

Chapter 5

Loops

Outline

1. Motivate Loop Statement
2. *While* Loop Statement
3. *do-while* Loop Statement
4. *for* Loop Statement
5. Infinite Loops
6. Nested Loops
7. Using `break` and `continue`

Motivation

Suppose that you need to print a string (e.g., "Welcome to Java!") a thousand times. It would be tedious to have to write the following statement a hundred times:


```
System.out.println("Welcome to Java!");
```

So, how do you solve this problem?

Motivation

Problem:

1000
times



```
System.out.println("Welcome to Java!");  
System.out.println("Welcome to Java!");  
System.out.println("Welcome to Java!");  
System.out.println("Welcome to Java!");  
System.out.println("Welcome to Java!");  
System.out.println("Welcome to Java!");  
  
...  
...  
...  
...  
...  
  
System.out.println("Welcome to Java!");  
System.out.println("Welcome to Java!");  
System.out.println("Welcome to Java!");
```

Motivation

A solution using *While* Loop:

```
int count = 0;
while (count < 1000)
{
    System.out.println("Welcome to Java!");
    count = count + 1;
}
```

A solution using *for* Loop:

```
for (int count = 1; count <= 1000; count = count + 1)
    System.out.println("Welcome to Java!");
```

1. Loop Statements

- ***Loops are repetition statements*** that allow us to execute a statement (or block of statements) multiple times
- Like conditional statements, they are controlled by **boolean expressions**
- Java has three types of loop statements:
 - the *while loop*
 - the *do-while loop*
 - the *for loop*
- The programmer should choose the right type of loop for the situation at hand

Loop Statements

- The *while and do-while* loops are also called **conditional loops** since they use **boolean expressions** to control the loop behavior
- The *while and do-while* loops run un-determined (unknown) number of iterations (some call them **non-deterministic** loops)
- The *for* loop, on the other hand, runs a pre-determined (known) number of iterations (some call it **deterministic** loop or **counting** loop)

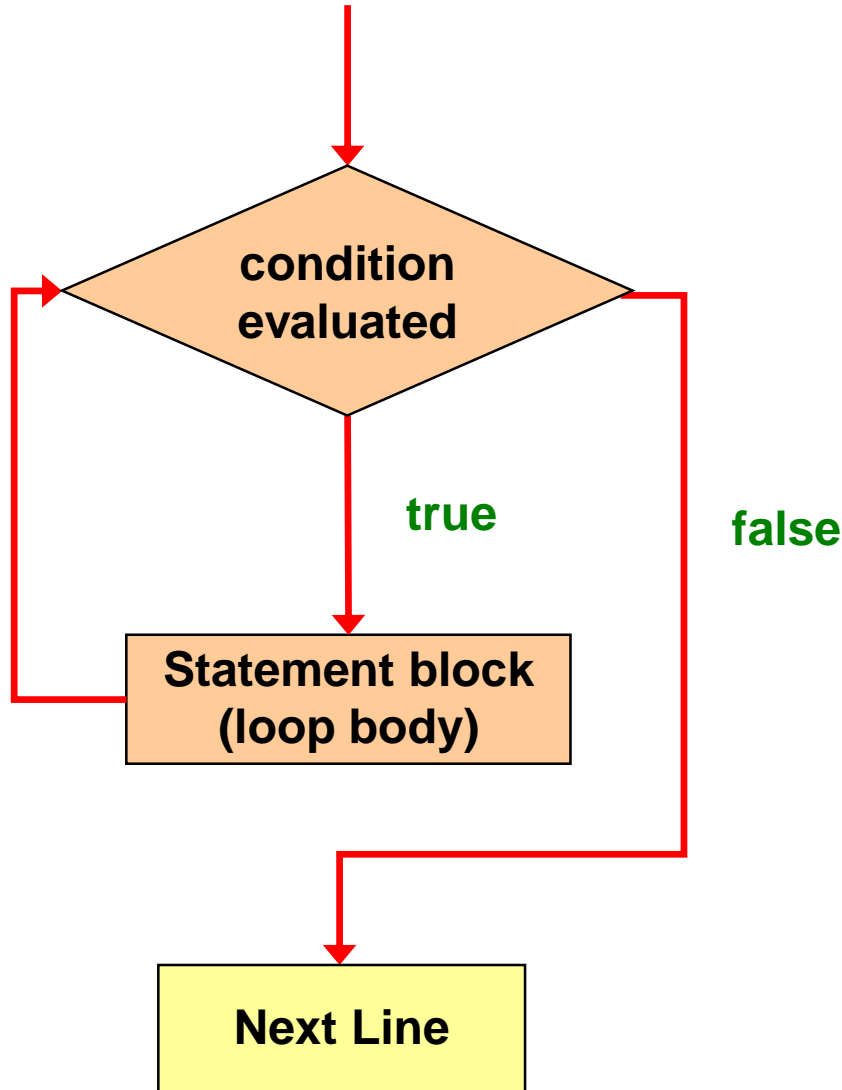
2. *while* Loop Statement

- A *while* loop (*statement*) has the following syntax:

```
while (condition)  
    statement block; //loop body
```

- If the *condition* is true, the *statement block* is executed
- Then the condition is evaluated again, and if it is still *true*, the statement is executed again
- The statement is executed repeatedly until the condition becomes *false*

while Loop Logic



Note: If the initial evaluation of the condition is false, the loop body executes zero times. Therefore, the while loop executes **zero or more times**

Trace while Loop

```
int count = 0;
```

Initialize count

```
while (count < 2) {  
    System.out.println("Welcome to Java!");  
    count++;  
}
```

Trace while Loop, cont.

```
int count = 0;
```

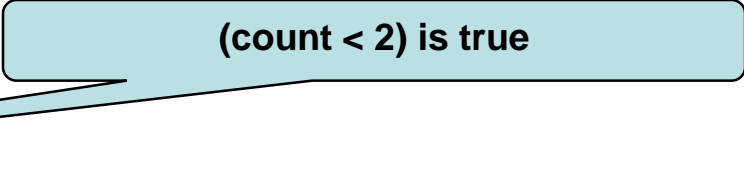
```
while (count < 2) {
```

```
    System.out.println("Welcome to Java!");
```

```
    count++;
```

```
}
```

(count < 2) is true



Trace while Loop, cont.

```
int count = 0;
```

```
while (count < 2) {
```

```
    System.out.println("Welcome to Java!");
```

```
    count++;
```

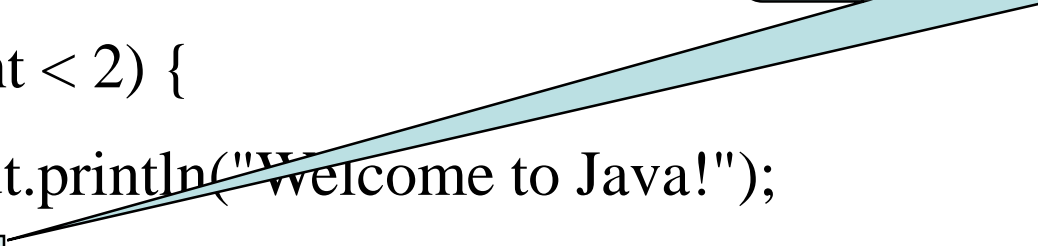
```
}
```



Print Welcome to Java

Trace while Loop, cont.

```
int count = 0;  
while (count < 2) {  
    System.out.println("Welcome to Java!");  
    count++;  
}
```



**Increase count by 1
count is 1 now**

Trace while Loop, cont.

```
int count = 0;
```

```
while (count < 2) {
```

```
    System.out.println("Welcome to Java!");
```

```
    count++;
```

```
}
```

(count < 2) is still true since count is 1

Trace while Loop, cont.

```
int count = 0;
```

```
while (count < 2) {
```

```
    System.out.println("Welcome to Java!");
```

```
    count++;
```

```
}
```



Print Welcome to Java

Trace while Loop, cont.

```
int count = 0;  
while (count < 2) {  
    System.out.println("Welcome to Java!");  
    count++;  
}
```



**Increase count by 1
count is 2 now**

Trace while Loop, cont.

```
int count = 0;
```

```
while (count < 2) {
```

```
    System.out.println("Welcome to Java!");
```

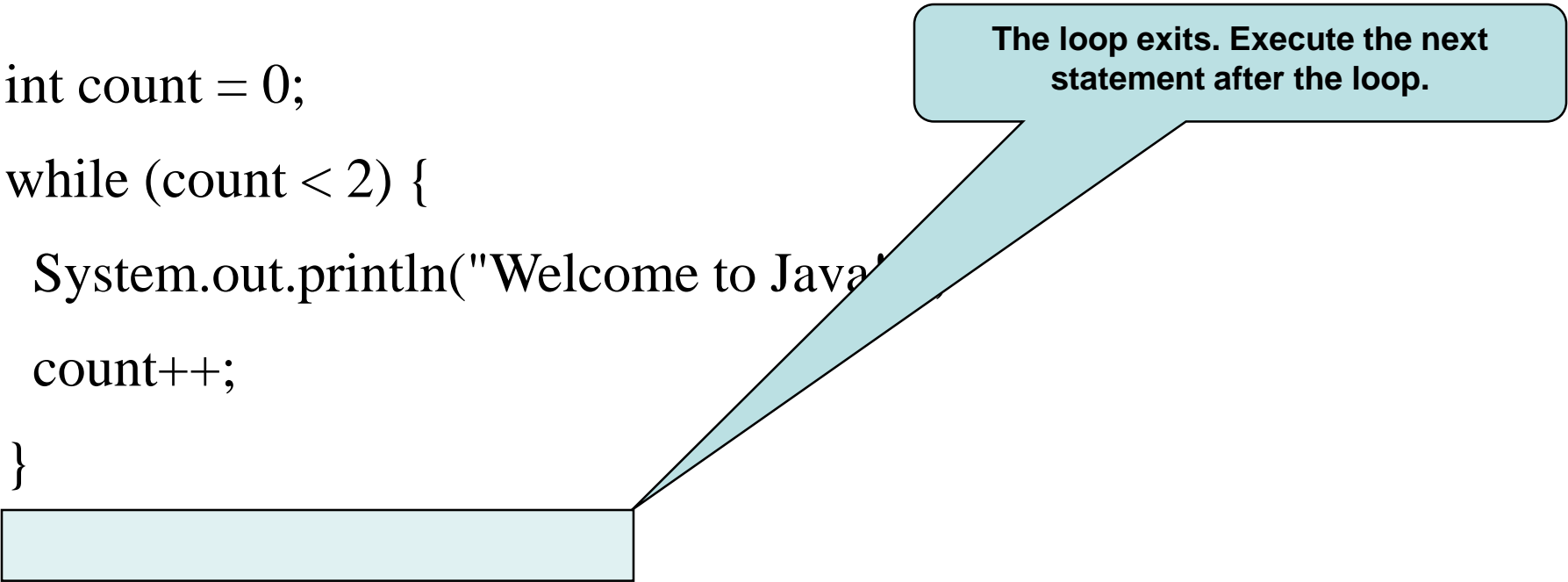
```
    count++;
```

```
}
```

(count < 2) is false since count is 2 now

Trace while Loop

```
int count = 0;  
while (count < 2) {  
    System.out.println("Welcome to Java");  
    count++;  
}
```



The loop exits. Execute the next statement after the loop.

while Loop Example

- An example of a while statement:

```
int count = 1;
while (count <= 5)
{
    System.out.println (count);
    count = count + 1;
}
```

- If the condition is false initially, the statement (loop body) is never executed
- Therefore, the body of a `while` loop will execute **zero or more times**

while Loop Sentinel Value

Question: How can we control a while loop?

- A *sentinel value* is a special input value that represents the *end of inputs* from the user
- The *sentinel value* should be included in the prompt so that the user knows how to stop the loop. For example,

```
System.out.println("Enter a grade (type 9999 to quit): ");
```

- A *sentinel value* gives the user control over the loop
- See [Average.java](#) next slide

Sentinel Value Example

```
// Demonstrates the use of a while loop using a sentinel value
import java.text.DecimalFormat;
import java.util.Scanner;
public class Average
{
    public static void main (String[] args)
    { int sum = 0, value, count = 0;
      double average;
      Scanner scan = new Scanner (System.in);
      System.out.print ("Enter an integer (0 to quit): ");
      value = scan.nextInt();
      while (value != 0) //sentinel value of 0 to terminate loop
      { count = count + 1;
        sum = sum + value;
        System.out.println ("The sum so far is " + sum);
        System.out.print ("Enter an integer (0 to quit): ");
        value = scan.nextInt();
      }
      System.out.println ();
      if (count == 0)
          System.out.println ("No values were entered.");
      else
          System.out.println ("Sum of all values = " + sum + "\n" +
                              "Average of all values = " + (sum/(double)count));
    }
}
```

while Loops for Input Validation

- A while loop can be used for *input validation*, making a program more *robust*
- Input validation allows the program to ensure correct input values before the input is processed
- It also allows the program to issue error messages to the user when invalid data is entered
- See [WinPercentage.java](#) next slide

Input Validation Example

```
// Demonstrates the use of a while loop for input validation
import java.text.NumberFormat;
import java.util.Scanner;
public class WinPercentage
{
    public static void main (String[] args)
    {
        final int NUM_GAMES = 12;
        int won;
        double ratio;
        Scanner scan = new Scanner (System.in);
        System.out.print ("Enter the number of games won (0 to "
                        + NUM_GAMES + "): ");
        won = scan.nextInt();

        //input validation
        while (won < 0 || won > NUM_GAMES)
        {
            System.out.print ("Invalid input. Please reenter: ");
            won = scan.nextInt();
        }

        ratio = (double)won / NUM_GAMES;
        NumberFormat fmt = NumberFormat.getPercentInstance();
        System.out.println ();
        System.out.println ("Winning percentage: " + fmt.format(ratio));
    }
}
```

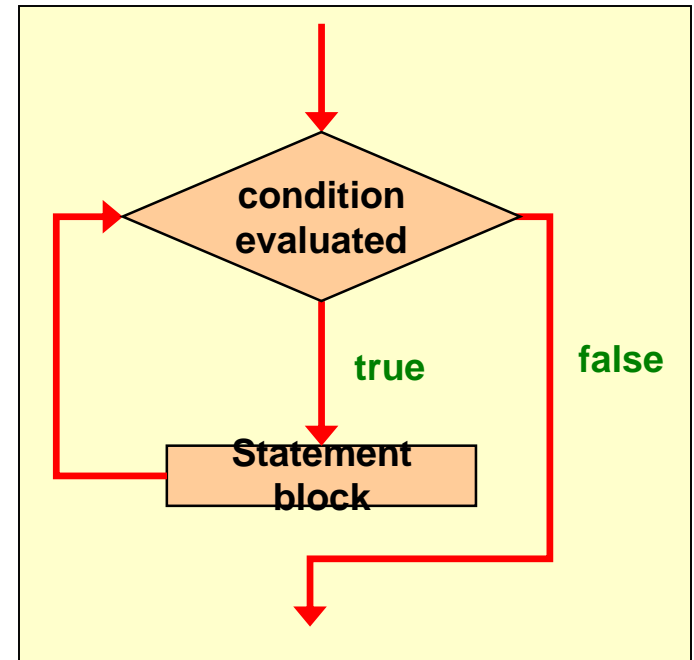
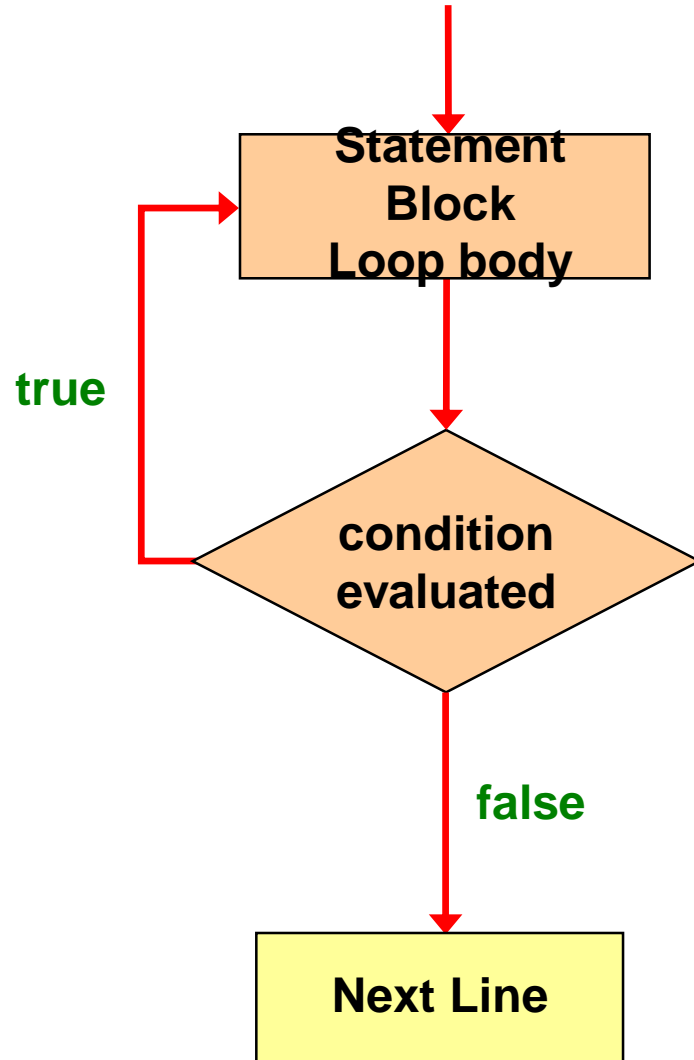
3. *do-while* Loop

- A *do-while* loop has the following syntax:

```
do
{
    statement block;
} while (condition)
```

- The *statement* is executed once initially, and then the *condition* is evaluated
- The statement is executed repeatedly **until the condition becomes false**

Logic of *do-while* Loop



While Loop

do-while Loop Example

- An example of a do loop:

```
int count = 0;  
do  
{  
    count = count +1;  
    System.out.println (count) ;  
} while (count < 5) ;
```

- The body of a do loop executes at least once
- See [ReverseNumber.java](#) next slide

do-while Loop Example

```
// Demonstrates the use of a do loop
import java.util.Scanner;
public class ReverseNumber
{
    public static void main (String[] args)
    {
        int number, lastDigit, reverse = 0;
        Scanner scan = new Scanner (System.in);
        System.out.print ("Enter a positive integer: ");
        number = scan.nextInt();

        do
        {
            lastDigit = number % 10;
            reverse = (reverse * 10) + lastDigit;
            number = number / 10;
        } while (number > 0);

        System.out.println ("That number reversed is " + reverse);
    }
}
```

4. *for* Loop

- A *for statement* has the following syntax:

The *initialization*
is executed once
before the loop begins



The *statement* is
executed until the
condition becomes false

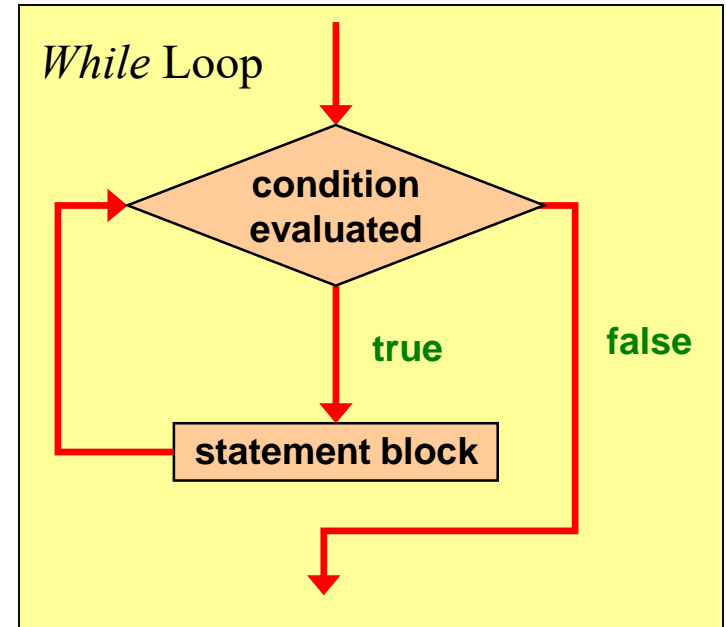
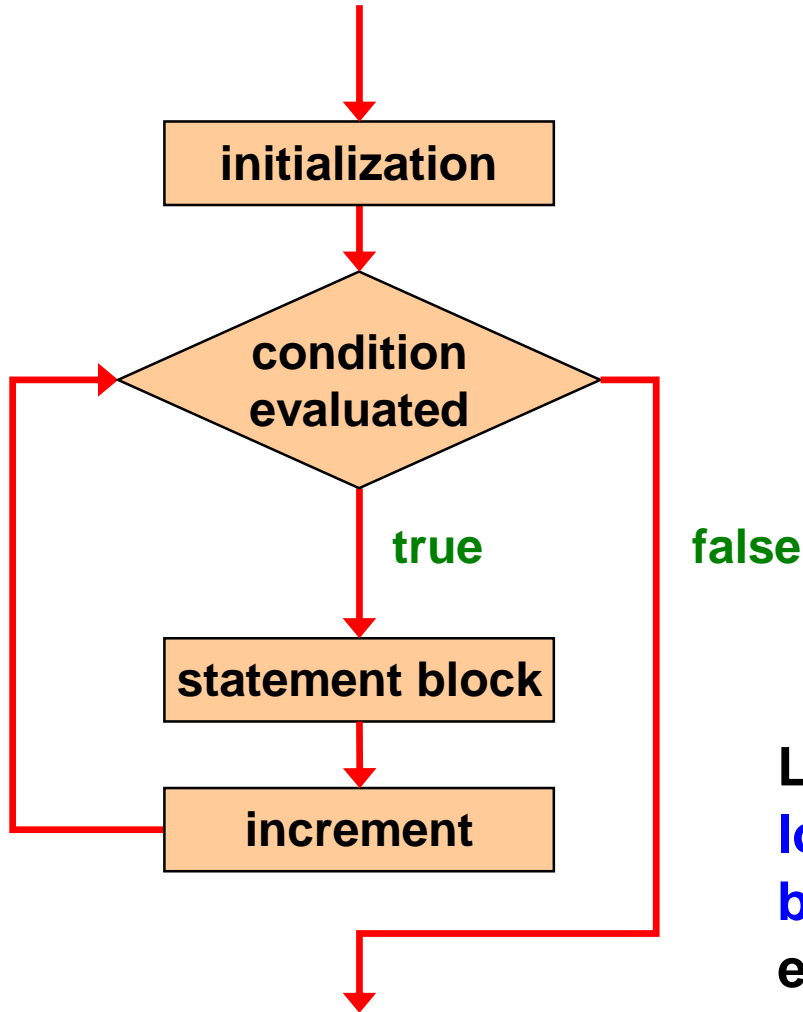


```
for (initialization; condition; increment)  
    statement;
```



The *increment* portion is executed
at the end of each iteration

for Loop Logic



Like a *while* loop, the condition of a *for* loop is tested prior to executing the loop body. Therefore, the *for* loop body will execute zero or more times

Trace for Loop

int i;

Declare i

```
for (i = 0; i < 2; i++) {  
    System.out.println("Welcome to Java!");  
}
```

Trace for Loop, cont.

```
int i;  
for (i = 0; i < 2; i++) {  
    System.out.println("Welcome to Java!");  
}
```

Execute initializer
i is now 0

Trace for Loop, cont.

```
int i;  
for (i = 0; i < 2; i++) {  
    System.out.println("Welcome to Java!");  
}
```

(i < 2) is true
since i is 0

Trace for Loop, cont.

```
int i;  
for (i = 0; i < 2; i++) {  
    System.out.println("Welcome to Java!");  
}
```



Print Welcome to Java

System.out.println("Welcome to Java!");

Trace for Loop, cont.

```
int i;  
for (i = 0; i < 2; i++) {  
    System.out.println("Welcome to Java!");  
}
```

Execute adjustment statement
i now is 1

Trace for Loop, cont.

```
int i;  
for (i = 0; i < 2; i++) {  
    System.out.println("Welcome to Java!");  
}
```

**(i < 2) is still true
since i is 1**

Trace for Loop, cont.

```
int i;  
for (i = 0; i < 2; i++) {  
    System.out.println("Welcome to Java!");  
}
```



Print Welcome to Java

Trace for Loop, cont.

```
int i;  
for (i = 0; i < 2; i++) {  
    System.out.println("Welcome to Java!");  
}
```

**Execute adjustment statement
i now is 2**

Trace for Loop, cont.

```
int i;  
for (i = 0; i < 2; i++) {  
    System.out.println("Welcome to Java!");  
}
```

(i < 2) is false
since i is 2

Trace for Loop, cont.

```
int i;  
for (i = 0; i < 2; i++) {  
    System.out.println("Welcome to Java");  
}
```



**Exit the loop. Execute the next
statement after the loop**

for Loop as a *while* Loop

- A `for` loop is functionally equivalent to `while` loop.

```
for (initialization; condition; increment)  
    statement block;
```

```
initialization;  
while (condition)  
{  
    statement block;  
    increment;  
}
```


for to while Loop Example

- The for loop:

```
for (int count = 1; count <= 5; count = count+1)  
    System.out.println (count);
```

- The initialization section can be used to declare a variable, making it local variable to the loop body.

```
int count = 1;  
while (count <= 5)  
{  
    System.out.println (count);  
    count = count + 1;  
}
```

for Loop Example

- The increment section can perform any calculation

```
for (int num = 100; num > 0; num = num - 5)  
    System.out.println (num);
```

- A `for` loop is well suited for executing a block of statements a **specific number of times** that can be calculated or determined in advance
- See [Multiples.java](#) next slide

for Loop Example

```
// Demonstrates the use of a for loop to print multiples of a number
import java.util.Scanner;
public class Multiples
{
    public static void main (String[] args)
    {
        final int PER_LINE = 5;
        int value, limit, multiple, count = 0;
        Scanner scan = new Scanner (System.in);
        System.out.print ("Enter a positive value: ");
        value = scan.nextInt();
        System.out.print ("Enter an upper limit: ");
        limit = scan.nextInt();
        System.out.println ();
        System.out.println ("The multiples of " + value + " between " +
                           value + " and " + limit + " (inclusive) are:");
        for (multiple = value; multiple <= limit; multiple = multiple + value)
        {
            System.out.print (multiple + "\t");
            // Print a specific number of values per line of output
            count = count + 1;
            if (count % PER_LINE == 0)
                System.out.println(); // go to next line
        }
    }
}
```

5. Infinite Loops

- The body of a `while` loop eventually must make the condition false
- If not, it is called an *infinite loop*, which will execute until the user interrupts the program
- This is a common logical error
- You should always double check the logic of a program to ensure that your loops will terminate normally

Example

- An example of an infinite loop:

```
int count = 1;
while (count <= 25)
{
    System.out.println (count);
    count = count - 1; //Error
}
```

- This loop will continue executing until interrupted (**Control-C**) or until an underflow error occurs

Be Careful!

- If the condition is left out, it is always considered to be true, and therefore creates an **infinite loop**
- If the increment is left out, no increment operation is performed, and therefore creates an **infinite loop**

```
for (int count=1; count <= 5; count = count+1)  
    System.out.println (count);
```

```
for ( ; ; ) {  
    //Do something  
}
```

Equivalent

```
while (true) {  
    //Do something  
}
```

6. Nested Loops

- **Similar to nested `if` statements, loops can be nested as well**
- **That is, the body of a loop can contain other loop statements**
- **For each iteration of the outer loop, the inner loop iterates completely**
- **See [PalindromeTester.java](#) next slide**

Example

```
// Demonstrates the use of nested while loops.
import java.util.Scanner;
public class PalindromeTester
{
    public static void main (String[] args)
    {
        String str, another = "y";
        int left, right;
        Scanner scan = new Scanner (System.in);
        while (another.equalsIgnoreCase("y")) // allows y or Y
        {
            System.out.println ("Enter a potential palindrome string:");
            str = scan.nextLine();
            left = 0;
            right = str.length() - 1;
            while (str.charAt(left) == str.charAt(right) && left < right)
            {
                left = left + 1;
                right = right - 1;
            }
            System.out.println();
            if (left < right)
                System.out.println ("That string is NOT a palindrome.");
            else
                System.out.println ("That string IS a palindrome.");
            System.out.println();
            System.out.print ("Test another palindrome (y/n)? ");
            another = scan.nextLine();
        }
    }
}
```


Example

// Demonstrates the use of nested for loops to print stars

```
public class Stars
{
    public static void main (String[] args)
    {
        final int MAX_ROWS = 10;

        for (int row = 1; row <= MAX_ROWS; row++)
        {
            for (int star = 1; star <= row; star++)
                System.out.print ("*");

            System.out.println();
        }
    }
}
```

```
*
**
***
****
*****
*****
*****
*****
*****
*****
*****
```

Nested Loops Iterations

How many times will the string "I am here" be printed?

```
// Demonstrates the use of nested loops
public class NestedLoops
{
    public static void main (String[] args)
    { String str, another = "y";

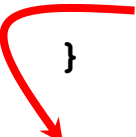
        int count1 = 1;
        while (count1 <= 10)
        {
            int count2 = 1;
            while (count2 <= 5)
            {
                System.out.println("I am here!");
                count2 = count2 + 1;
            }
            System.out.println(); // blank line
            count1 = count1 + 1;
        }
    }
}
```

7. Using break and continue

Examples for using the break statement:

```
// demonstrate break statement
public class TestBreak {
    public static void main(String[] args) {
        int sum = 0;
        int number = 0;

        while (number < 20)
        {
            number = number + 1;
            sum = sum + number;
            if (sum >= 100) // stop if sum is over 100
                break;
        }
        System.out.println("The number is " + number);
        System.out.println("The sum is " + sum);
    }
}
```



Using break and continue

Examples for using the continue statement:

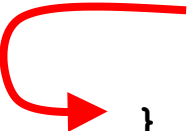
```
// demonstrate continue statement
public class TestContinue {
    public static void main(String[] args) {
        int sum = 0;
        int number = 0;

        while (number < 10) {
            number = number + 1;
            if (number == 5 || number == 6)
                continue; // do not add 5 and 6 to sum
            sum = sum + number;

            }

        System.out.println("The number is " + number);
        System.out.println("The sum is " + sum);

    }
}
```



End of Chapter 5