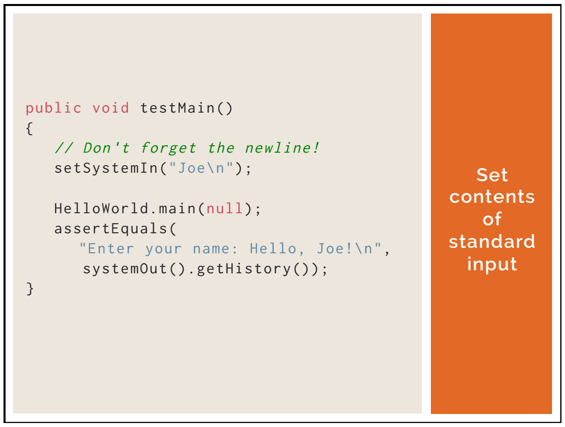
Testing output from main()

```java
public static void main(String[] args)
{
    System.out.println("Hello world!");
}



public void testMain()
{
    HelloWorld.main(null);
    assertEquals("Hello world!\n",
      systemOut().getHistory());
}
```



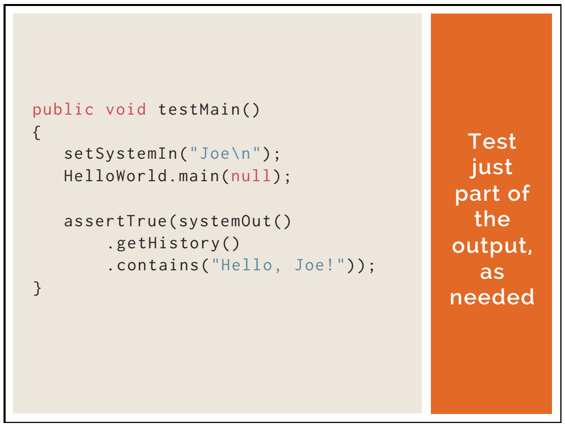
Consider this example

```java
import java.util.Scanner;

public class HelloWorld
{
   public static void main(String[] args)
   {
      Scanner in = new Scanner(System.in);

      System.out.print(
         "Enter your name: ");
      String name = in.next();
      System.out.println(
         "Hello, " + name + "!");
   }
}
```



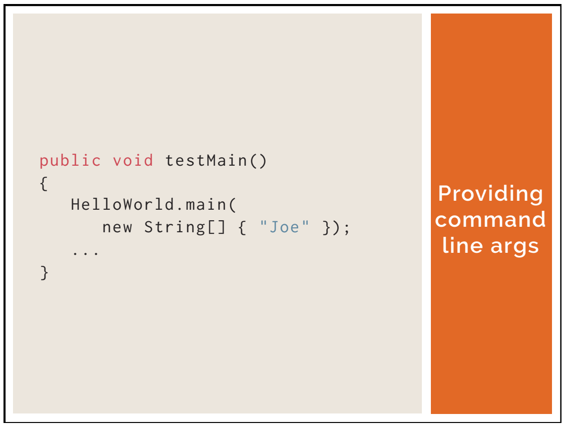
Set contents of standard input

```java
public void testMain()
{
   // Don't forget the newline!
   setSystemIn("Joe\n");

   HelloWorld.main(null);
   assertEquals(
     "Enter your name: Hello, Joe!\n",
      systemOut().getHistory());
}
```



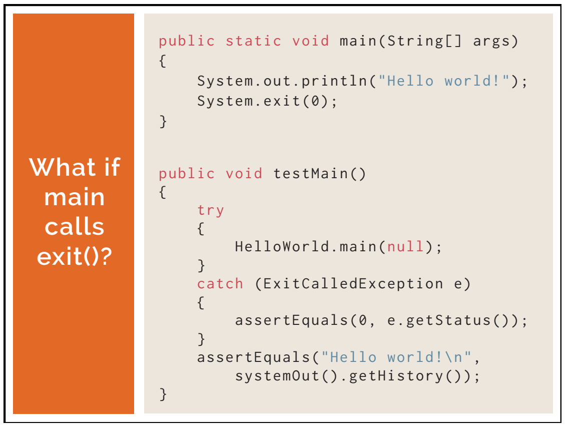
Test just part of the output, as needed

```java
public void testMain()
{
   setSystemIn("Joe\n");
   HelloWorld.main(null);

   assertTrue(systemOut()
       .getHistory()
       .contains("Hello, Joe!"));
}
```



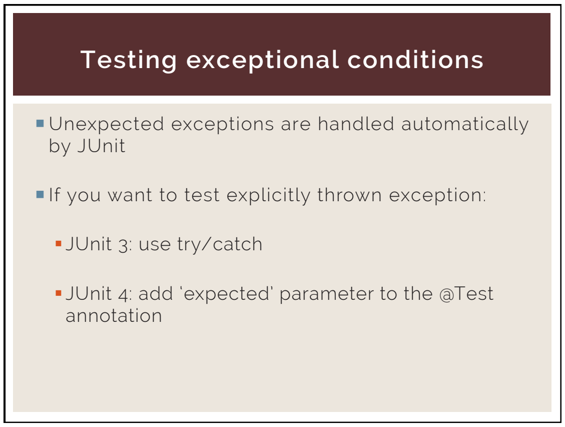
Providing command line args

```
public void testMain()
{
   HelloWorld.main(
      new String[] { "Joe" });
   ...
}
```



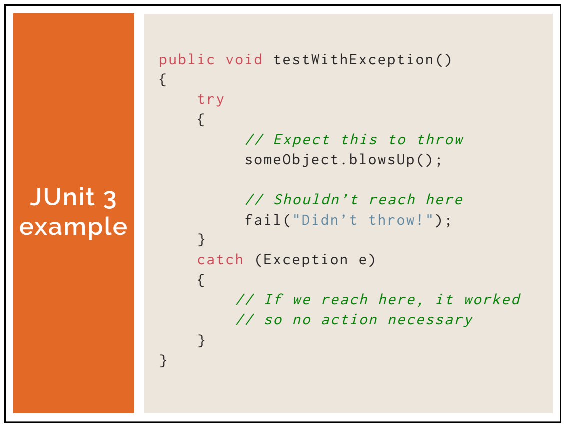
What if main calls exit()?

```
public static void main(String[] args)
{
    System.out.println("Hello world!");
    System.exit(0);
}

public void testMain()
{
    try
    {
        HelloWorld.main(null);
    }
    catch (ExitCalledException e)
    {
        assertEquals(0, e.getStatus());
    }
    assertEquals("Hello world!\n",
        systemOut().getHistory());
}
```



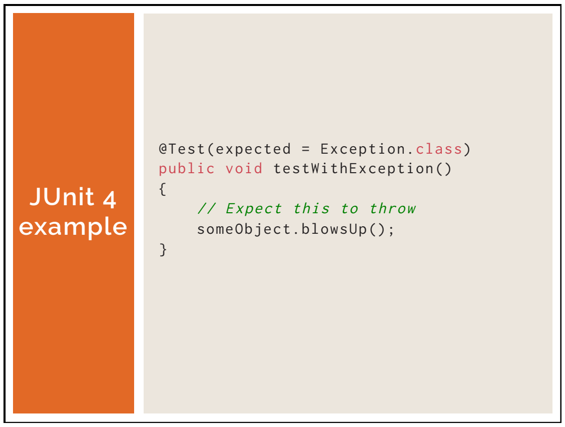
Testing exceptional conditions

- Unexpected exceptions are handled automatically by JUnit
- If you want to test explicitly thrown exception:
  - JUnit 3: use try/catch
  - JUnit 4: add 'expected' parameter to the @Test annotation



JUnit 3 example

```
public void testWithException()
{
    try
    {
        // Expect this to throw
        someObject.blowsUp();

        // Shouldn't reach here
        fail("Didn't throw!");
    }
    catch (Exception e)
    {
        // If we reach here, it worked
        // so no action necessary
    }
}
```

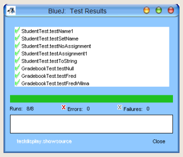


JUnit 4 example

```
@Test(expected = Exception.class)
public void testWithException()
{
    // Expect this to throw
    someObject.blowsUp();
}
```

Tools and test runners

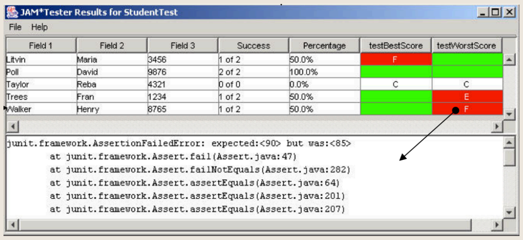
Tools make running tests easy



```
✓ StudentTest.testName1
✓ StudentTest.testSetName
✓ StudentTest.testNoAssignment
✓ StudentTest.testAssignment1
✓ StudentTest.testToString
✓ GradebookTest.testNull
✓ GradebookTest.testFred
✓ GradebookTest.testFredWilma

Runs: 8/8     Errors: 0     Failures: 0
```

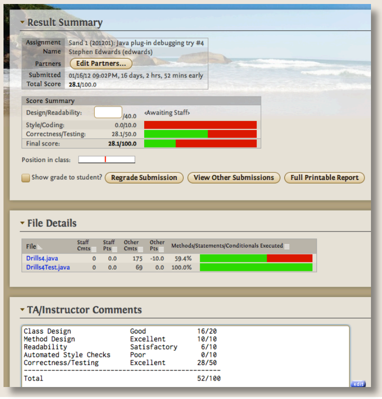
- Most XUnit frameworks include **test runners** that allow you to directly execute test cases from one class or many
- Often, either textual or graphical output is available
- Many IDEs include direct support for running such test cases (BlueJ, Eclipse, JGRASP, …)

One example: JAM*Tester



Field 1	Field 2	Field 3	Success	Percentage	testBestScore	testWorstScore
Litvin	Maria	3456	1 of 2	50.0%	🟥 F	🟩
Poll	David	9876	2 of 2	100.0%	🟩	🟩
Taylor	Reba	4321	0 of 0	0.0%	C	C
Trees	Fran	1234	1 of 2	50.0%	🟩	🟥 E
Walker	Henry	8765	1 of 2	50.0%	🟩	🟥 F

```
junit.framework.AssertionFailedError: expected:<90> but was:<85>
        at junit.framework.Assert.fail(Assert.java:47)
        at junit.framework.Assert.failNotEquals(Assert.java:282)
        at junit.framework.Assert.assertEquals(Assert.java:64)
        at junit.framework.Assert.assertEquals(Assert.java:201)
        at junit.framework.Assert.assertEquals(Assert.java:207)
```



Result Summary

Assignment: Sand 1 (201201): Java plug-in debugging try #4
Name: Stephen Edwards (edwards)
Partners: Edit Partners…
Submitted: 01/16/12 09:02PM, 16 days, 2 hrs, 52 mins early
Total Score: 28.1/100.0

Score Summary		
Design/Readability:	/40.0	<Awaiting Staff>
Style/Coding:	0.0/10.0	
Correctness/Testing:	28.1/50.0	
Final score:	**28.1/100.0**	

Position in class:

□ Show grade to student?

File Details

File	Staff Cmts	Staff Pts	Other Cmts	Other Pts	Methods/Statements/Conditionals Executed
Drills4.java	0	0.0	175	-10.0	59.4%
Drills4Test.java	0	0.0	69	0.0	100.0%

TA/Instructor Comments

```
Class Design            Good          16/20
Method Design           Excellent     10/10
Readability             Satisfactory   6/10
Automated Style Checks  Poor           0/10
Correctness/Testing     Excellent     28/50
-------------------------------------------
Total                                 52/100
```

Another: Web-CAT

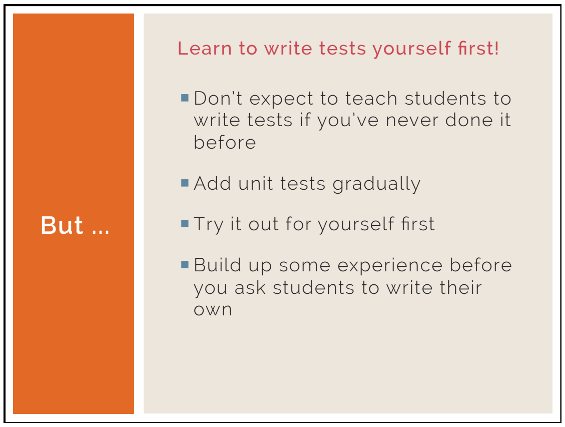
Adding Tests to Assignments

1. Use test cases as **specifications**
2. Write "**acceptance tests**" for grading
3. Require **student-written tests** as part of the assignment
4. Use a **reference model** to assess student tests
5. Write assignments that focus on **testing and/or debugging** instead of writing code

There are five main strategies for adding testing to assignments

If you give students tests instead of writing their own

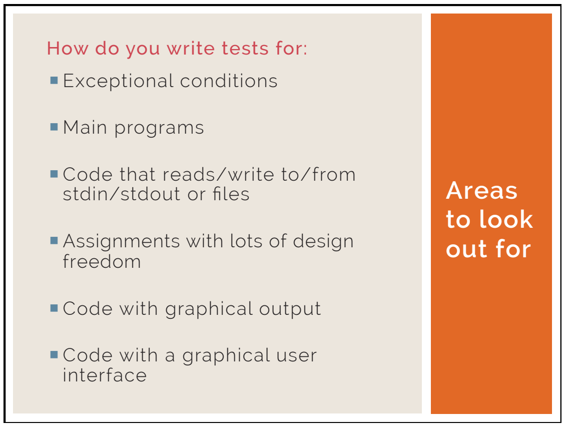
- Students appreciate the feedback from tests, but will **avoid thinking** more deeply about the problem
- Seeing the results from a complete set of tests discourages student from thinking about how to check about their solution on their own
- This **limits their learning …**



But ...

Learn to write tests yourself first!

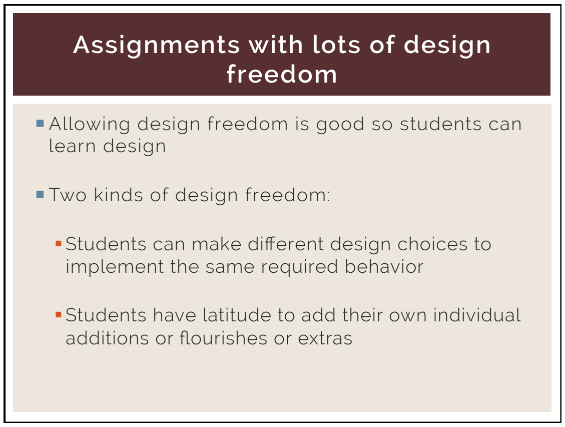
- Don't expect to teach students to write tests if you've never done it before
- Add unit tests gradually
- Try it out for yourself first
- Build up some experience before you ask students to write their own



Areas to look out for

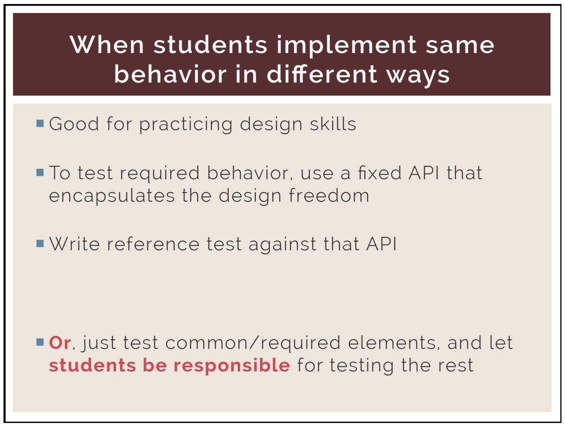
How do you write tests for:

- Exceptional conditions
- Main programs
- Code that reads/write to/from stdin/stdout or files
- Assignments with lots of design freedom
- Code with graphical output
- Code with a graphical user interface



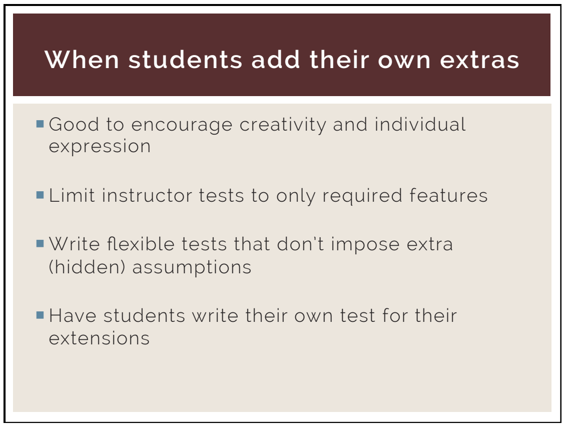
Assignments with lots of design freedom

- Allowing design freedom is good so students can learn design
- Two kinds of design freedom:
  - Students can make different design choices to implement the same required behavior
  - Students have latitude to add their own individual additions or flourishes or extras



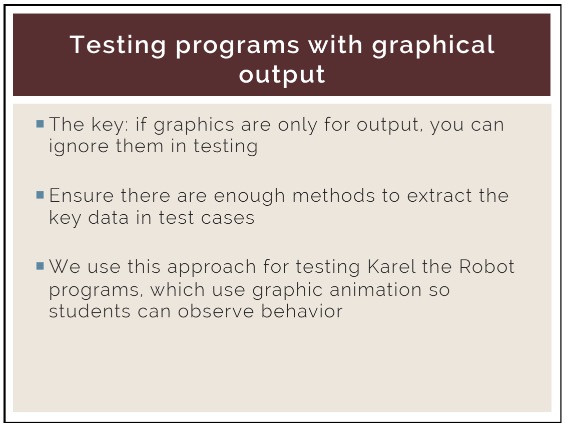
When students implement same behavior in different ways

- Good for practicing design skills
- To test required behavior, use a fixed API that encapsulates the design freedom
- Write reference test against that API
- **Or**, just test common/required elements, and let **students be responsible** for testing the rest



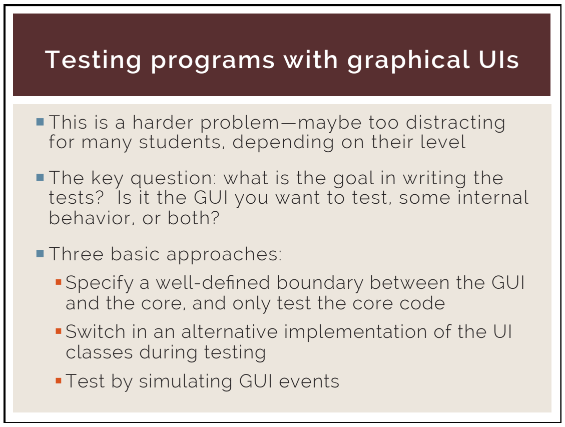
When students add their own extras

- Good to encourage creativity and individual expression
- Limit instructor tests to only required features
- Write flexible tests that don't impose extra (hidden) assumptions
- Have students write their own test for their extensions



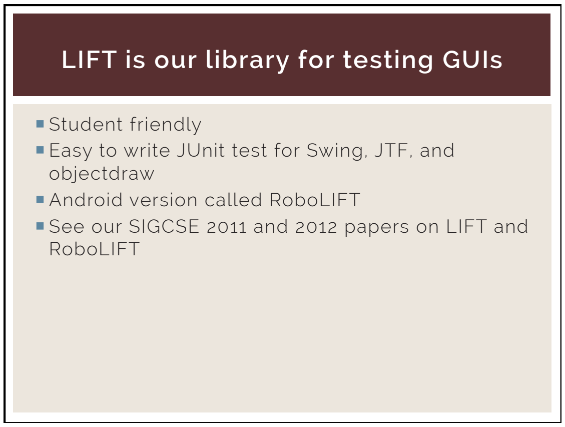
Testing programs with graphical output

- The key: if graphics are only for output, you can ignore them in testing
- Ensure there are enough methods to extract the key data in test cases
- We use this approach for testing Karel the Robot programs, which use graphic animation so students can observe behavior



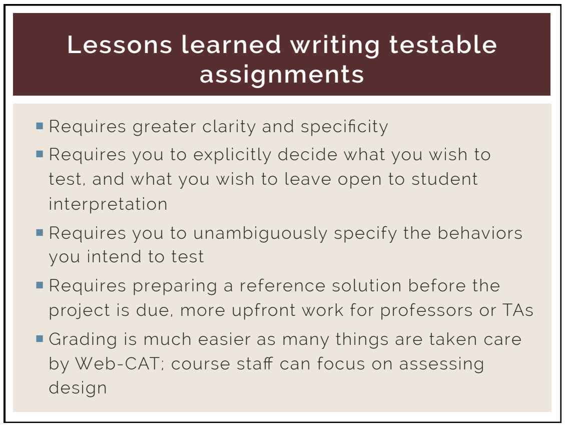
Testing programs with graphical UIs

- This is a harder problem—maybe too distracting for many students, depending on their level
- The key question: what is the goal in writing the tests? Is it the GUI you want to test, some internal behavior, or both?
- Three basic approaches:
  - Specify a well-defined boundary between the GUI and the core, and only test the core code
  - Switch in an alternative implementation of the UI classes during testing
  - Test by simulating GUI events



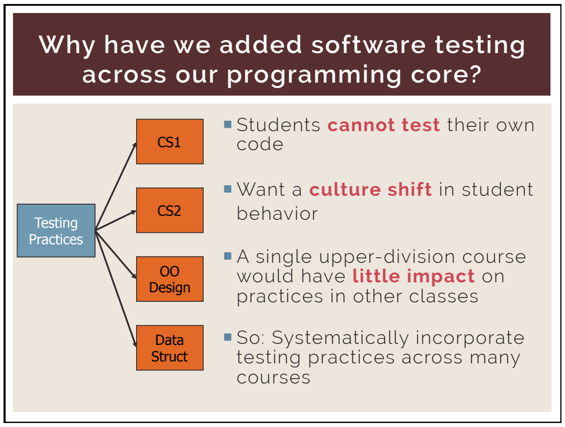
LIFT is our library for testing GUIs

- Student friendly
- Easy to write JUnit test for Swing, JTF, and objectdraw
- Android version called RoboLIFT
- See our SIGCSE 2011 and 2012 papers on LIFT and RoboLIFT



Lessons learned writing testable assignments

- Requires greater clarity and specificity
- Requires you to explicitly decide what you wish to test, and what you wish to leave open to student interpretation
- Requires you to unambiguously specify the behaviors you intend to test
- Requires preparing a reference solution before the project is due, more upfront work for professors or TAs
- Grading is much easier as many things are taken care by Web-CAT; course staff can focus on assessing design



Why have we added software testing across our programming core?

Testing Practices

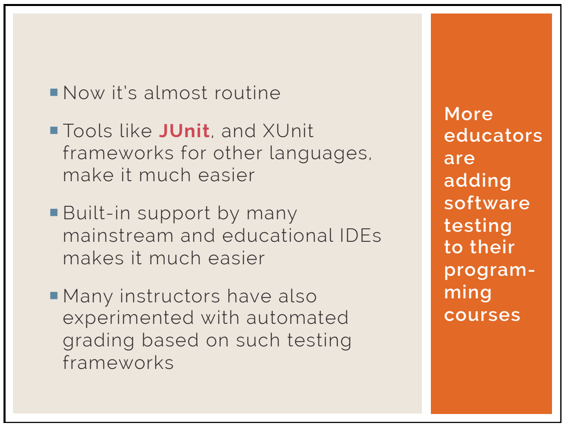
CS1

CS2

OO Design

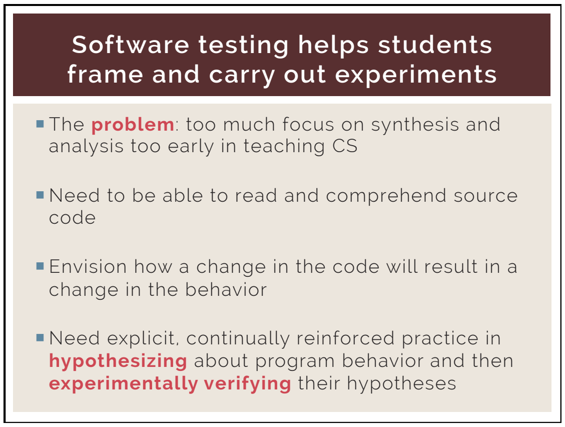
Data Struct

- Students **cannot test** their own code
- Want a **culture shift** in student behavior
- A single upper-division course would have **little impact** on practices in other classes
- So: Systematically incorporate testing practices across many courses



- Now it's almost routine
- Tools like **JUnit**, and XUnit frameworks for other languages, make it much easier
- Built-in support by many mainstream and educational IDEs makes it much easier
- Many instructors have also experimented with automated grading based on such testing frameworks

More educators are adding software testing to their programming courses



Software testing helps students frame and carry out experiments

- The **problem**: too much focus on synthesis and analysis too early in teaching CS
- Need to be able to read and comprehend source code
- Envision how a change in the code will result in a change in the behavior
- Need explicit, continually reinforced practice in **hypothesizing** about program behavior and then **experimentally verifying** their hypotheses

Thank You!

- Our community is our most valuable asset!

http://web-cat.org