Inf1B

Testing and Debugging

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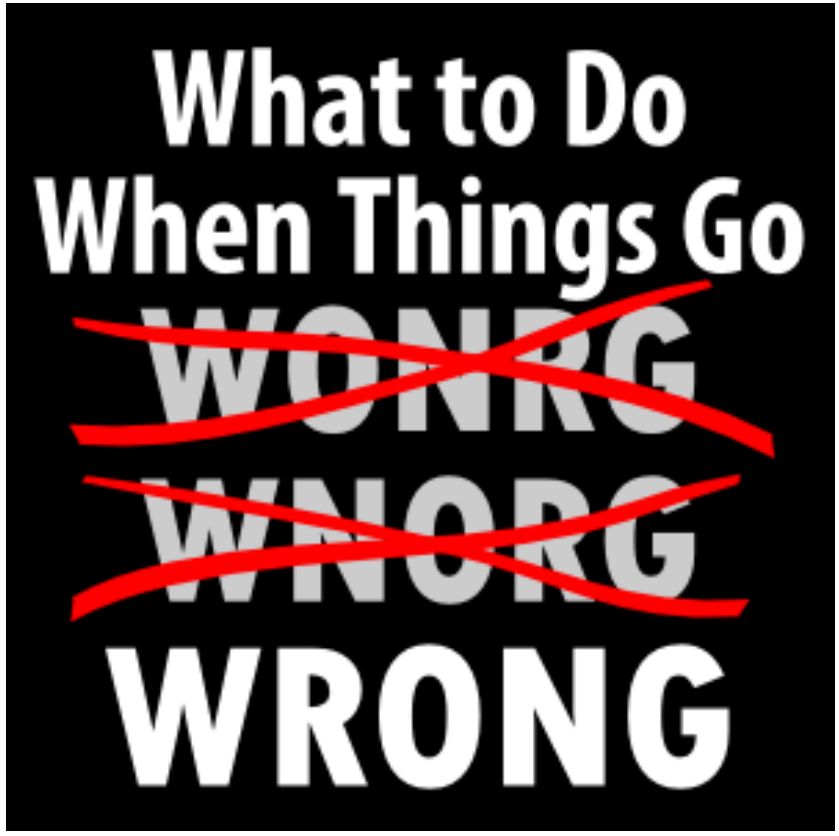
Things will go wrong



There is usually an error in your code somewhere.

https://4pyz335b69-flywheel.netdna-ssl.com/wp-content/uploads/2014/05/things-go-wrong.png

Types of Errors

Ordered by difficulty to detect and fix them.

- Syntax Errors
- Runtime Errors
- Logical Errors

Syntax Errors

Comparable to a spelling mistake in a text.

This is a speling mistake!

```
int value = 5;
if (value < 10
    Systm.out.println("Here we are.")
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An IDE can help you detect them.

Syntax Errors

Syntax errors are detected at compile time.

Compiler Output

```
Main.java:5: error: ')' expected
        if (value < 10
                    ^
Main.java:6: error: ';' expected
           Systm.out.println("Here we are.")
                                             ^
2 errors
```

Syntax Errors

Not always easy to identify despite compiler and IDE help.

```
1  public class Main {
2      public static int add(int a, int b) {
3          return a + b;
4
5      public static void main(String[] args) {
6          System.out.println(add(5,5));
7      }
8  }
```

Compiler Output

```
Main.java:5: error: illegal start of expression
    public static void main(String[] args) {
    ^
1 error
```

Runtime Errors

Comparable to a grammar mistake in a text.

There taking they're kids their.

```
int[] arr = { 1, 2, 3, 4 };
System.out.println(arr[4]);
```

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```

Compiler and IDE are unable to detect them.

Runtime Errors

The Java Runtime will detect them and crash your program.

```
int[] arr = { 1, 2, 3, 4 };
System.out.println(arr[4]);
```

Runtime Output

```
Exception in thread "main"
java.lang.ArrayIndexOutOfBoundsException:
Index 4 out of bounds for length 4
at Main.main(Main.java:5)
```

Logical Errors

Comparable to an incorrect or unintended statement in a text.

The swan is an orange bird.

```
public static int add(int a, int b) {
    return a - b;
}
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public static int add(int a, int b) {
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}
```

Neither compiler, nor IDE or Java Runtime can detect them.

Logical Errors

You need to test your code to catch them.

```
public static int add(int a, int b) {
    return a - b;
}

public static void main(String[] args) {
    if (add(5,5) != 10)
        System.out.println("Unexpected sum!");
}
```

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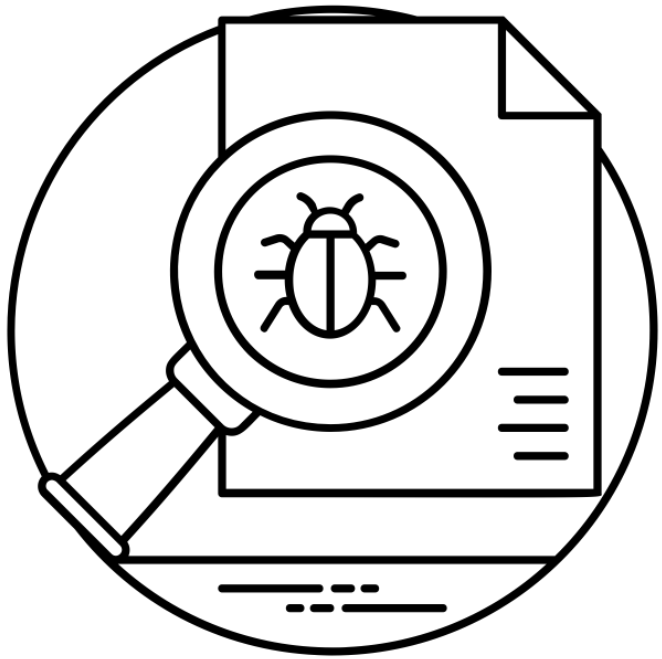
- Runtime Errors **Caught at runtime**
- Logical Errors **Caught via testing**

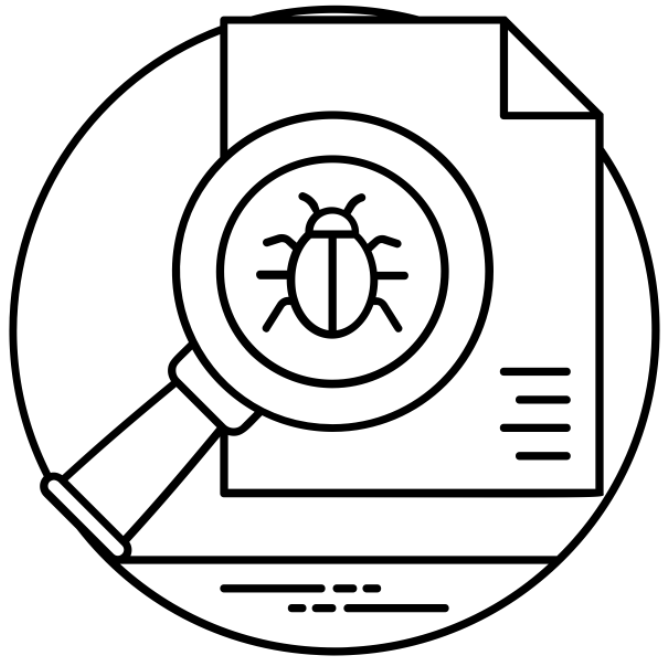
NB Since tests execute your code, they will also catch runtime errors.

Let's hunt some bugs!



Created by Vectors Market
from Noun Project

Let's hunt some bugs!



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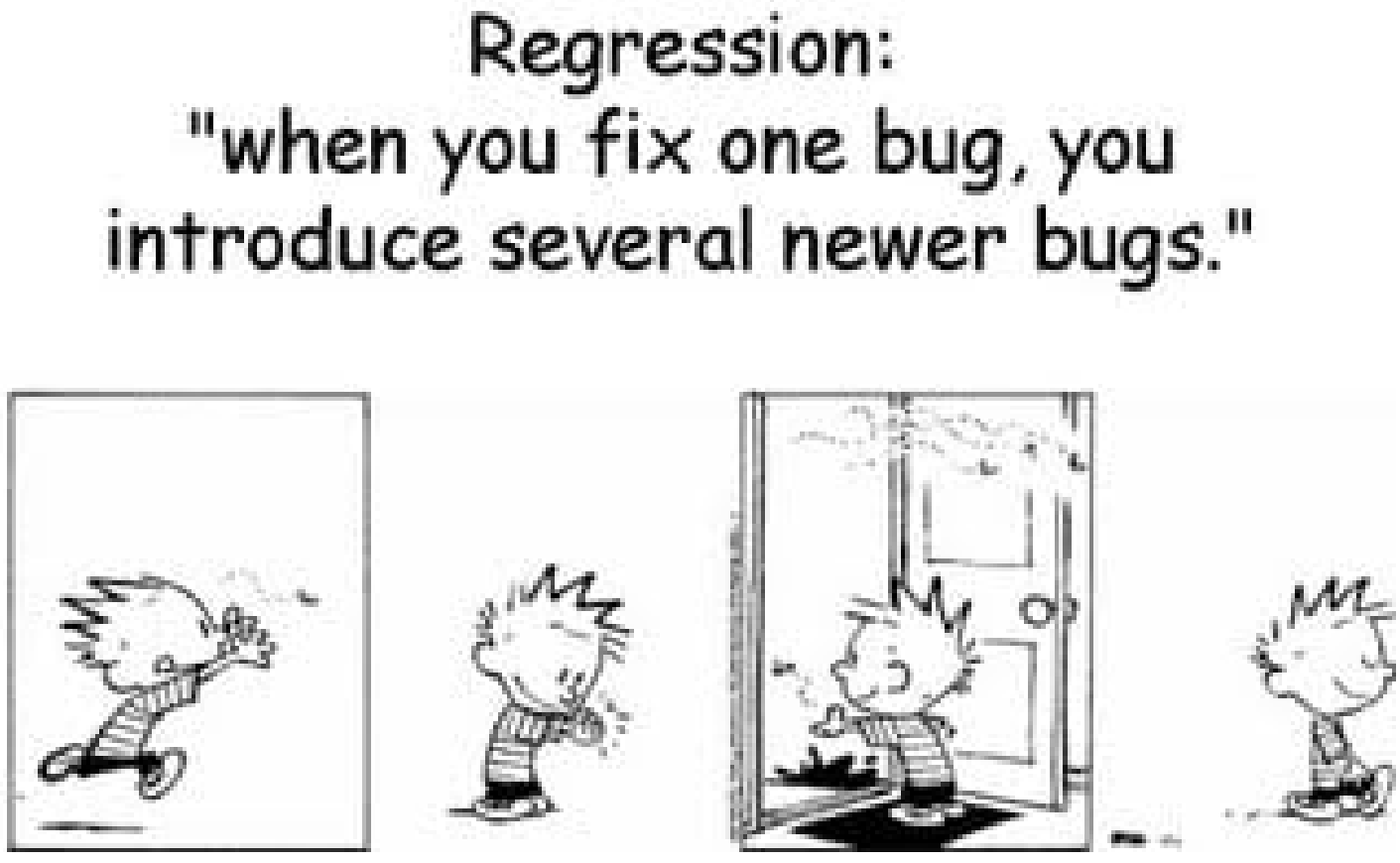
1. Testing *detect the errors*
2. Debugging *find and fix the errors*

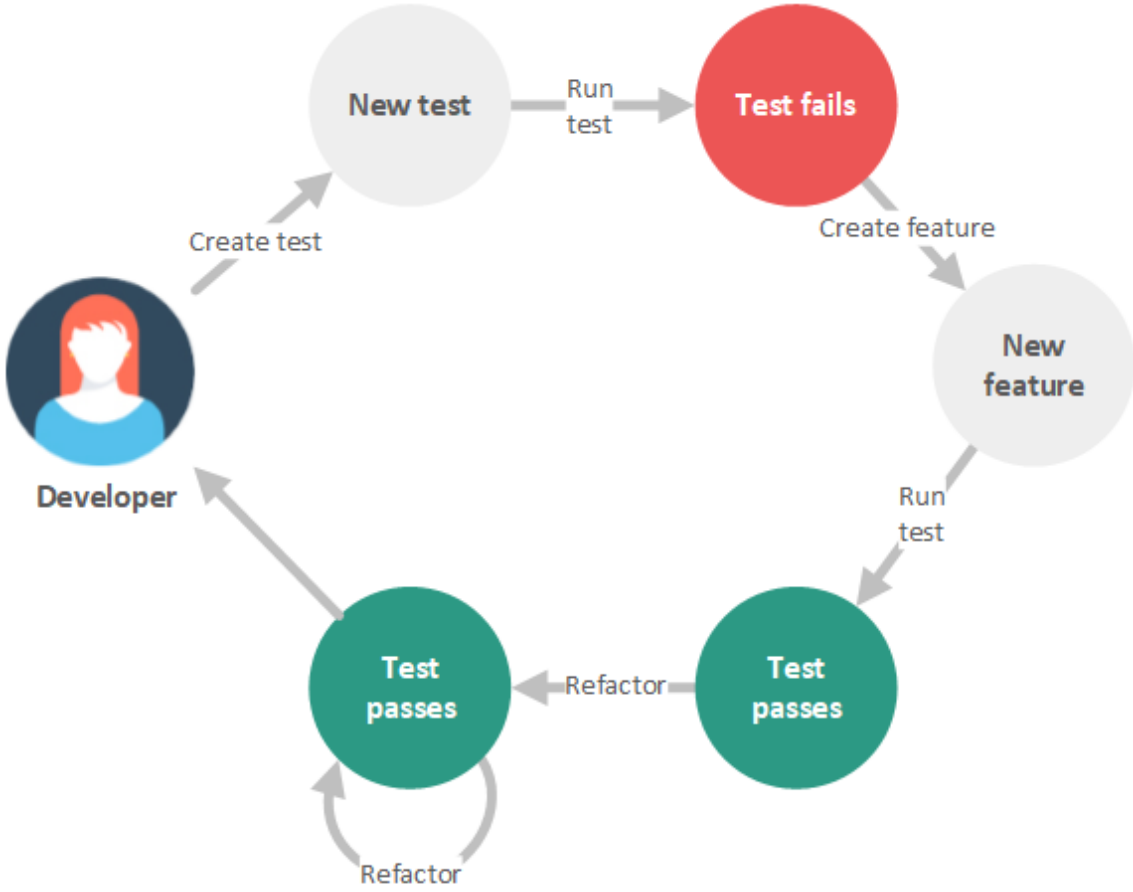
Testing

Regression Testing



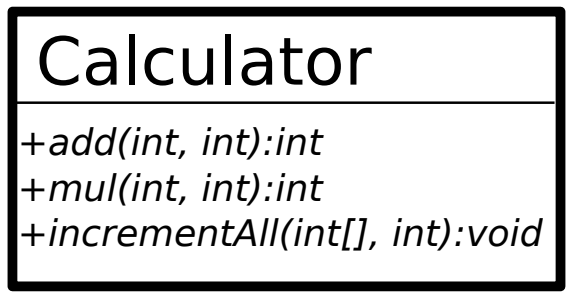
Source: https://www.softwaretestinghelp.com/regression-testing-tools-and-methods/

Test Driven Development



Source: https://dzone.com/articles/what-is-refactoring

Simple Calculator



Implement a utility class with calculator functionality.

How would you test the functionality of a class?

Demo

Main Method as Test Client

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  $\rightarrow$ use assertions instead!

Automatic evaluation with assertions

Demo

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  $\rightarrow$ use assertions instead!
- tests are unorganised, no easy way to test only certain methods

  $\rightarrow$ use a test framework instead!

Organising Tests with a Test Framework

Demo

Testing Strategies

- test for regular use cases
- test for corner cases
- test for invalid input (how should it be handled?)
- positive testing vs. negative testing

Debugging

Manual walk through

Something is wrong with this array rotation code.

```
1  int[] arr = { 1, 2, 3, 4, 5 };
2  int tmp = arr[arr.length - 1];
3  for (int i = 0; i < arr.length - 1; i++) {
4      arr[i + 1] = arr[i];
5  }
6  arr[0] = tmp;
```

Let's find out what without the help of machines.

Logging

With Compiler and Runtime, we can use a logging approach.

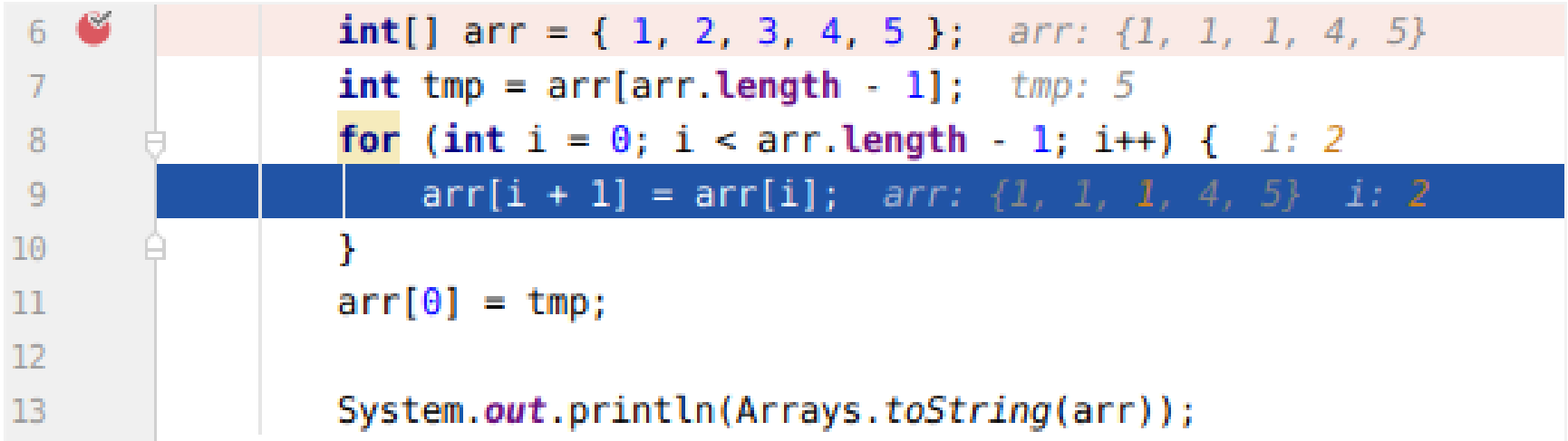
```
int[] arr = { 1, 2, 3, 4, 5 };
int tmp = arr[arr.length - 1];
for (int i = 0; i < arr.length - 1; i++) {
    arr[i + 1] = arr[i];
    System.out.println(Arrays.toString(arr));
}
arr[0] = tmp;
System.out.println(Arrays.toString(arr)):
```

Output

```
[1, 1, 3, 4, 5]
[1, 1, 1, 4, 5]
[1, 1, 1, 1, 5]
[1, 1, 1, 1, 1]
[5, 1, 1, 1, 1]
```

Using a Debugger

With the help of a debugger, we can get a lot of information without much effort from our side.



Demo

Debugging Strategies

- Manual Walk Through
- Logging
- Debugger

Bug Hunting

1. Testing *detect the errors*
2. Debugging *find and fix the errors*

Bug Hunting

0. Write Robust and Maintainable Code

avoid errors in the first place

1. Testing *detect the errors*
2. Debugging *find and fix the errors*

Error Handling

Handling Invalid Input

Given a function that generates a sequence of numbers ...

What could go wrong here?

```
1  public static int[] sequence(int start, int end) {
2   int[] result = new int[end - start];
3   int index = 0;
4   while (start < end) {
5    result[index++] = start++;
6   }
7   return result;
8  }
```

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Start could be smaller than end!

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```

Start could be smaller than end!

How could we handle this best?

Handling Invalid Input

Make a note in the function documentation.

```
1  /** Start must always be smaller or equal to end! */
2  public static int[] sequence(int start, int end) {
3   int[] result = new int[end - start];
4   int index = 0;
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```

Helpful but not a good way to enforce rules.

Handling Invalid Input

Add a check and print an error message.

```
1  /** Start must always be smaller or equal to end! */
2  public static int[] sequence(int start, int end) {
3   if (start > end)
4    System.err.println("ERROR: Start must be smaller end!");
5
6   int[] result = new int[end - start];
7   int index = 0;
8   while (start < end) {
9    result[index++] = start++;
10  }
11  return result;
12 }
```

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```

More helpful, but this will still crash.

Handling Invalid Input

For internal code during development, a crash might be sufficient. But you should use an assertion in that case.

```
1  /** Start must always be smaller or equal to end! */
2  public static int[] sequence(int start, int end) {
3   assert start < end : "Start must be smaller end.";
4
5   int[] result = new int[end - start];
6   int index = 0;
7   while (start < end) {
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```

Not enough for publicly exposed function used by others.

Handling Invalid Input

Return an error value.

```
1  /** Start must always be smaller or equal to end!
2   * Null will be returned otherwise. */
3  public static int[] sequence(int start, int end) {
4   if (start > end) return null;
5
6   int[] result = new int[end - start];
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12 }
```

This will avoid the error and report it to the calling code but it does not always work.

Handling Invalid Input

Return an error value.

```
1  public static int sum(int[] data) {
2      if (data.length == 0) return ??????
3
4      int result = 0;
5      for(int d : data) {
6          result += data;
7      }
8      return data;
9  }
```

This will avoid the error and report it to the calling code but it does not always work.

Handling Invalid Input

Throw an Exception.

```
1   /** Start must always be smaller or equal to end!
2    * IllegalArgumentException is thrown otherwise. */
3   public static int[] sequence(int start, int end) {
4    if (start > end)
5        throw new IllegalArgumentException("Start must be smaller end.");
6
7    int[] result = new int[end - start];
8    int index = 0;
9    while (start < end) {
10    result[index++] = start++;
11   }
12   return result;
13  }
```

This reports the error without contaminating the return value.

There is a short exercise on handling errors in the calling code in the labs.

Inf1B Coding Conventions:

For private methods:
Use assertions if it helps you during development.

For public methods:

- Note error handling in the documentation.
- Throw IllegalArgumentExceptions for illegal arguments.
- Throw NullPointerExceptions for null arguments.
- If explicitly stated: handle via return value.

Summary

- Three types of errors:
  syntax, *runtime* and *logical*
- Three testing strategies:
  main, *assert*, *unit*
- Three debugging strategies:
  manual, *print*, *debugger*
- Three ways for error handling:
  assert, *return*, *exception*

Reading

Objects First

Chapter 9 (some *BlueJ* specifics and techniques I have not yet fully taught you but good examples. Feel free to ignore functional bit.)

Java Tutorial

Chapter 10 (Mostly about exceptions and exception handling.)