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Repetitive Structures

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Lecture Topics

- Repetitive Structures
  - Count-Controlled Loops (For)
  - Unary Addition/Subtraction
  - Sentinel-Controlled Loops (While/Do-While)
- Nested Loops
- Branching Statements
- Infinite Loops
- Random Number Generators

Colors/Fonts

- Local Variable Names – Brown
- Primitive data types – Fuchsia
- Literals – Blue
- Keywords – Orange
- Object names – Green
- Operators/Punctuation – Black
- Field Names – Lt Blue
- Method Names – Purple
- Parameter Names – Gold
- Comments – Gray
- Package Names – Pink

Source Code – **Consolas**
Output – Courier New

Boolean expression is false

Boolean expression is true

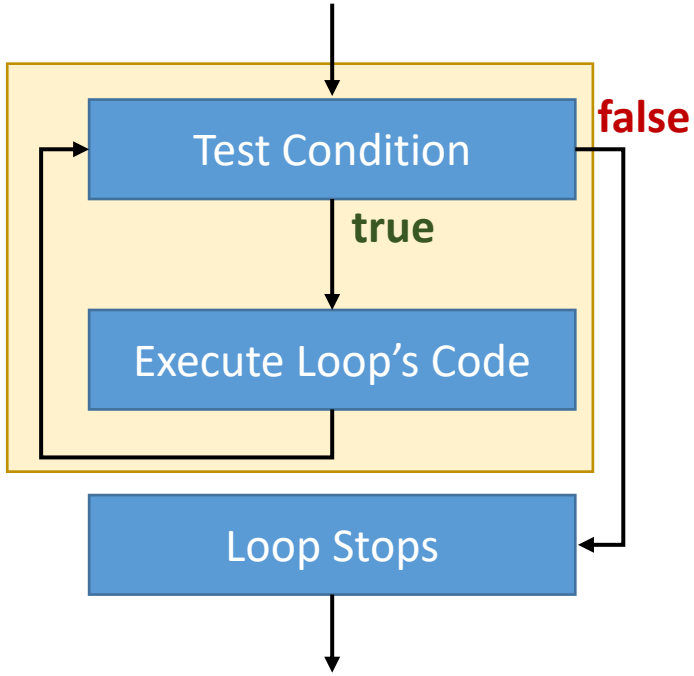
Loops

- A ***loop*** is a programming structure that allows code to be repeatedly executed, usually as long as some condition (Boolean expression) evaluates to true.
  - Each repetition of the loop's code is called an ***iteration***.

- Programming languages have a few types of loops.
  - Pre-test and Post-test Loops
  - Sentinel-Controlled and Count-Controlled.

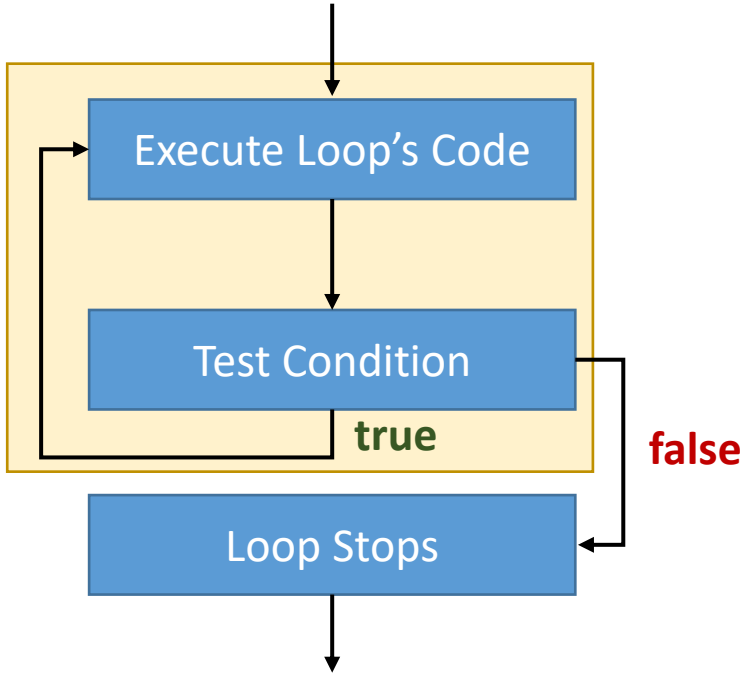
Types of Loops

- ***Pre-test loops*** test the condition *before* starting each iteration.



Types of Loops

- ***Post-test loops*** test the condition *after* completing each iteration.



For Loops

- A ***for loop*** is a pre-test, count-controlled loop.

- Java has two types of for loops:
  - A traditional (“C-Style”) for loop.
  - An “enhanced” for loop.

- The enhanced for loop will be demonstrated in a future lecture.

For Loops

- A traditional for loop has three parts, separated by semicolons:
  - Initialization- Declares an int variable to be used as a *control counter*.
  - Termination Condition- A Boolean expression tested at the beginning of each iteration.
    - If true, the loop's code executes; If false, the loop stops.
  - Increment/Decrement- Happens at the end of each iteration; Normally increments or decrements the control counter.

```
for(initialization; termination; increment/decrement) {
   //Code that executes each iteration
}
```

For Loops

Initialization- Here, we have initialized an int (named "counter") to the value 1.

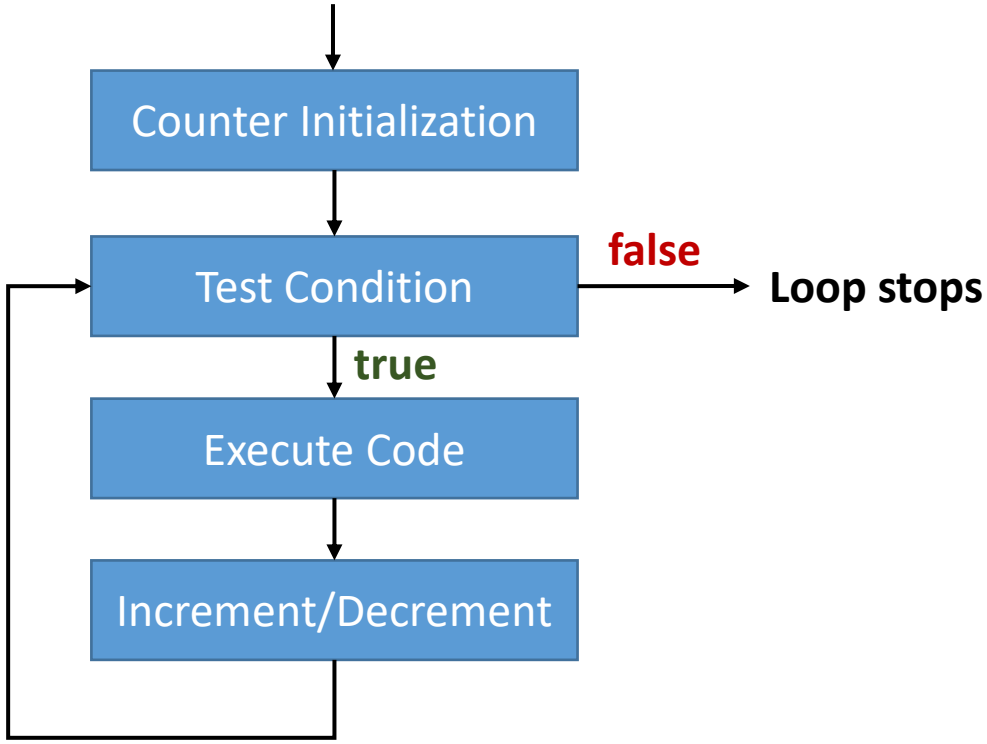
Termination- As long as counter is less than or equal to 5, the loop will iterate again.

Increment- At the end of the iteration, add 1 to the value of counter.

```
for(int counter = 1; counter <= 5; counter++) {
   System.out.println("Lap #" + counter);
}
System.out.println("Finished!");
```

Note- The "counter" variable is only accessible *inside* the loop.

For Loops


Counter Initialization
Test Condition
false
Loop stops
true
Execute Code
Increment/Decrement

Increment (Unary Addition) Operator

- The increment/unary addition operator **++** adds one to the value of a numeric variable.

```
int testNumber = 5;
testNumber++; //Value of testNumber is now 6
```

Increment (Unary Addition) Operator

- The increment operator can come before the variable name (prefix) or after the variable name (postfix).
- Both increment the variable by one.

```
int testNumber = 5;
```

- Prefix:

```
++testNumber;
```

- Postfix:

```
testNumber++;
```

Prefix Unary Addition

- With prefix, 1 will be added **before** the value is returned.
  - This usually will only matter when you are performing the increment as you assign the value to another variable.
  - Example:

```
int testNumber = 5;
int otherNumber = ++testNumber;
```

- In the second line…
  - 1 will be added to testNumber, making the value of testNumber to be 6
  - This new value of 6 will be assigned to otherNumber.

Postfix Unary Addition

- With postfix, 1 will be added **after** the value is returned.
  - Example:

```
int testNumber = 5;
int otherNumber = testNumber++;
```

- In the second line…
  - The value of testNumber, which is 5, is assigned to otherNumber.
  - 1 is then added to testNumber, making the value of testNumber 6.

Decrement (Unary Subtraction) Operator

- The decrement/unary subtraction operator **--** subtracts one from the value of a numeric variable.

```
int testNumber = 5;
testNumber--; //Value of testNumber is now 4
```

Decrement (Unary Subtraction) Operator

- The decrement operator can come before the variable name (prefix) or after the variable name (postfix).
- Both decrement the variable by one.

```
int testNumber = 5;
```

- Prefix:

```
--testNumber;
```

- Postfix:

```
testNumber--;
```

Prefix Unary Subtraction

- With prefix, 1 will be subtracted **before** the value is returned.
  - This usually will only matter when you are performing the decrement as you assign the value to another variable.
  - Example:

```
int testNumber = 5;
int otherNumber = --testNumber;
```

- In the second line…
  - 1 will be subtracted from testNumber, making the value of testNumber 4
  - This new value of 4 will be assigned to otherNumber.

Postfix Unary Subtraction

- With postfix, 1 will be subtracted **after** the value is returned.
  - Example:

```
int testNumber = 5;
int otherNumber = testNumber--;
```

- In the second line…
  - The value of testNumber, which is 5, is assigned to otherNumber.
  - 1 is then subtracted from testNumber, making the value of testNumber 4.

Increment and Decrement Operators

- To recap:
  - Prefix increment/decrement: 1 is added/subtracted **before** the value is returned or used.
  - Postfix increment/decrement: 1 is added/subtracted **after** the value is returned or used.

- If you just want to add or subtract 1 to/from a numeric value, pre/postfix doesn't matter.

For Loops

Initialization- Here, we have initialized an int (named "counter") to the value 1.

Condition- As long as counter is less than or equal to 5, the loop will iterate again.

Increment- At the end of the iteration, add 1 to the value of counter.

```
for(int counter = 1; counter <= 5; counter++) {
   System.out.println("Iteration #" + counter);
}
System.out.println("Finished!");
```

No semicolon!

Note- The value of "counter" is only accessible *inside* the loop.

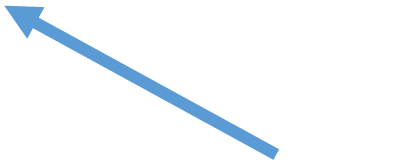
For Loops

```
for(int counter = 1; counter <= 5; counter++) {
   System.out.println("Iteration #" + counter);
}
System.out.println("Finished!");
```

```
Iteration #1
Iteration #2
Iteration #3
Iteration #4
Iteration #5
Finished!
```

For Loops – Use caution when not using braces

```
for(int counter = 1; counter <= 5; counter++)
System.out.println("Lap #" + counter);
System.out.println("Finished!");
```



- The example above works identically as the previous example, even though there are no curly braces.
- When there are no curly braces, the for loop operates on only the next line.
- It is good to always use braces though; it makes it easier to read and see exactly what code is included in the loop and what code is not.

For Loops

```
for(int i = 3; i <= 7; i++) {
   System.out.println("Number: " + i);
}
```

What is the output?

For Loops – Decrement Example

```
for(int i = 3; i >= 0; i--) {
   System.out.println("Number: " + i);
}
```

```
Number: 3
Number: 2
Number: 1
Number: 0
```

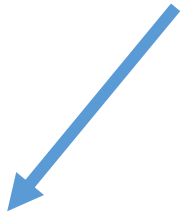
For Loops

```
for(int i = 10; i >= 3; i--) {
   System.out.println("Number: " + i);
}
```

What is the output?

For Loops

Unlike previous examples that increment or decrement by one, this example shows that we can increment or decrement by a larger step.



```
for(int i = 2; i < 10; i += 2) {
   System.out.println("Number: " + i);
}
```

```
Number: 2
Number: 4
Number: 6
Number: 8
```

For Loops

```
for(int i = 3; i <= 2; i--) {
   System.out.println("Number: " + i);
}
```

- What is the output?

For Loops

```
for(int i = 3; i <= 2; i--) {
   System.out.println("Number: " + i);
}
```

- There is no output!
- Remember, the Boolean condition is tested at the beginning of each iteration.
- 3 is NOT less than or equal to 2, so the condition is false; The loop doesn't even iterate once.

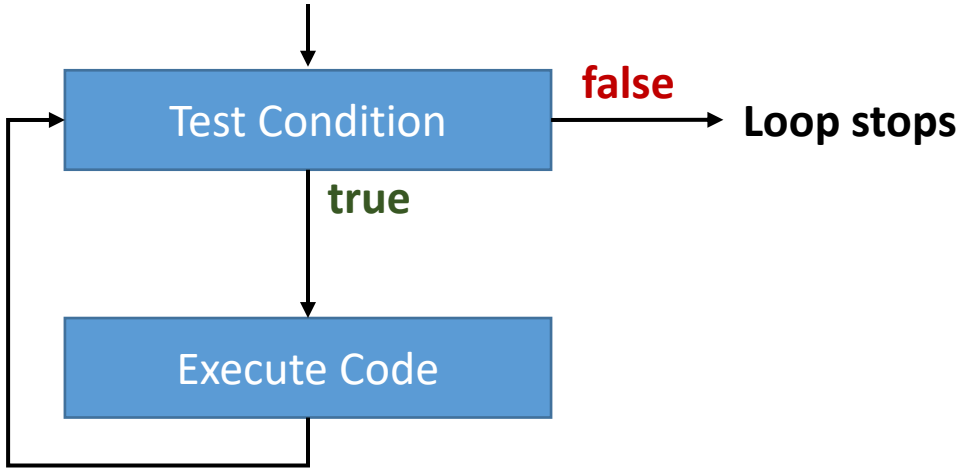
While Loops

- A ***while loop*** repeats as long as its Boolean expression is true

```
while(Boolean Expression) {
   //Code that will be
   //executed as long as the
   //Boolean Expression is true
}
```

While Loops

- A while loop is a pre-test, sentinel-controlled loop.



While Loops

```
Scanner keyboard = new Scanner(System.in);
String input = ""; //Will hold the user's entry
System.out.print("Enter word: ");
input = keyboard.nextLine();
while(!input.equals("exit")) {
  //Print the input in uppercase
  System.out.println("toUpperCase: " + input.toUpperCase());
  //Prompt for input again
  System.out.print("Enter word: ");
  input = keyboard.nextLine();
}
System.out.print("Goodbye!");
```

```
Enter word: cat
toUpperCase: CAT
Enter word: dog
toUpperCase: DOG
Enter word: llama
toUpperCase: LLAMA
Enter word: exit
Goodbye!
```

While Loops

- This next example will allow the user to enter a number and the program will display the number, squared.

- When the user enters 0, the program will stop.

While Loops

```
Scanner keyboard = new Scanner(System.in);
boolean done = false;

int numberToSquare = 0;

while(!done) {
    System.out.print("Enter a number: ");
     numberToSquare = Integer.parseInt(keyboard.nextLine());
    if(numberToSquare < 1) {
        done = true;
    }
    else {
        System.out.println("Your number squared is: " + Math.pow(numberToSquare, 2));
    }
}
```

While Loops

```
Scanner keyboard = new Scanner(System.in);
System.out.print("Enter a number between 1 and 10: ");
int input = Integer.parseInt(keyboard.nextLine());

while(input < 1 || input > 10) {
  System.out.println("Error. Try again.");
  System.out.print("Enter a number between 1 and 10: ");
  input = Integer.parseInt(keyboard.nextLine());
}

System.out.print("Thank you!");
```

```
Enter a number between 1 and 10: 11
Error. Try Again.
Enter a number between 1 and 10: 7
Thank you!
```

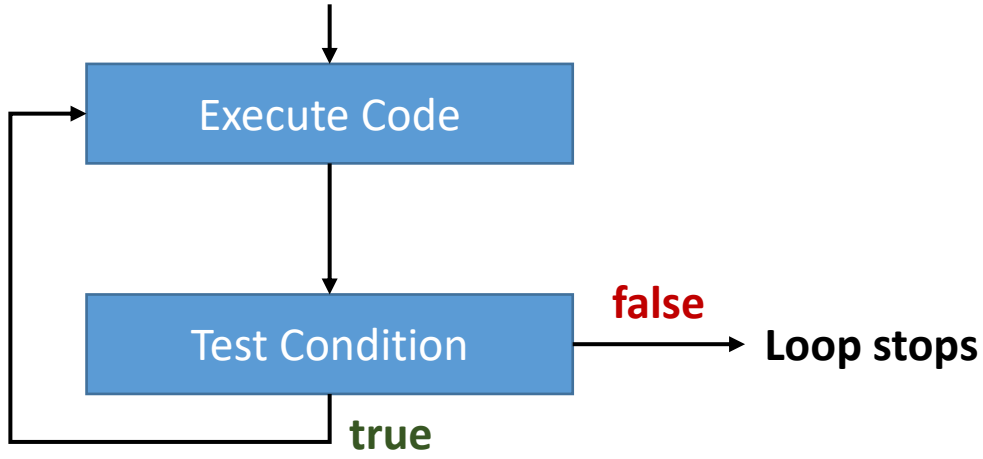
Do-While Loops

- A ***do-while loop*** is a *post-test*, sentinel-controlled loop.
- It will always iterate at least once.
  - Unlike the while loop that tests the condition before the first iteration, the do-while loop tests the condition *after* the first iteration.
- In many cases, the behavior of a do-while loop will be equivalent to the same while loop.

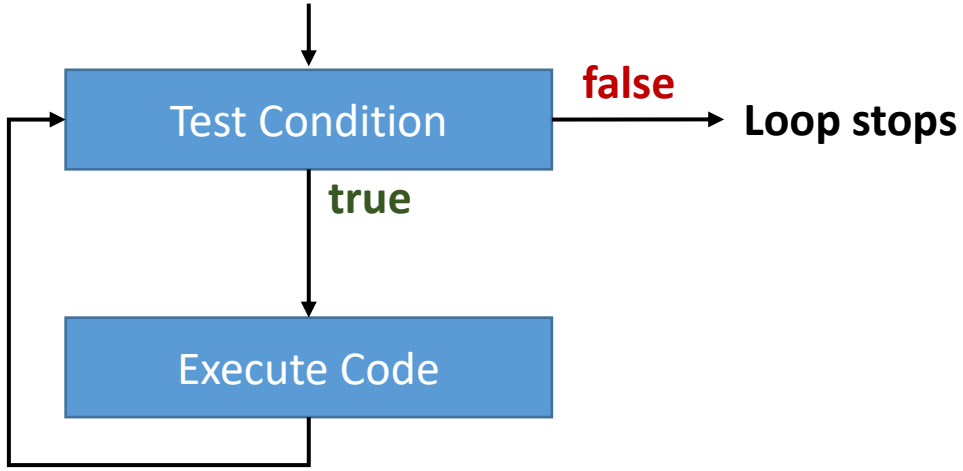
```
do {
   //Code that executes at least once
   //and iterates as long as the
   //condition is true
} while(Boolean expression);
```

Semicolon!

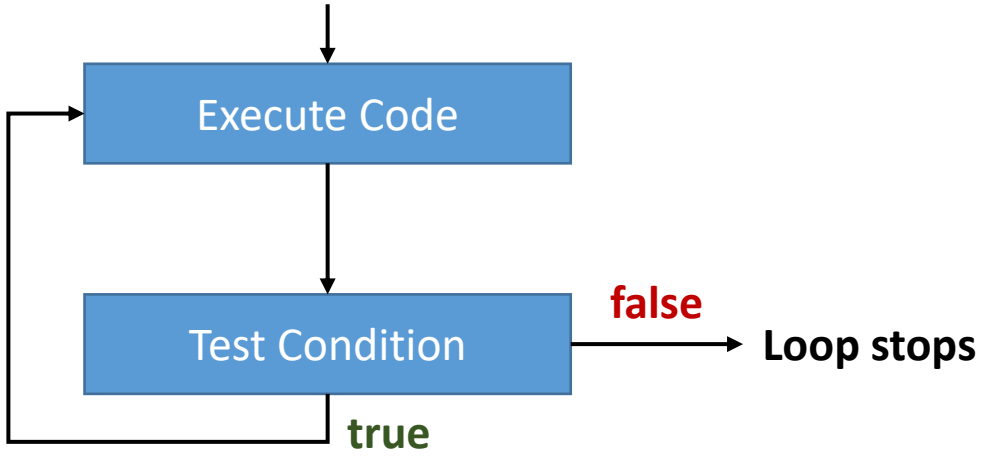
Do-While Loops



Do-While Loops



While Loop



Do-While Loop

Do-While Loops

- This do-while loop verifies that the user's input was non-negative.

```
Scanner keyboard = new Scanner(System.in);
int sales = 0;
do {
   System.out.print("Enter the total sales for the store: ");
   sales = Integer.parseInt(keyboard.nextLine());
} while(sales < 0);
System.out.print("Thank you.");
```

```
Enter the total sales for the store: -100
Enter the total sales for the store: -5
Enter the total sales for the store: 10
Thank you.
```

When to use a While or Do-While Loop

- In many cases, it won't matter which you use.

- Use a Do-While loop when you want to *guarantee* the loop to iterate at least once, before the boolean condition is ever tested.

Nested Loops

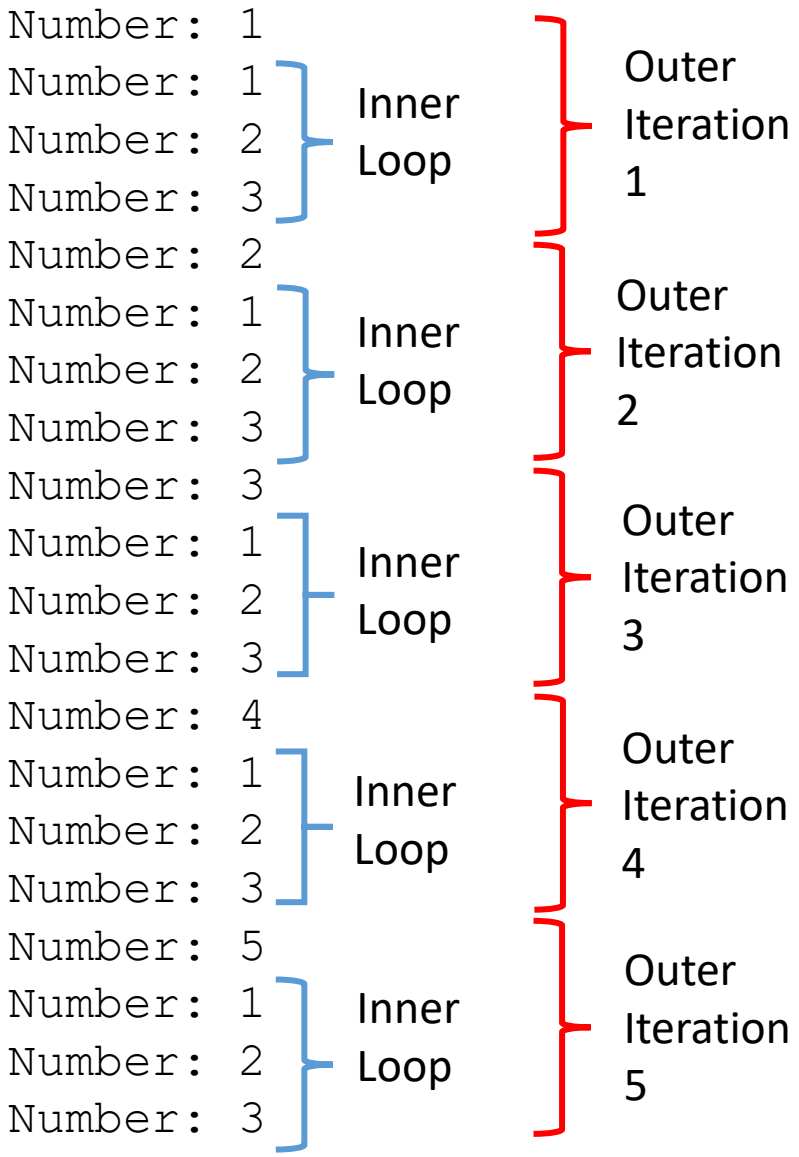
- A nested loop is a loop within a loop.
- For every iteration of the outer loop, the inner loop will be iterated to completion.

```
for(int i = 1; i <= 5; i++) {
  System.out.println("Number: " + i);
  for(int j = 1; j <= 3; j++) {
    System.out.println("Number: " + j);
  }
}
```

Be sure to use different names for your counters. Any variables declared in outer loops will be accessible by any inner loops, including the counter.

Nested Loops

```
for(int i = 1; i <= 5; i++) {
  System.out.println("Number: " + i);
  for(int j = 1; j <= 3; j++) {
    System.out.println("Number: " + j);
  }
}
```



Nested Loops – Variable scope

```
for(int i = 1; i <= 3; i++) {
  String str = "TestString";
  for(int j = 1; j <= 3; j++) {
    System.out.println(str + i);
  }
}
```

```
TestString1
TestString1
TestString1
TestString2
TestString2
TestString2
TestString3
TestString3
TestString3
```

- Even though the String “str” and the counter “i” are declared and assigned outside of the inner loop, the inner loop is still able to access them.
- This does not work both ways! Variables declared in inner loops are not accessible by outer loops.

Branching Statements

- There are two branching statements that allow us to either:
  - Immediately exit a loop.
  - Immediately begin the next iteration.

`break;`

- We have already seen the break statement when using a switch.
- It works in a similar fashion for a loop. Once encountered, the loop will immediately stop where it is. Any code outside/after of the loop will begin to be executed.

`continue;`

- Once encountered, the loop will immediately stop where it is and begin the next iteration.

break statement – for loop

```
for(int myInt = 1; myInt < 11; myInt++) {
  if(myInt > 5) {
    break;
  }
  System.out.println("Number: " + myInt);
}
System.out.println("All done!");
```

```
Number: 1
Number: 2
Number: 3
Number: 4
Number: 5
All done!
```

- This loop normally would have printed “Number: 1” through “Number: 10”
- However, once the value of myInt is greater than 5, the break statement will be encountered.
- The loop will exit immediately and resume the code outside of the loop.
- Works the same way in a while/do-while loop.

continue statement – for loop

```
for(int myInt = 1; myInt != 11; myInt++) {
  if(myInt % 2 == 1) {
    continue;
  }
  System.out.println("Number: " + myInt);
}
System.out.println("All done!");
```

```
Number: 2
Number: 4
Number: 6
Number: 8
Number: 10
All done!
```

- If myInt is odd, the continue statement will be encountered.
- Instead of finishing the iteration and printing out the number, the loop stops there and restarts.
- In the case of a for loop, the continue statement will increment/decrement the counter as in a normal iteration.
- In the case of a while/do-while loop, the continue statement will force the next iteration; the condition will still be tested before the next iteration begins, as normal.

Infinite Loops

- An infinite loop is a loop that does not stop or exit.
- The only way to stop an infinite loop (that is the result of poor design) is to forcibly stop the program.
- In most cases, an infinite loop is the result of poor programming.
- However, sometimes programmers intentionally create infinite loops.

Infinite Loops

- The two biggest culprits for unintentional, program-crashing infinite loops are:
  - Forgetting to change a value that the Boolean condition of a while/do-while loop depends on.
    - Hence, the condition stays true and never evaluates as false.
  - Changing the increment/decrement counter's value within the body of its for loop.

Infinite While Loop

```
boolean done = false;
int myInt = 0;
while(!done) {
   myInt++;
   System.out.println("Number: " + myInt);
}
```

```
Number: 1
Number: 2
Number: 3
Number: 4
Number: 5
…
```

- Since the value of “done” is never changed in the body of the loop, there is no way the Boolean condition will ever be false.

Infinite For Loop

```
for(int i = 1; i <= 15; i++) {
   i--;
   System.out.println("Number: " + i);
}
```

```
Number: 0
Number: 0
Number: 0
Number: 0
Number: 0
…
```

- Even though “i” is incremented by 1 after every iteration, it is first being decremented by 1 in the body of the loop.
- There is no way the Boolean condition will ever be false, so there is no way this loop would ever end.

Infinite Loops

- With some care and sound logic, infinite loops can be useful.
  - For example, perpetually getting user input until they enter a command to exit (similar to earlier examples)

- However, when we intentionally create an infinite loop, we normally will want to provide some way for the loop to exit.
  - Use a break statement to stop the loop.

For-ever Loop

```
System.out.println("Forever");
for(;;) {
   System.out.println("and ever");
}
```

```
Forever
and ever
and ever
and ever
and ever
…
```

- A for loop with no counter, condition, or increment creates an infinite loop colloquially called a “for-ever loop”.

For-ever Loop – Exponents Program

```
for(;;) {
  System.out.print("Enter a number: ");
  numberToSquare = Integer.parseInt(keyboard.nextLine());
  if(numberToSquare == 0) {
    break;
  }
  else {
    System.out.println("Your number squared is: " + Math.pow(numberToSquare, 2));
  }
}
```

Infinite While Loop

```
while(true) {
  System.out.print("Enter a number: ");
  numberToSquare = Integer.parseInt(keyboard.nextLine());
  if(numberToSquare == 0) {
    break;
  }
  else {
    System.out.println("Your number squared is: " + Math.pow(numberToSquare, 2));
  }
}
```

Random Number Generators

- A ***random number*** is number chosen from a set of possible values, each with the same probability of being selected.

- A ***random number generator*** is software or hardware that produces a random number.

- A ***seed*** is a number provided to an algorithm to produce strings of random numbers.

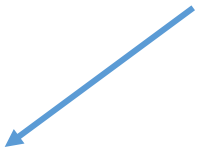
Types of Random Number Generators

- A Pseudo-Random Number Generator (PRNG) uses a mathematical algorithm to generate random numbers.

- A True Random Number Generator (TRNG) uses an unpredictable physical means to generate random numbers.
  - Atmospheric noise (Using radio waves of atmospheric disturbances)
  - Nuclear decay radiation (Using Geiger counters)
  - Lava lamps (…..Wait, what?)

Example

Import the Random object from java.util
The Random object can be used as a Random Number Generator

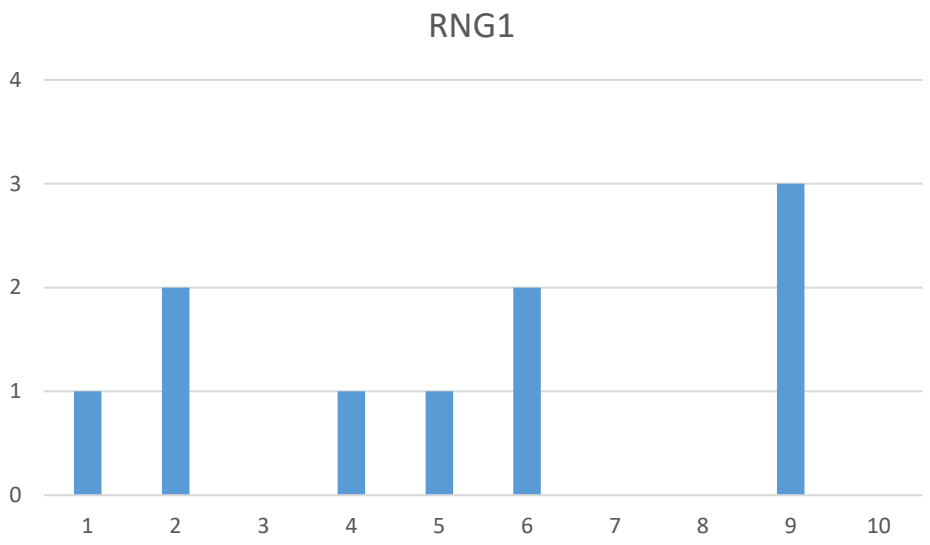


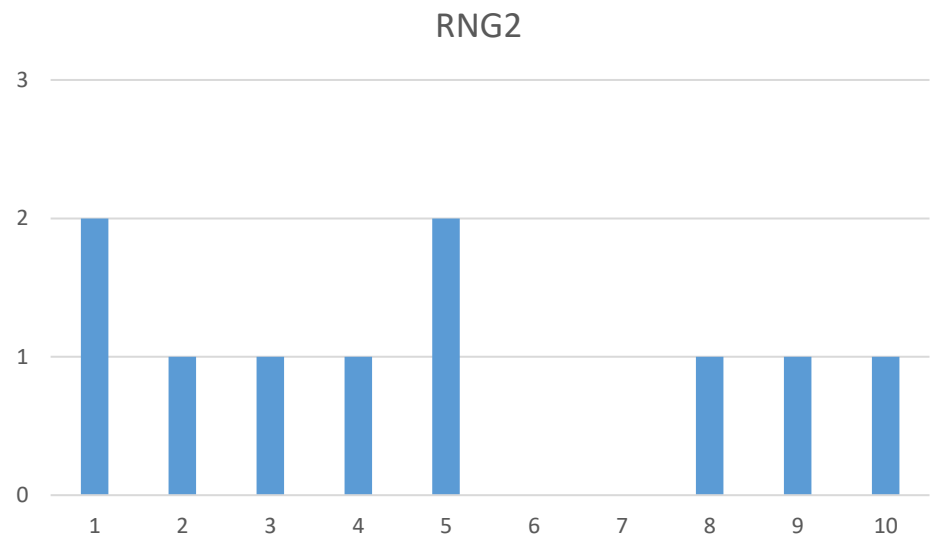
```
import java.util.Random;

public class RandomNumberGenerator {

    public static void main(String[] args) {
        //Create a new instance of the Random object.
        //Uses a random seed generated by the JVM.
        Random myGenerator = new Random();

        //Assigns a random number between 0 and 4 to someNumber.
        int someNumber = myGenerator.nextInt(5);
    }

}
```

Example – User Supplied Seed

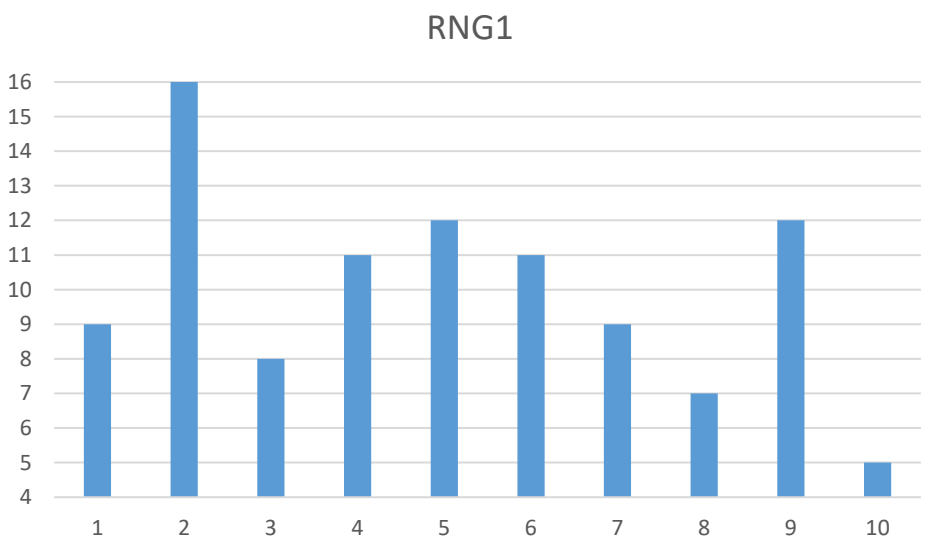
```
import java.util.Random;

public class RandomNumberGenerator {

    public static void main(String[] args) {
        //Create a new instance of the Random object.
        //Uses a supplied seed.
        Random myGenerator = new Random(1034);

        //Assigns a random number between 0 and 4 to someNumber.
        int someNumber = myGenerator.nextInt(5);
    }

}
```

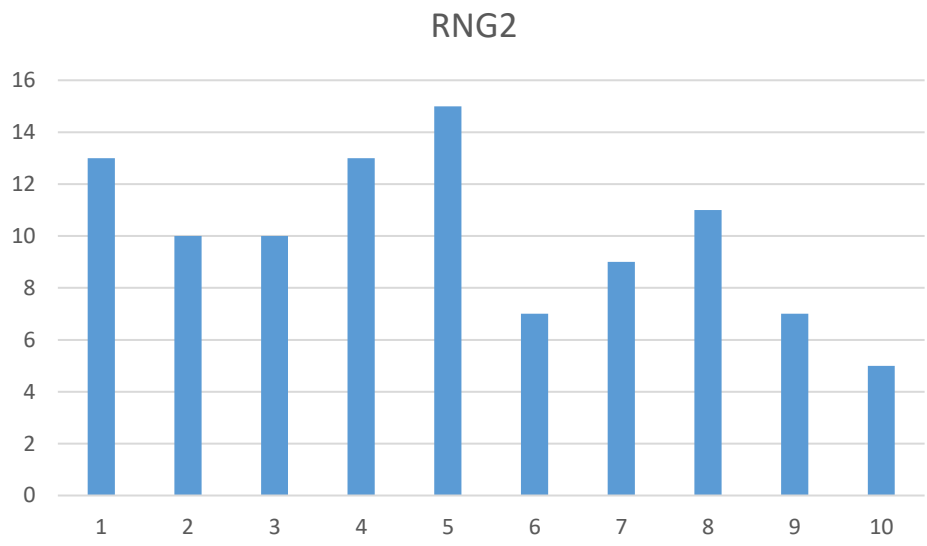
Evaluating Random Number Generators



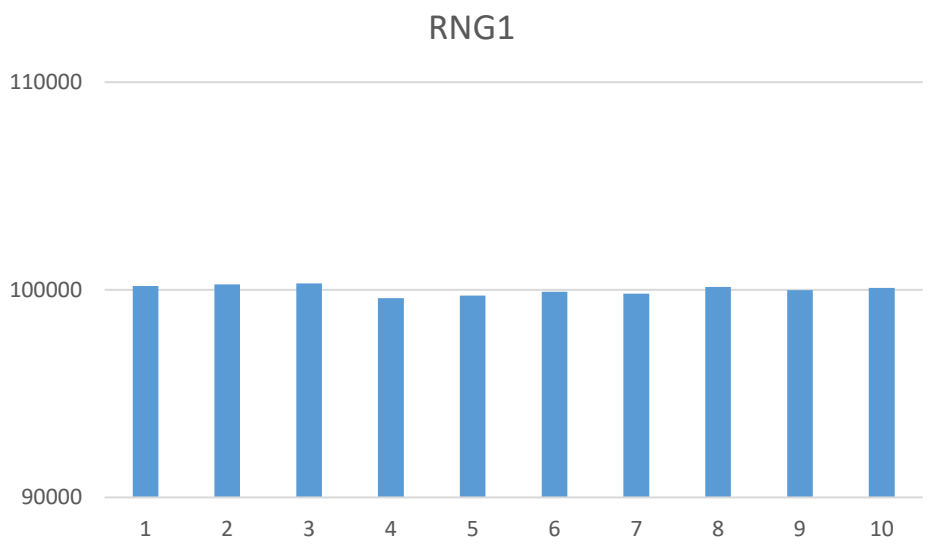


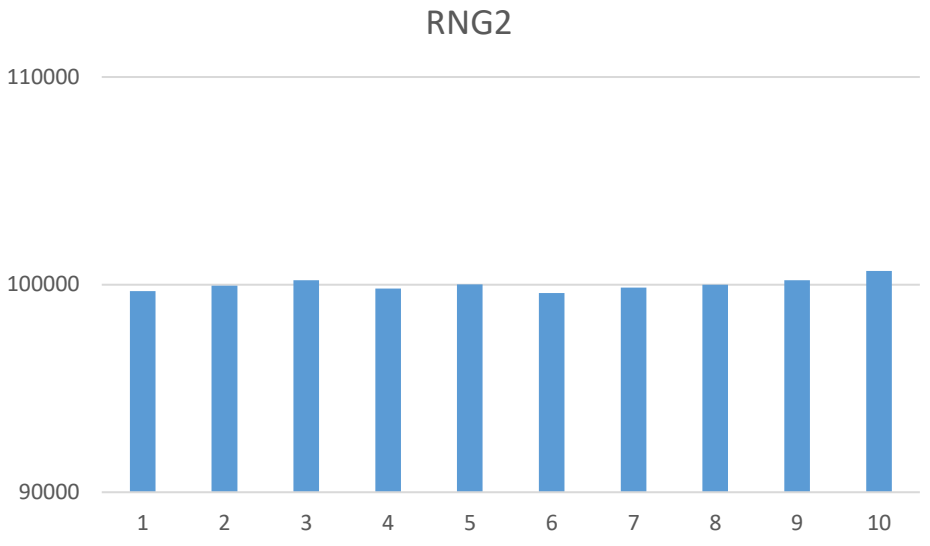
Evaluating Random Number Generators





Evaluating Random Number Generators





Rolling dice

- Have a Random Number Generator pick two numbers between one and six.

- Sum the two numbers.

Example

```
import java.util.Random;

public class DiceRoller {

     public static void main(String[] args) {

          //Instantiate a new Random object.
          Random myGenerator = new Random();

          //Assigns a random number between 1 and 6 to firstDieNumber.
          int firstDieNumber = myGenerator.nextInt(6) + 1;

          //Assigns a random number between 1 and 6 to secondDieNumber.
          int secondDieNumber = myGenerator.nextInt(6) + 1;

          //Calculates the sum of the two “rolls”.
          int rollTotal = firstDieNumber + secondDieNumber;

     }
}
```

Rolling dice