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Java Foundations

8-4

Debugging Concepts and Techniques

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Objectives

- This lesson covers the following objectives:
 - Test and debug a Java program
 - Identify the three types of errors
 - Apply debugging techniques
 - `print` statements
 - Using your IDE's debugger
 - Apply some debugging tips and techniques



Testing a Java Program

- Richie wrote a Java program to find the maximum among three integers:

```
public static void main(String[] args) {  
    int num1 = 3, num2 = 3, num3 = 3;  
    int max = 0;  
    if (num1 > num2 && num1 > num3) {  
        max = num1;  
    }//endif  
    if (num2 > num1 && num2 > num3) {  
        max = num2;  
    }//endif  
    if (num3 > num1 && num3 > num2) {  
        max = num3;  
    }//endif  
    System.out.println("The max of 3 numbers is " + max);  
}//end method main
```

Testing a Java Program

- Richie tested it on many sets of data, such as $\langle 3, 5, 9 \rangle$, $\langle 12, 1, 6 \rangle$, and $\langle 2, 7, 4 \rangle$
- The program works for all data
- However, he was told that the program doesn't work, and he couldn't figure out why

Exercise 1

- Create a new project and add the `MaxIntegers.java` file to the project
- Observe `MaxIntegers.java`
 - Can you identify what Richie missed in his testing?

Identify the Error

- The program fails when it's tested with duplicate values, such as $\langle 3, 3, 3 \rangle$ and $\langle 7, 2, 7 \rangle$, and it displays the output as zero
 - You identified the error
 - The next step is to fix the error

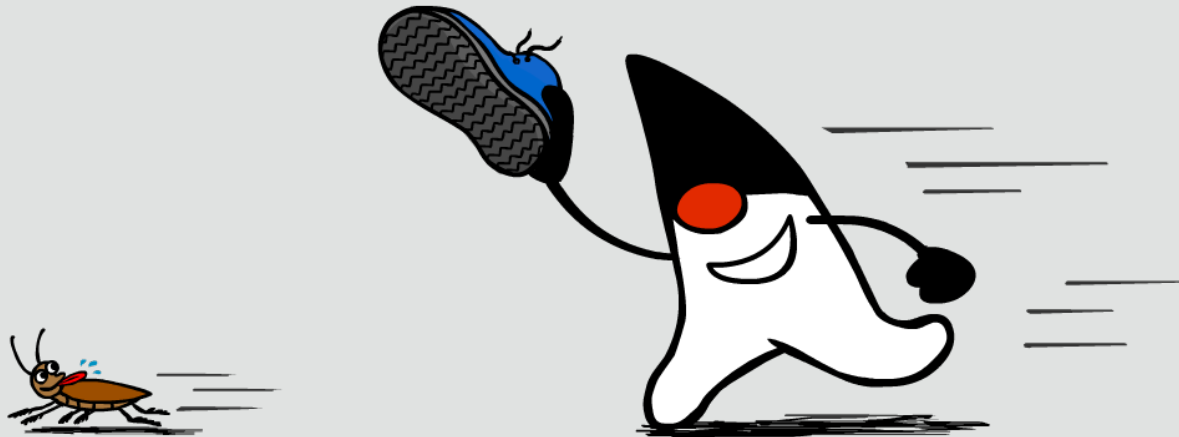
Fix the Error

- Modify the program and test it on many data sets, including duplicate values

```
public static void main(String[] args) {  
    int num1 = 3, num2 = 3, num3 = 3;  
    int max = 0;  
    if (num1 > max) {  
        max = num1;  
    }//endif  
    if (num2 > max) {  
        max = num2;  
    }//endif  
    if (num3 > max) {  
        max = num3;  
    }//endif  
    System.out.println("The max of 3 numbers is " + max);  
}//end method main
```

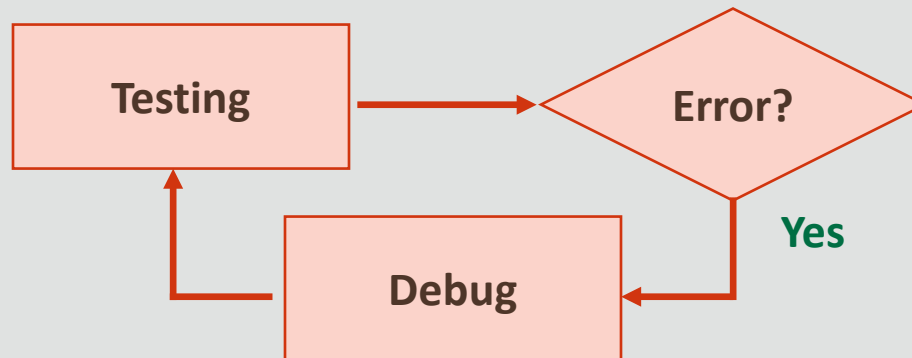

Testing and Debugging

- As you observed from the previous example, testing and debugging are important activities in software development



Testing and Debugging

- Testing:
 - To determine if a code contains errors
- Debugging:
 - To identify an error and fix it



Three Types of Errors

- Errors
 - Compilation errors
 - Logic errors
 - Runtime errors

Compilation Errors

- Syntax error
- Easiest type of errors to fix
- Examples:
 - Example 1: Missing semicolon
 - `int a = 5 // semicolon is missing`
 - Example 2: Errors in expression
 - `x = (3 + 5; // missing closing parenthesis`
 - `y = 3 + * 5; // missing argument between '+'
// and '*'`

Logic Errors

- Program runs but produces incorrect result
- Hard to characterize, and so it's hardest to fix
- Example: Noninitialized variable

```
- int i;  
- i++; // the variable i isn't initialized
```

Runtime Errors

- These errors occur at run time
- Java's exception handling mechanism can catch such errors
- Some of the common exceptions:
 - `ArrayIndexOutOfBoundsException`
 - `NullPointerException`
 - `ArithmeticException`

Debugging Techniques

- Let's look at two debugging techniques:
 - Using `print` statements
 - Using an IDE debugger

print Statements: Advantages

- Easy to add
- Provide information
 - Which methods have been called
 - The value of parameters
 - The order in which methods have been called
 - The values of local variables and fields at strategic points

`print` Statements: Disadvantages

- It isn't practical to add `print` statements to every method
- Too many `print` statements lead to information overload
- Removal of `print` statements is tedious

print Statements: Example

- Consider this Java code :

```
int n = 10;
int sum = 10;
while (n > 1){
    sum = sum + n;
    n--;
}//end while
System.out.println("The sum of the integers 1 to 10 is " + sum);
```

- On running this program, it doesn't work correctly
- To find out what's wrong, you can trace the value of the n and sum variables by inserting `print` statements

Modified Program with Additional `print` Statements for Debugging

```
int n = 10;  
int sum = 10;  
while (n > 1) {
```

```
    System.out.println("At the beginning of the loop: n = " + n);  
    System.out.println("At the beginning of the loop:sum= " + sum);
```

```
    n--;
```

```
    System.out.println("At the end of the loop: n = " + n);  
    System.out.println("At the end of the loop: sum = " + sum);
```

```
}
```

```
System.out.println("The sum of the integers 1 to 10 is " + sum);
```

Output

- Here are the first four lines of the output after the first iteration of the loop:
 - At the beginning of the loop: $n = 10$
 - At the beginning of the loop: $\text{sum} = 10$
 - At the end of the loop: $n = 9$
 - At the end of the loop: $\text{sum} = 20$
- You can see that something is wrong:
 - The variable `sum` has been set to 20
 - Because it was initialized to 10, it's set to $10 + 10$, which is incorrect if you want to add the numbers from 1 to 10

The IDE Debugger

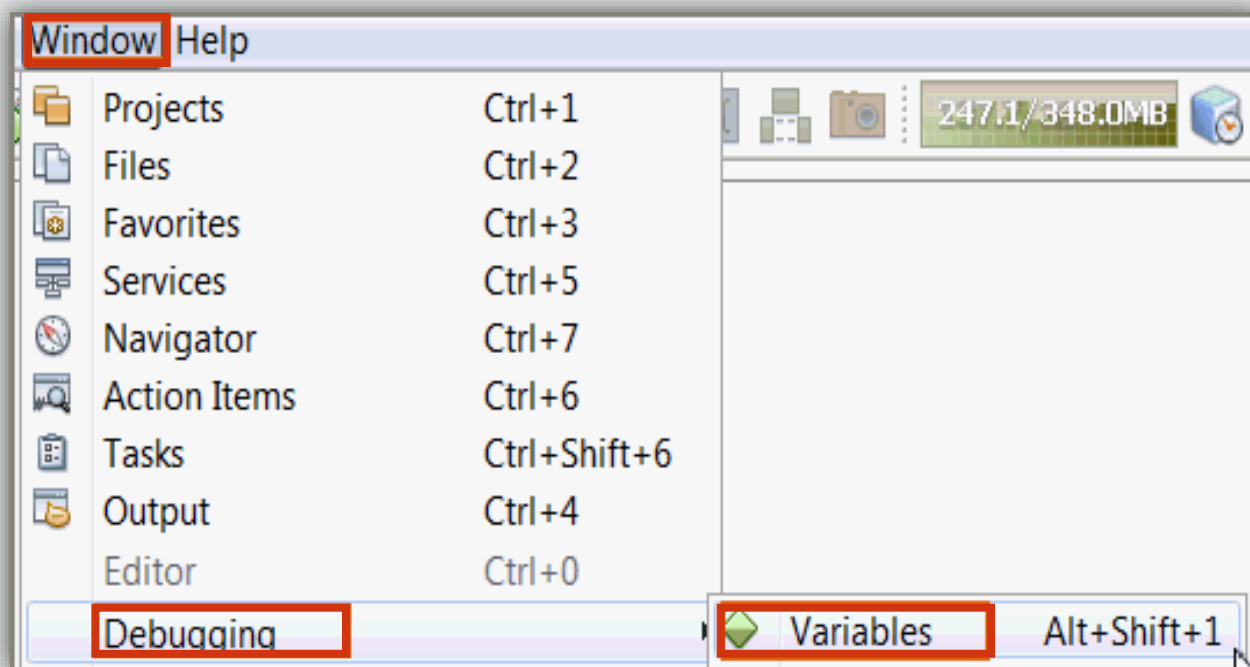
- You have already used the IDE graphical-based debugging environment
- You have used the following features of the debugger:
 - Set breakpoints
 - Trace through a program one line at a time
- Let's use another very important feature to view the contents of variables

Variables Window

- When you reach a set breakpoint, you can use the Variables window to see the value of the variables at that moment
- You can find out values of variables without having to put a lot of print statements in your program
- The following slides demonstrate using the debugger in NetBeans
- If you are using a different IDE, consult the documentation for how to do this

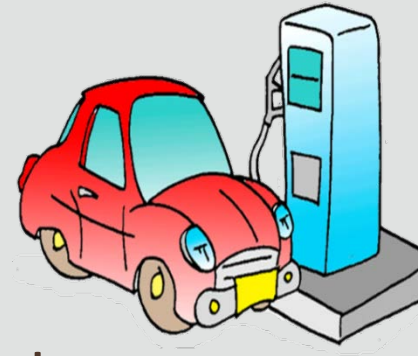
Accessing the Variables Window

- To see the Variable window, in the NetBeans main menu:
 - Click Window > Debugging > Variables




Exercise 2: Scenario

- Let's assume you have a car, and you want to go to the gas station, you have the following details:
 - Car's current position: x_1 and y_1
 - Gas station's location: x_2 and y_2
 - Speed of the car
- You want to compute the time it will take for the car from its current position (x_1, y_1) to reach the gas station (x_2, y_2)
- A Java program to compute the time by using the $\text{time} = \text{distance} / \text{speed}$ formula is available in the ComputeTime project

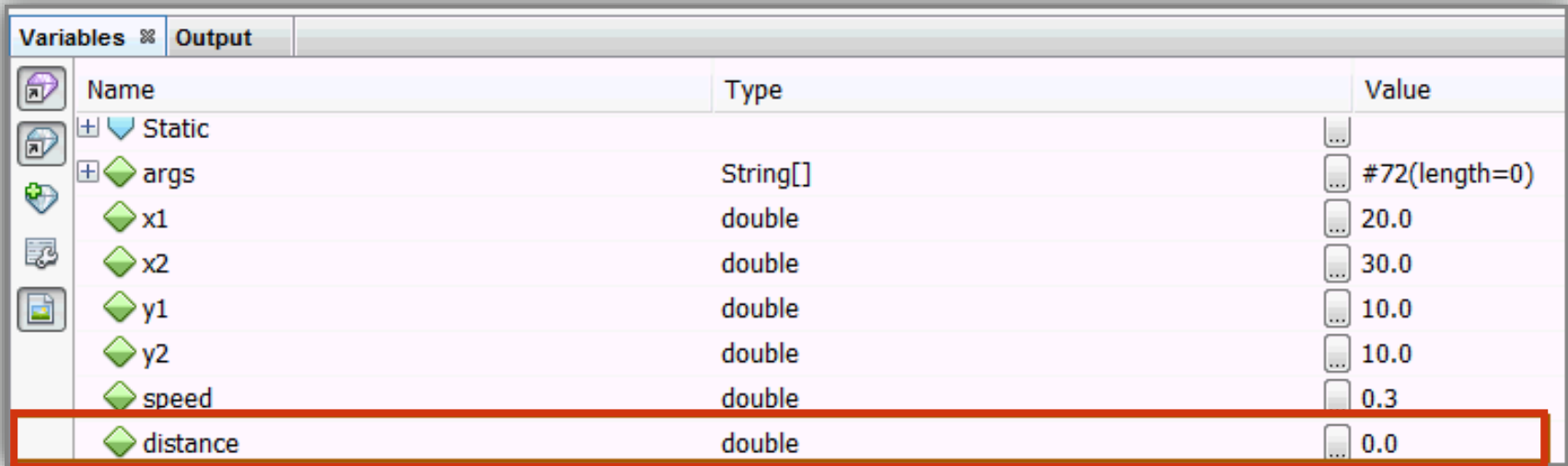


Exercise 2

- Add the file `ComputeTime.java` to the project you created for exercise 1
- Observe `ComputeTime.java`
- Run the program with your IDE's debugger to debug this program:
 - Set the breakpoint in the `getDistance` method
 - Press Step In to go to the next line 
 - Observe the values of the `x1`, `x2`, `y1`, `y2`, `speed`, `distance`, and `time` variables
- Can you identify the bug?

Observe the Value of distance

- In the previous exercise using your IDE's debugging features, you identified the bug:



The screenshot shows the 'Variables' window of an IDE. It contains a table with columns 'Name', 'Type', and 'Value'. The 'distance' variable is highlighted with a red box. The table lists several variables: Static, args (String[]), x1 (double), x2 (double), y1 (double), y2 (double), speed (double), and distance (double). The values for these variables are: Static (empty), args (#72(length=0)), x1 (20.0), x2 (30.0), y1 (10.0), y2 (10.0), speed (0.3), and distance (0.0).

Name	Type	Value
Static		
args	String[]	#72(length=0)
x1	double	20.0
x2	double	30.0
y1	double	10.0
y2	double	10.0
speed	double	0.3
distance	double	0.0

- As you can see, distance is 0.0, the formula for computing distance was wrong, and it caused an incorrect return value for the distance variable

Identifying the Potential Bug

```
public static void main(String[] args) {  
    double x1 = 20;  
    double x2 = 30;  
    double y1 = 10;  
    double y2 = 10;  
    double speed = 0.3;  
    double distance = getDistance(x1, x2, y1, y2);  
    double time = distance/speed;  
    System.out.println("Time taken to reach the gas station is " + time);  
  
} //end method main  
  
static double getDistance(double x1, double x2, double y1, double y2){  
    return Math.sqrt((x1 - x1) * (x1 - x2) + (y1 - y2) * (y1 - y2));  
} //end method getDistance
```

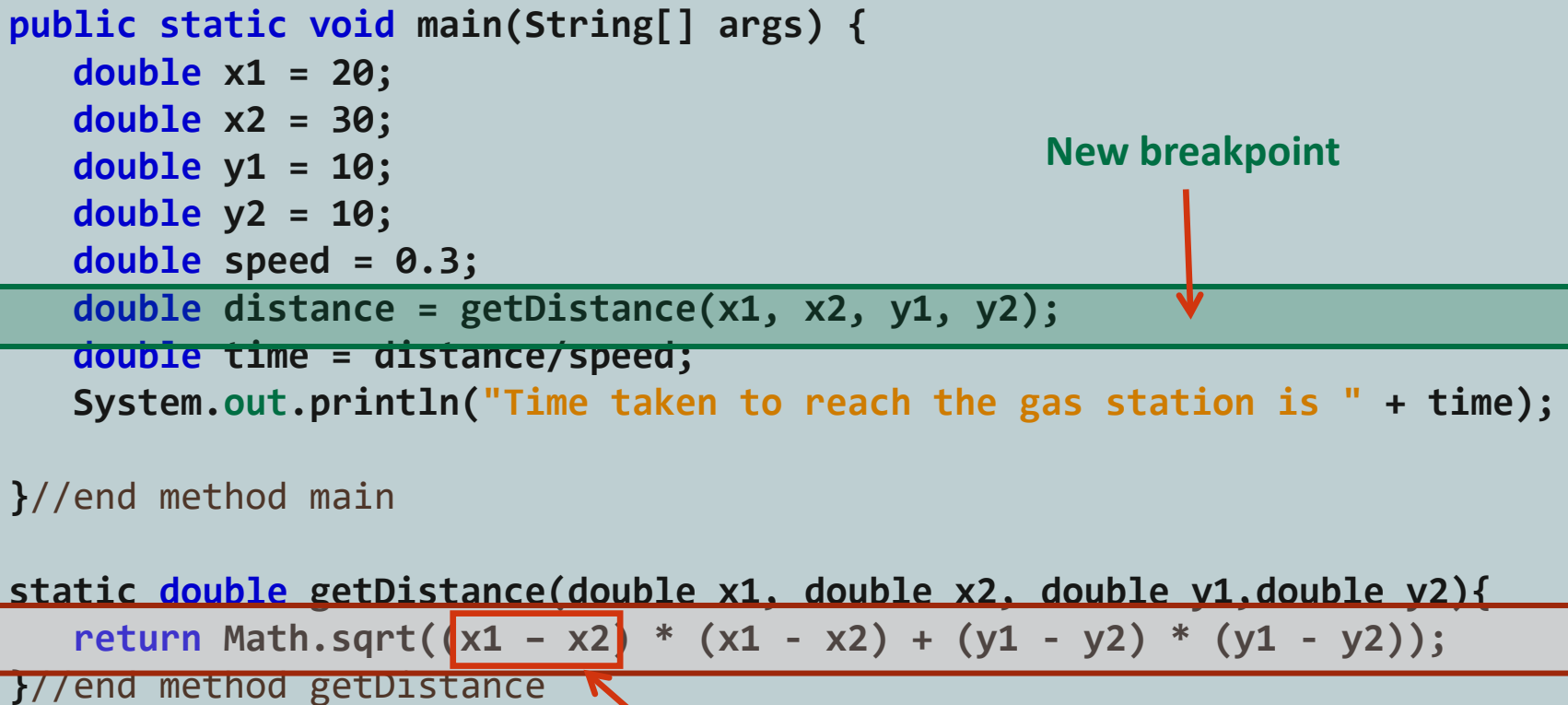
Potential bug

Fixing the Bug

- Because you identified the bug, you can change the location of the breakpoint to where the `getDistance()` method is called
- This saves having to step through code that you already looked at
- So let's modify the code and rerun the debugger with the new breakpoint to see what we get

Rerunning the Debugger

```
public static void main(String[] args) {  
    double x1 = 20;  
    double x2 = 30;  
    double y1 = 10;  
    double y2 = 10;  
    double speed = 0.3;  
    double distance = getDistance(x1, x2, y1, y2);  
    double time = distance/speed;  
    System.out.println("Time taken to reach the gas station is " + time);  
}  
//end method main  
  
static double getDistance(double x1, double x2, double y1, double y2){  
    return Math.sqrt((x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2));  
}  
//end method getDistance
```

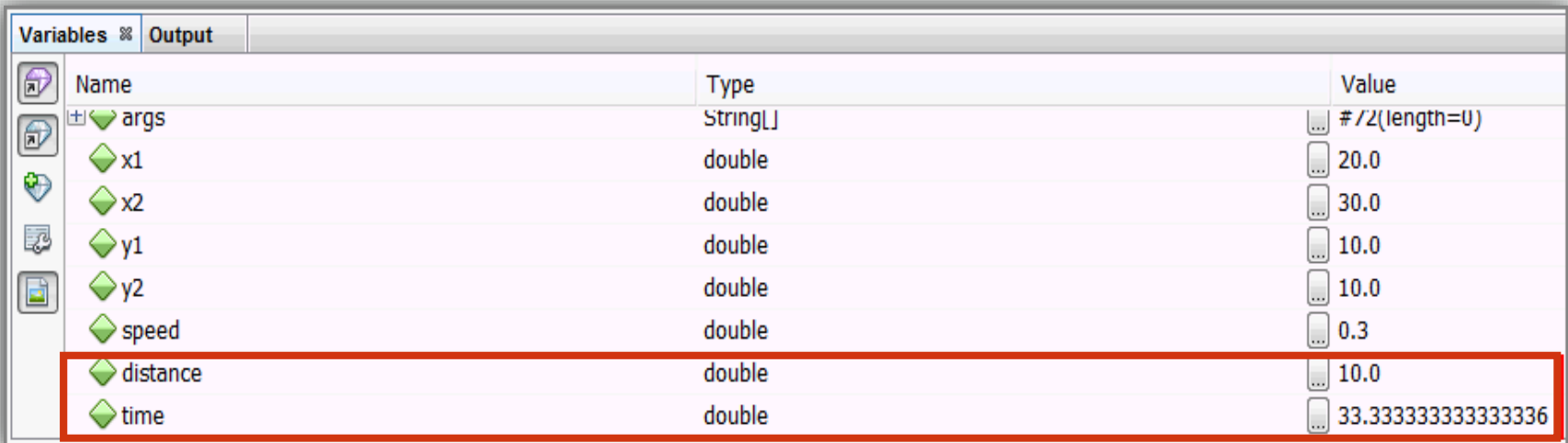


The diagram illustrates a Java program with two methods. The `main` method calculates the distance and time to reach a gas station. The `getDistance` method calculates the Euclidean distance between two points. A green box highlights the line `double distance = getDistance(x1, x2, y1, y2);` in the `main` method, with a green arrow pointing to it from the text "New breakpoint". A red box highlights the `return` statement in the `getDistance` method, with a red arrow pointing to it from the text "Modified code".

Modified code

Observing the Variables

- We fixed the bug!
 - The distance variable is now reporting a value of 10.0, and the time variable is now reporting a value of 33.33



Name	Type	Value
args	String[]	#/2(length=0)
x1	double	20.0
x2	double	30.0
y1	double	10.0
y2	double	10.0
speed	double	0.3
distance	double	10.0
time	double	33.333333333333336

Single Versus Double Equals Operator

- Assignment (=) versus Comparison (==) Operator
 - 1. Comparison operator
 - `if(x = 0)` instead of `if(x == 0)`
 - Look for it in if, for, and while statements
 - 2. Assignment operator
 - `int x == 1; instead of int x = 1;`

Misplaced Semicolon

- Check for the semicolon after the if statement or the for/while loop statements

```
if (x == 0); {  
    <statements>  
}
```

instead of

```
if(x == 0) {  
    <statements>  
}
```

```
while(<boolean expression>); {  
    <statements>  
}
```

instead of

```
while(<boolean expression>) {  
    <statements>  
}
```


Invoking Methods with Wrong Arguments

- Method call parameter types must match method definition parameter types

- For example:

- Given a method definition:

- `void methodName(int x, char y) { }`

- Invoke this method:

- `methodName(a, b)`



a must be an int and b must be a char

Boundary Conditions

- It's important to test the boundary conditions
- The rationale behind testing them is that errors tend to occur near the boundary values of an input variable
- For example, boundary condition for:
 - Input data (test with valid versus invalid)
 - Loops (beginning and ending of loops)

Testing Boundary Conditions for Loops

- This allows for boundary case tests like “less than” and “greater than” for loop iteration conditions to be accurately tested
- For example, given this loop:

```
if ( num >= 50 && num <= 100 ) {  
    //do stuff  
} //endif
```

- To test boundary conditions, you would test with numbers near 50 and 100, that is, 49, 50, 51, 99, 100 and 101

Exercise 3

- Add the file `BoundaryTesting.java` to the project you created for exercise 1
- Observe `BoundaryTesting.java`
- Validate the input by executing the program with the following boundary test values for year and month:

Year	Month
1582	2
1583	0
1583	13
1583	1
1583	12

Summary

- In this lesson, you should have learned how to:
 - Test and debug a Java program
 - Identify the three types of errors
 - Apply debugging techniques
 - `print` statements
 - Using your IDE's debugger
 - Apply some debugging tips and techniques





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