Objectives

- Testing
- Collaboration
- Coverage

1

Review

1. What are the steps to a JUnit test case?
   - How do we implement them?
2. What approaches did you take to writing good test cases to reveal the mutants?
   - How is programming tests the same/different from programming generally?
3. What are the benefits of unit testing/using JUnit?
   - Consider if you were developing/maintaining the `thirdShortest` method
   - How would your testing/development process change?
4. True or False. Unit testing is all the testing that needs to be done for an application.

2

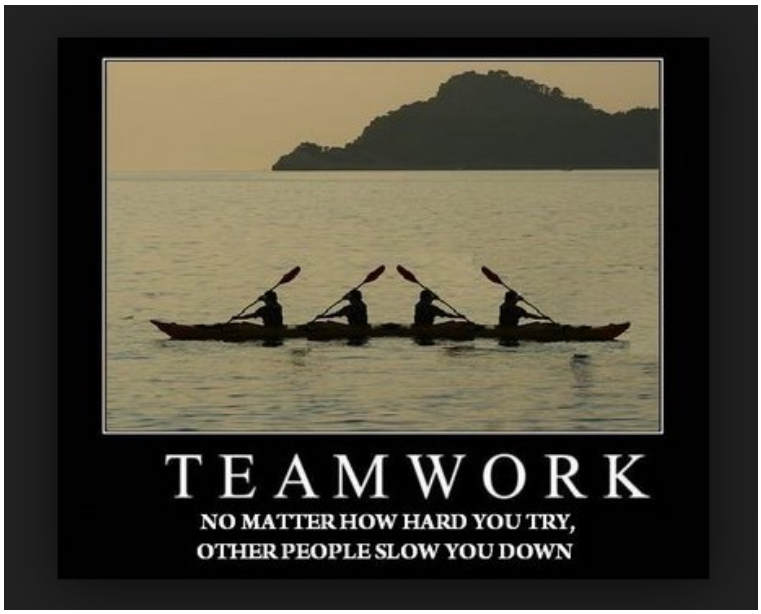
Review: Some Approaches to Testing Methods

- 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

Catching the Mutants: Post-Mortem

- What are the benefits of unit testing/using JUnit?
  - Consider if you were developing/maintaining the method
  - How would your testing/development process change?
- Why did the output from `RevealingMutantsEvaluator` come out in strange/unexpected orders sometimes?
- Is it okay that some mutants passed some of the test cases?
- Recall the characteristics of good unit tests
  - How did you achieve them in your testing?



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Think about Team (Group) Projects

- Why did some work well?
- Why were some disasters?

6

Teams Work Best When They are **Interdependent**

- In code terms, we want *loose coupling*
  - Depend on each other but don't depend on their details
- Consider
  - Are you allowing your team to truly be interdependent?
  - Who might be you be ignoring?
  - Who might be allowing themselves to feel inadequate?
  - How do you show appreciation for each other and yourself?

Collaboration: Team Project

- Version Control does not eliminate need for communication
  - Process becomes much more difficult if developers do not communicate
- Keep the version to be graded in `main` branch
- Before picking up again on development, **pull** the repository
  - Get others' changes
- Each student on team must make significant commits to the project's repository

Collaboration: Team Project

- Need to talk about the solution
- Discuss your plan, e.g.,
  - Your assumptions about the Car class
  - Your system for testing to make sure that you test everything
  - Organization of test cases
  - Naming
  - Division of labor
- Maintain planning documents too
  - in GitHub or elsewhere

Collaboration: Workflow – Seeking Feedback

1. Create a branch for your work
   - Commit periodically
   - Write descriptive comments so your team members know what you did and why
2. Push your branch
3. Open a ***Pull Request*** on your branch in GitHub
   - You can tag your teammates to let them know that you've completed your work
   - Team: discuss and review potential changes – can still update
4. Merge pull request into `main` branch
5. Pull the `main` branch to get the latest code

Collaboration: Workflow

1. Create a branch for your work
   - Commit periodically
   - Write descriptive comments so your team members know what you did and why
2. Switch to `main`
3. Pull `main` branch
4. Merge your branch into the `main` branch
   - Handle merge conflicts
   - Commit
5. Push `main` branch

Guidance for Writing JUnit Tests

- 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
- Testing isn't typically "creative" and doesn't need to be generalizable
  - Code should be straightforward
- See examples linked from course schedule page

Guidance for Organizing JUnit Tests

- Group tests in methods, classes
- Classes could be distinguished by behavior, by error conditions, by set up method…
- Name methods based on what they test
  - Template: `functionality_state_expectedresult`
  - Example: `go_fulltank_moves`

Software Testing Issues

- 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

Software Testing Issues

- How do we know if our code is correct?
  - How do we know that we've exposed all the faults?
  - How confident are we in its correctness?
- How do we know if we've tested enough?
  - Our customers want this product soon but we need product to be correct
    - Harder to fix after it has been released

Software Testing Issues

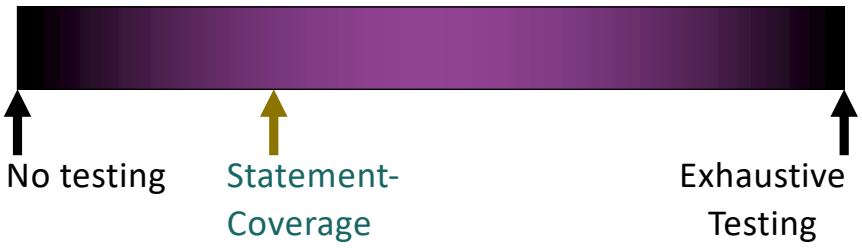
- How do we know if our code is correct?
  - How do we know that we've exposed all the faults?
  - How confident are we in its correctness?
- How do we know if we've tested enough?
  - Passes all of our TDD test suite
    - But did we come up with *all* the necessary test cases?
  - Time? It's been a couple hours/days/…
  - Number of test cases executed? A lot!
  - I asked my sister and she's really smart and she says that it's enough

Testing Continuum

- Give to customer immediately
- Likely buggy!
- Very little confidence in program's quality

- Test *every possible* input
- Costly, impractical
- Need to release application to customers *sometime!*

Testing Continuum



- Need to execute **all code**
- Cover (i.e., execute) all **statements** in the program

Analogy: Map coverage

Statement Coverage

- Cover all statements in the program

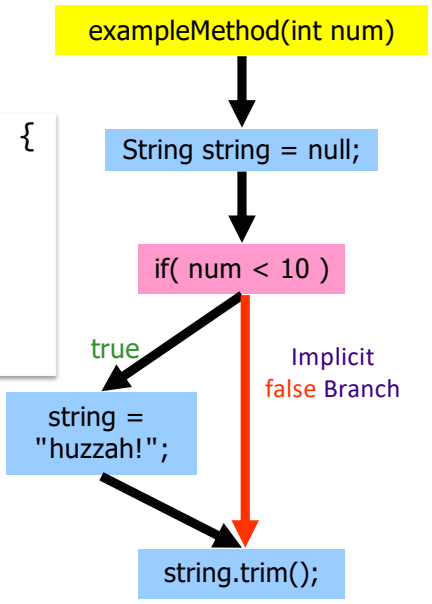
Test Suite: num=5

```
public String exampleMethod(int num) {
✓ 1   String string = null;
✓ 2   if (num < 10) {
✓ 3       string = "huzzah!";
      }
      // remove leading & trailing whitespace
✓ 4   return string.trim();
}
```

Is this method bug-free?

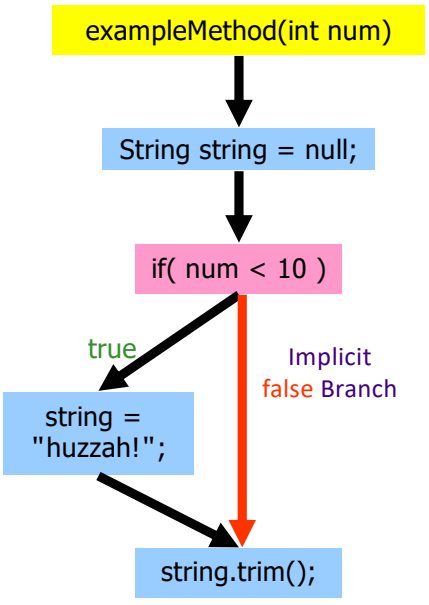
Program Flow

```
public String exampleMethod(int num) {
    String string = null;
    if (num < 10) {
        string = "huzzah!";
    }
    return string.trim();
}
```



What Went Wrong?

- Test suite had 100% statement coverage but missed a **branch/edge**
- Try covering all **edges** in program's flow
  - Also covers all **nodes**
  - Called **Branch Coverage**



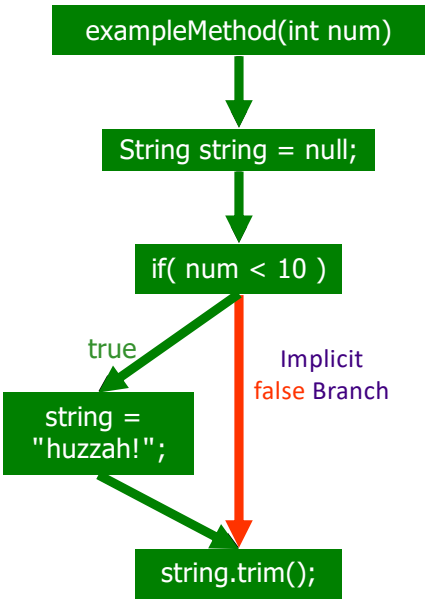
Branch Coverage

- Cover all **branches** in the program

Test Suite:

num=5,

num=10



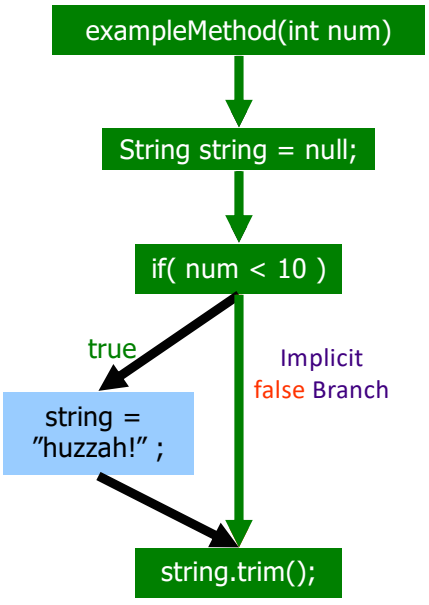
Branch Coverage

- Cover all **branches** in the program

Test Suite:

num=5,

num=10



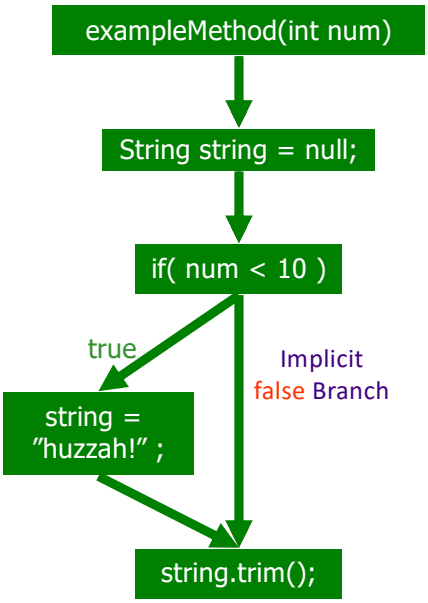
Branch Coverage

- Cover all **branches** in the program

Test Suite:

num=5,

num=10



Example 2

```
public static String exampleMethod(int a) {
   String str = "d";
   if ( a < 7 ) {
      a *= 2;
      str += "riv";
    } else {
      str = "co" + str;
    }

    if( a > 10 ) {
      str += "ing";
    } else {
      str += "es";
    }
   return str.substring(6);
}
```

Example 2

```
public String exampleMethod(int a) {
   String str = "d";
   if ( a < 7 ) {
      a *= 2;
      str += "riv";
    } else {
      str = "co" + str;
    }

    if( a > 10 ) {
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   return str.substring(6);
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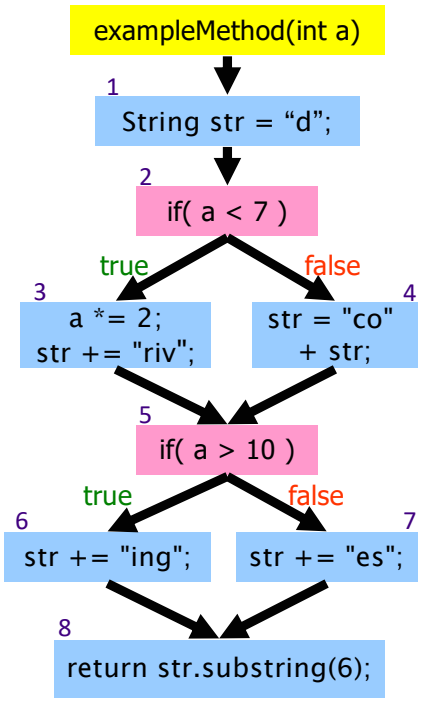


Branch Coverage

Test Suite:

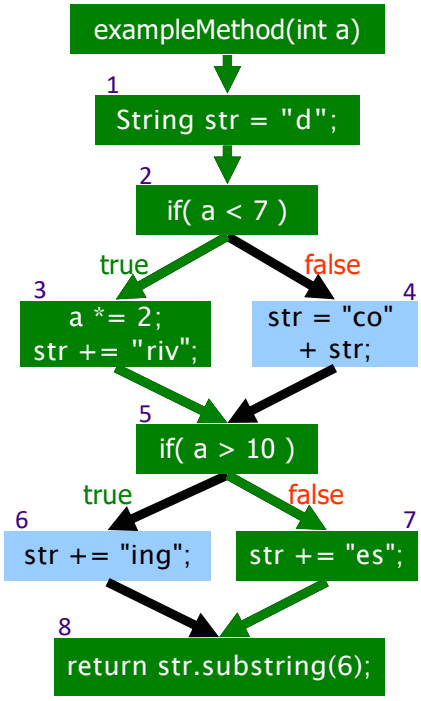
a=3,

a=30

str="driv"
a=6

str="drives"

""



Branch Coverage

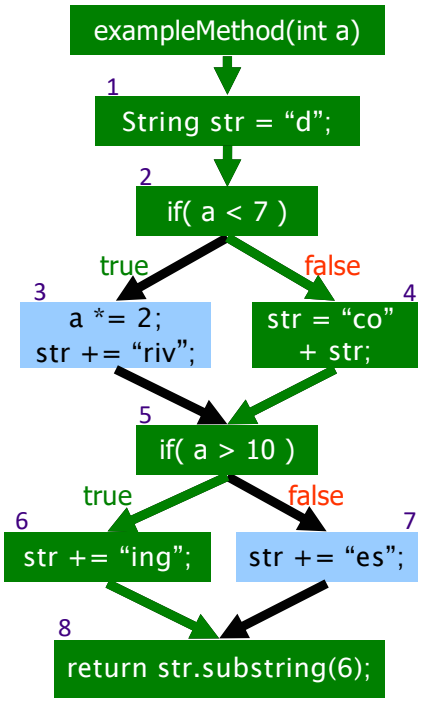
Test Suite:

a=3,
a=30

str="cod"
a=30

str="coding"

""

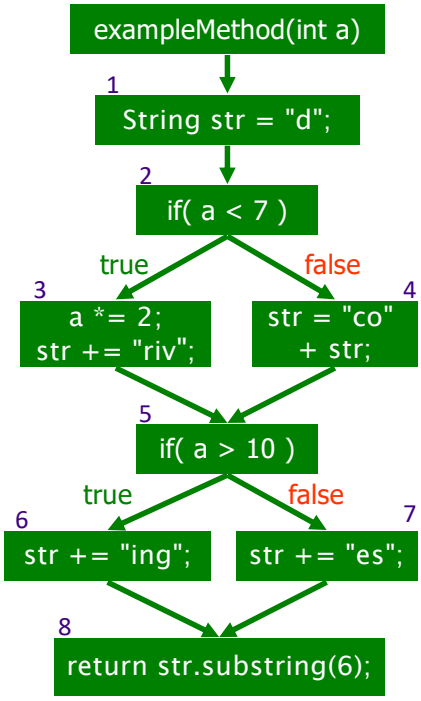


Branch Coverage

Test Suite:

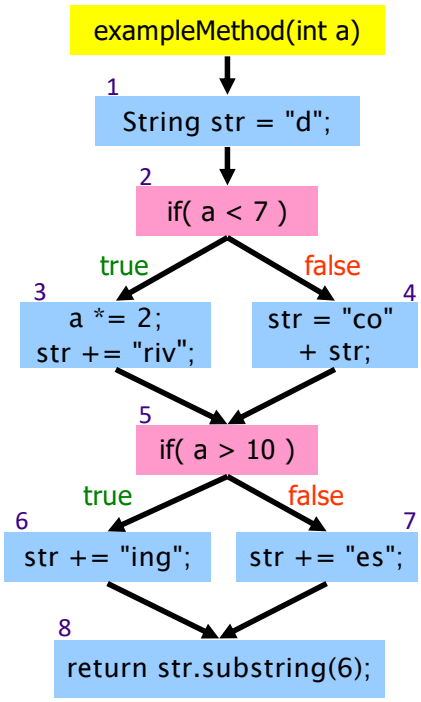
a=3,
a=30

Is this method bug free?



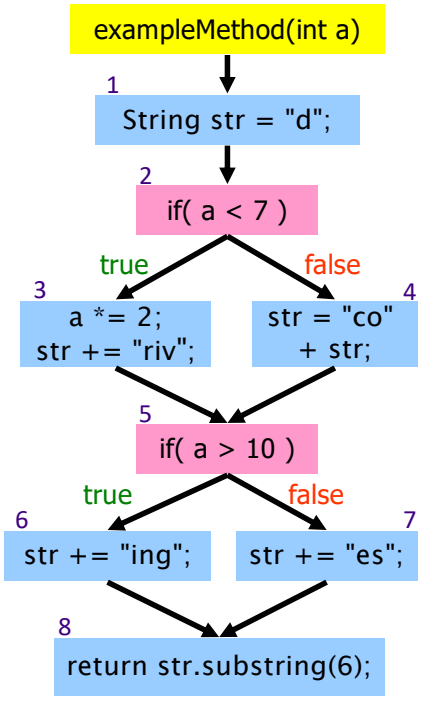
What Went Wrong?

- Test suite had 100% branch (and statement) coverage but missed a **path**
- Try to cover all **paths** in program's flow
  - Also gets all **branches, nodes**
  - Called **Path Coverage**



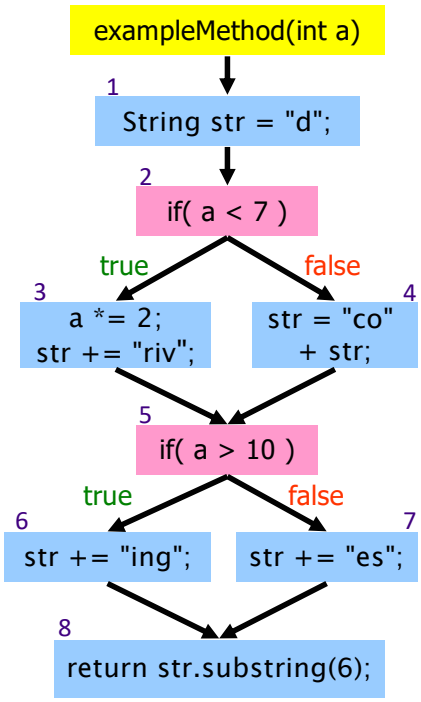
Path Coverage

- Cover all **paths** in program's flow
- How many paths through this method?
- What test cases would give us path coverage?



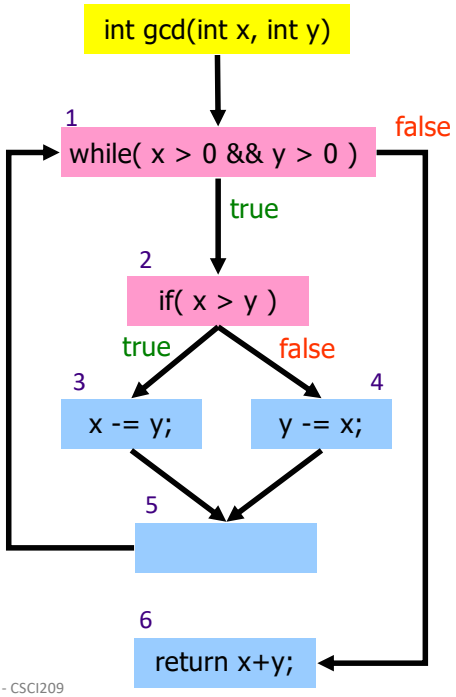
Path Coverage

- Cover all **paths** in program's flow
- How many paths through this method? 4
  - 1-2-**3**-5-**6**-8
  - 1-2-**3**-5-**7**-8
  - 1-2-**4**-5-**6**-8
  - 1-2-**4**-5-**7**-8
- What test cases would give us path coverage?
  - One possibility: a = 3, 30, 6, 10



Example 3

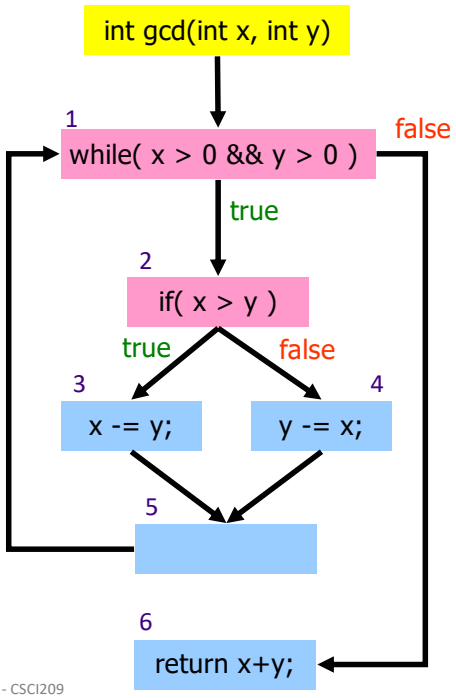
```
/**
 * Euclid's algorithm to calculate
 * greatest common divisor
 */
public int gcd( int x, int y ) {
    while ( x > 0 && y > 0 ) {
        if( x > y ) {
                x -=y ;
        } else {
                y -=x;
        }
    }
    return  x+y;
}
```



Path Coverage

- How many paths through this method?
  - Too many to count, test them all!

1-6
1-2-3-5-1-6
1-2-4-5-1-6
1-2-3-5-1-2-3-5-1-6
1-2-4-5-1-2-4-5-1-6
1-[2-(3|4)-5-1]*-6



Looking Ahead

- Friday
  - Coverage tools, Debugger
- Tuesday: Testing project