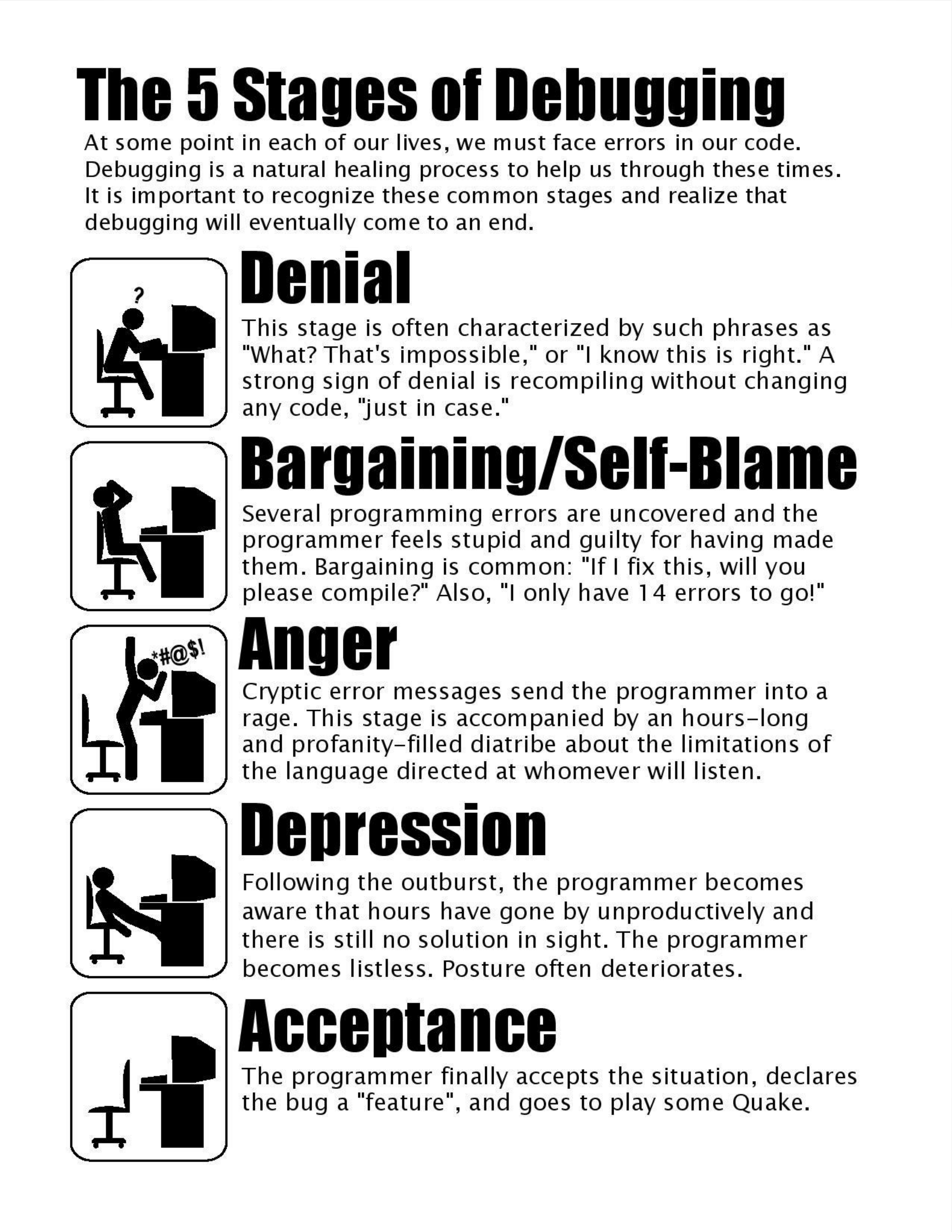


# The 5 Stages of Debugging

At some point in each of our lives, we must face errors in our code. Debugging is a natural healing process to help us through these times. It is important to recognize these common stages and realize that debugging will eventually come to an end.

## Denial

This stage is often characterized by such phrases as "What? That's impossible," or "I know this is right." A strong sign of denial is recompiling without changing any code, "just in case."

## Bargaining/Self-Blame

Several programming errors are uncovered and the programmer feels stupid and guilty for having made them. Bargaining is common: "If I fix this, will you please compile?" Also, "I only have 14 errors to go!"

## Anger

Cryptic error messages send the programmer into a rage. This stage is accompanied by an hours-long and profanity-filled diatribe about the limitations of the language directed at whomever will listen.

## Depression

Following the outburst, the programmer becomes aware that hours have gone by unproductively and there is still no solution in sight. The programmer becomes listless. Posture often deteriorates.

## Acceptance

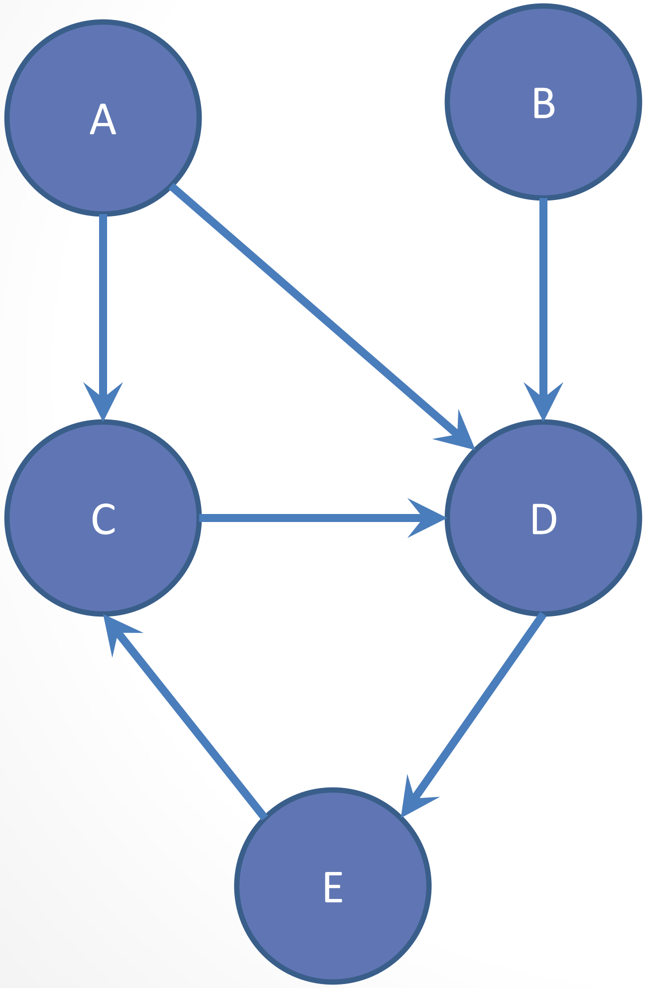
The programmer finally accepts the situation, declares the bug a "feature", and goes to play some Quake.

# Section 4:
# Graphs and Testing

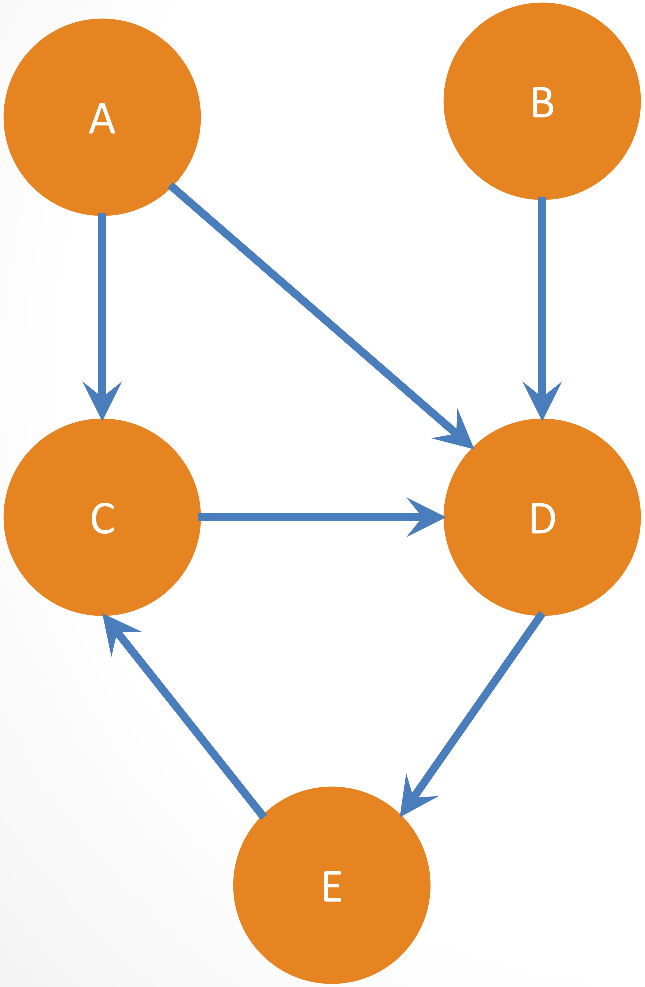
Slides by Alex Mariakakis

with material from Krysta Yousoufian,
Mike Ernst, Kellen Donohue

# Graphs

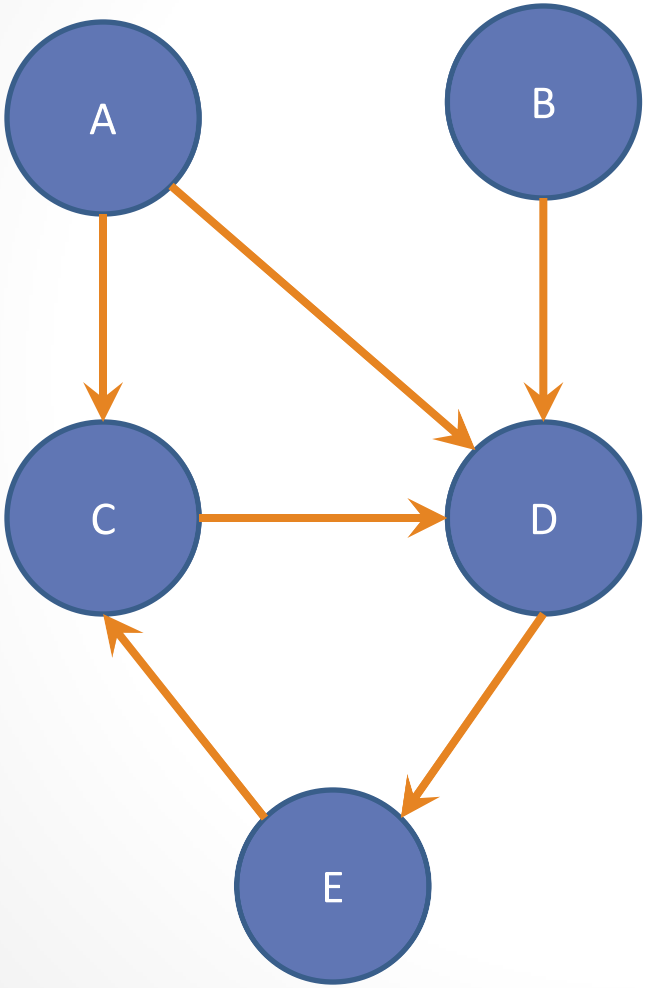


# Graphs



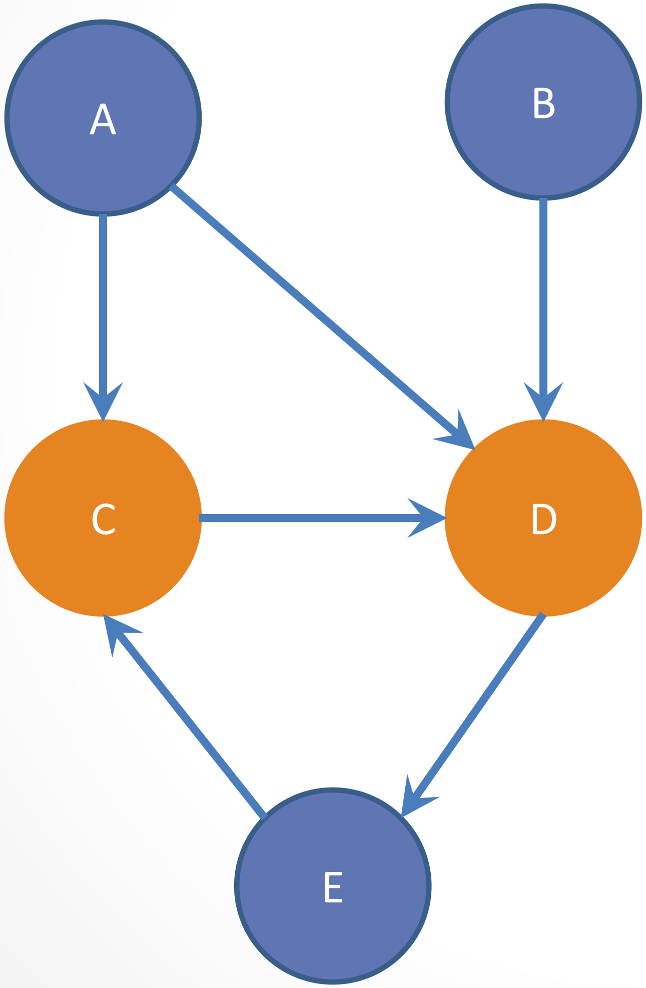
Nodes

# Graphs



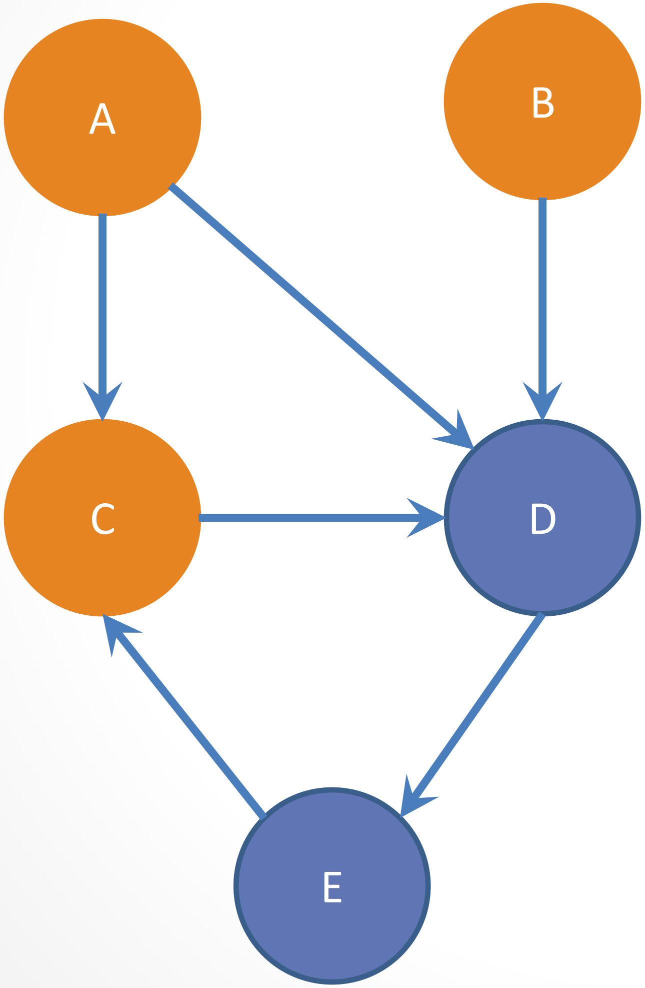
Edges

# Graphs



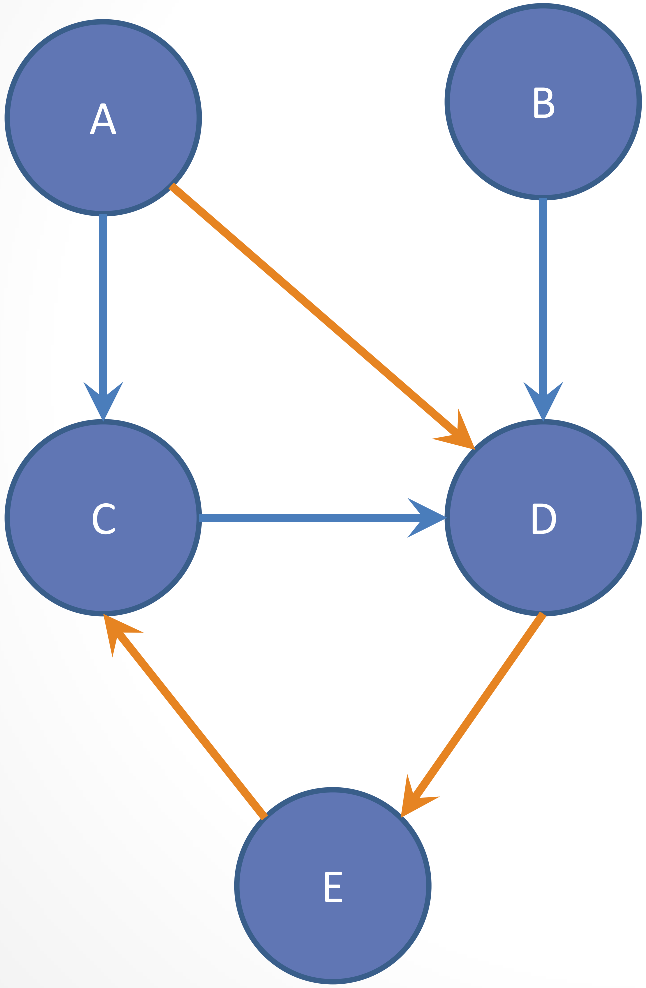
Children of A

# Graphs



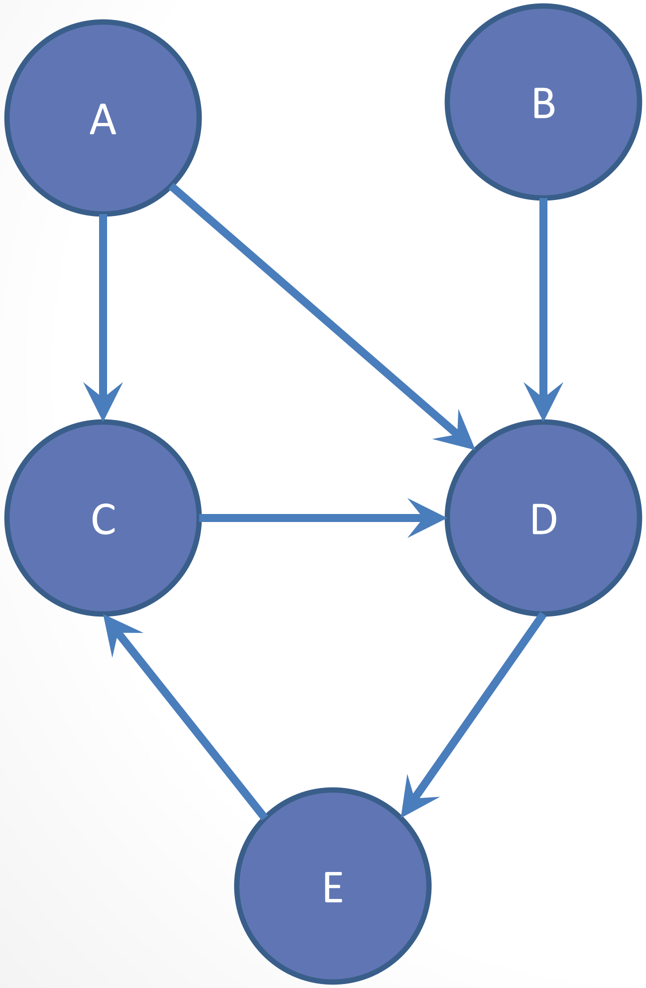
Parents of D

# Graphs



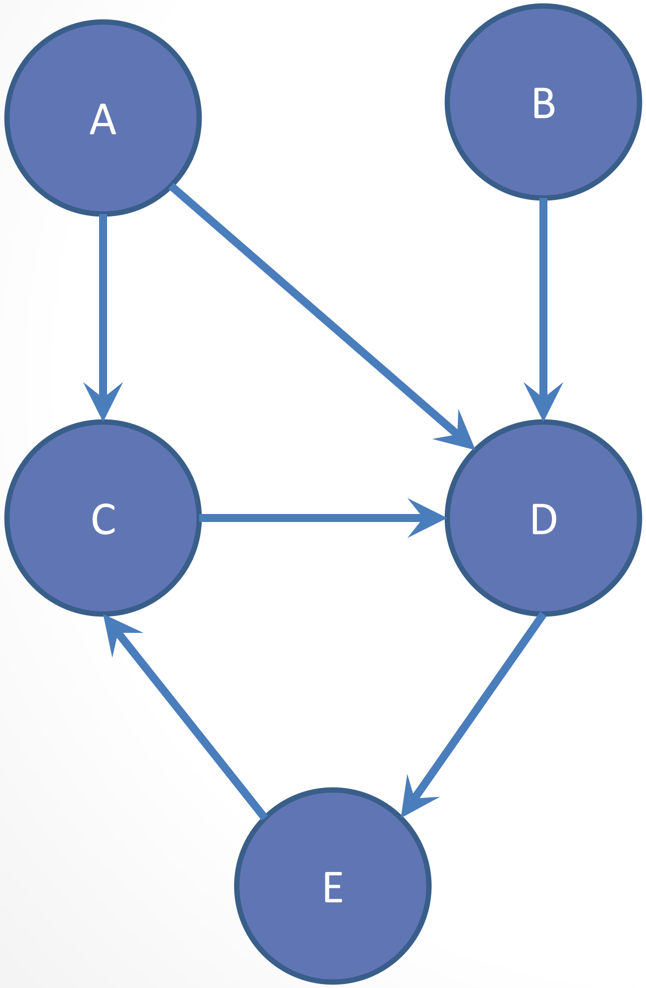
Path from A to C

# Graphs



Shortest path from A to C?

# Graphs



Shortest path from A to B?

# Internal vs. External Testing

- Internal : JUnit
  - How you decide to abstract the object
  - Checked with implementation tests
- External: test script
  - Client expects to see concrete object
  - Checked with specification tests

# A JUnit Test Class

- A method with `@Test` is flagged as a JUnit test
- All `@Test` methods run when JUnit runs

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

public class TestSuite {
   ...

    @Test
    public void TestName1() {
        ...
    }
}
```

# Using Assertions

- Verifies that a value matches expectations
  - `assertEquals(42, meaningOfLife());`
  - `assertTrue(list.isEmpty());`
- If the value isn't what it should be, the test fails
  - Test immediately terminates
  - Other tests in the test class are still run as normal
  - Results show details of failed tests

# Using JUnit Assertions

| Assertion | Case for failure |
|---|---|
| assertTrue(test) | the boolean test is false |
| assertFalse(test) | the boolean test is true |
| assertEquals(expected, actual) | the values are not equal |
| assertSame(expected, actual) | the values are not the same (by ==) |
| assertNotSame(expected, actual) | the values are the same (by ==) |
| assertNull(value) | the given value is not null |
| assertNotNull(value) | the given value is null |

- And others: http://www.junit.org/apidocs/org/junit/Assert.html
- Each method can also be passed a string to display if it fails:
  - assertEquals("message", expected, actual)

# Checking for Exceptions

- Verify that a method throws an exception when it should
- Test passes if specified exception is thrown, fails otherwise
- Only time it's OK to write a test without a form of `asserts`

```
@Test(expected=IndexOutOfBoundsException.class)
public void testGetEmptyList() {
   List<String> list = new ArrayList<String>();
   list.get(0);
}
```

# Setup and Teardown

- Methods to run before/after each test case method is called:

```
@Before
public void name() { ... }
@After
public void name() { ... }
```

- Methods to run once before/after the entire test class runs:

```
@BeforeClass
public static void name() { ... }
@AfterClass
public static void name() { ... }
```

# Setup and Teardown

```
public class Example {
      List empty;

      @Before
      public void initialize() {
            empty = new ArrayList();
      }
      @Test
      public void size() {
            ...
      }
      @Test
      public void remove() {
            ...
      }
}
```

# Don’t Repeat Yourself

- Can declare fields for frequently-used values or constants

  -
    ```
    private static final String DEFAULT_NAME =
    “MickeyMouse”;
    ```

  -
    ```
    private static final User DEFAULT_USER = new
    User(“lazowska”, “Ed”, “Lazowska”);
    ```

- Can write helper methods, etc.

  -
    ```
    private void eq(RatNum ratNum, String rep) {
         assertEquals(rep, ratNum.toString());
    }
    ```

  -
    ```
    private BinaryTree getTree(int[] items) {
      // construct BinaryTree and add each element in items
    }
    ```

# #1: Be descriptive

- When a test fails, JUnit tells you:
  - Name of test method
  - Message passed into failed assertion
  - Expected and actual values of failed assertion
- The more descriptive this information is, the easier it is to diagnose failures

| Level of goodness | Example |
|---|---|
| Good | `testAddDaysWithinMonth()` |
| Not so good | `testAddDays1(), testAddDays2()` |
| Bad | `test1(), test2()` |
| Overkill | `TestAddDaysOneDayAndThenFiveDaysStartingOnJanuaryTwentySeventhAndMakeSureItRollsBackToJanuaryAfterRollingToFebruary()` |

# #1: Be descriptive

- Take advantage of `message`, `expected`, and `actual` values
- No need to repeat expected/actual values or info in test name
- Use the right assert for the occasion:
  - `assertEquals(expected, actual)` instead of `assertTrue(expected.equals(actual))`

# Let’s put it all together!

```
public class DateTest {

    ...

    // Test addDays when it causes a rollover between months
    @Test
    public void testAddDaysWrapToNextMonth() {
        Date actual = new Date(2050, 2, 15);
        actual.addDays(14);
        Date expected = new Date(2050, 3, 1);
        assertEquals("date after +14 days", expected,
             actual);
    }
```

# Let’s put it all together!

Tells JUnit that this method is a test to run

```
public class DateTest {

    ...

    // Test addDays when it causes a rollover between months
    @Test
    public void testAddDaysWrapToNextMonth() {
        Date actual = new Date(2050, 2, 15);
        actual.addDays(14);
        Date expected = new Date(2050, 3, 1);
        assertEquals("date after +14 days", expected,
             actual);
    }
```

# Let’s put it all together!

Descriptive method name

```
public class DateTest {

    ...

    // Test addDays when it causes a rollover between months
    @Test
    public void testAddDaysWrapToNextMonth() {
        Date actual = new Date(2050, 2, 15);
        actual.addDays(14);
        Date expected = new Date(2050, 3, 1);
        assertEquals("date after +14 days", expected,
                     actual);
    }
```

# Let's put it all together!

Use assertion to check expected results

```
public class DateTest {

    ...

    // Test addDays when it causes a rollover between months
    @Test
    public void testAddDaysWrapToNextMonth() {
        Date actual = new Date(2050, 2, 15);
        actual.addDays(14);
        Date expected = new Date(2050, 3, 1);
        assertEquals("date after +14 days", expected,
            actual);
    }
```

# Let’s put it all together!

Message gives details about the test in case of failure

```
public class DateTest {

    ...

    // Test addDays when it causes a rollover between months
    @Test
    public void testAddDaysWrapToNextMonth() {
        Date actual = new Date(2050, 2, 15);
        actual.addDays(14);
        Date expected = new Date(2050, 3, 1);
        assertEquals("date after +14 days", expected,
            actual);
    }
```

# #2: Keep tests small

- Ideally, test one thing at a time
  - "Thing" usually means one method under one input condition
  - Not always possible – but if you test `x()` using `y()`, try to test `y()` in isolation in another test
- Low-granularity tests help you isolate bugs
  - Tell you exactly what failed and what didn't
- Only a few (likely one) assert statements per test
  - Test halts after first failed assertion
  - Don't know whether later assertions would have failed

# #3: Be thorough

- Consider each equivalence class
  - Items in a collection: none, one, many
- Consider common input categories
  - `Math.abs()`: negative, zero, positive values
- Consider boundary cases
  - Inputs on the boundary between equivalence classes
  - `Person.isMinor()`: age < 18, age == 18, age > 18
- Consider edge cases
  - -1, 0, 1, empty list, arr.length, arr.length-1
- Consider error cases
  - Empty list, null object

# JUnit Asserts vs. Java Asserts

- We've just been discussing JUnit assertions so far
- Java itself has assertions

```
public class LitterBox {
  ArrayList<Kitten> kittens;

  public Kitten getKitten(int n) {
      assert(n >= 0);
      return kittens(n);
  }
}
```

# Assertions vs. Exceptions

```
public class LitterBox {
   ArrayList<Kitten> kittens;

   public Kitten getKitten(int n) {
      assert(n >= 0);
      return kittens(n);
   }
}
```

```
public class LitterBox {
   ArrayList<Kitten> kittens;

   public Kitten getKitten(int n) {
      try {
         return kittens(n);
      } catch(Exception e) {
      }
   }
}
```

- Assertions should check for things that should never happen
- Exceptions should check for things that might happen
- “Exceptions address the robustness of your code, while assertions address its correctness”

# Test Script Language

- Text file with one command listed per line
- First word is always the command name
- Remaining words are arguments
- Commands will correspond to methods in your code

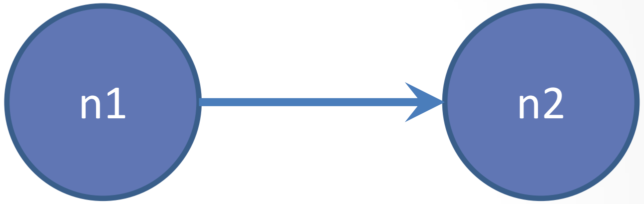
# Test Script Language

```
# Create a graph
CreateGraph graph1

# Add a pair of nodes
AddNode graph1 n1
AddNode graph1 n2

# Add an edge
AddEdge graph1 n1 n2 e1

# Print the nodes in the graph
and the outgoing edges from n1
ListNodes graph1
ListChildren graph1 n1
```

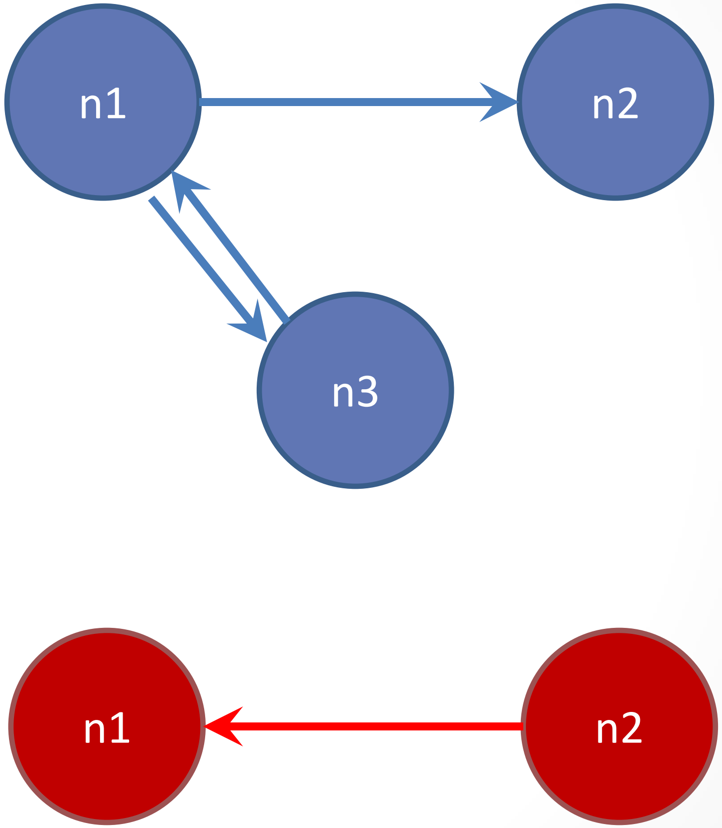


# Test Script Language

```
CreateGraph A
AddNode A n1
AddNode A n2

CreateGraph B
ListNodes B
AddNode A n3
AddEdge A n3 n1 e31
AddNode B n1
AddNode B n2
AddEdge B n2 n1 e21
AddEdge A n1 n3 e13
AddEdge A n1 n2 e12

ListNodes A
ListChildren A n1
ListChildren B n2
```



# DEMO: HOW TO CONNECT THE DOTS