Computer Programming I - CSC111

Chapter 4 – Flow of Control (Loops)

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Outline

- The `while` statement
- The `do-while` statement
- The `for` statement
- The loop body
- Initializing statements
- Controlling loop iterations
- Loop bugs
- Tracing variables

Java loop statements

- A portion of a program that repeats a statement or a group of statements is called a *loop.*
- The statement or group of statements to be repeated is called the *body* of the loop.
- A loop could be used to compute grades for each student in a class.
- There must be a means of exiting the loop.

The `while` statement

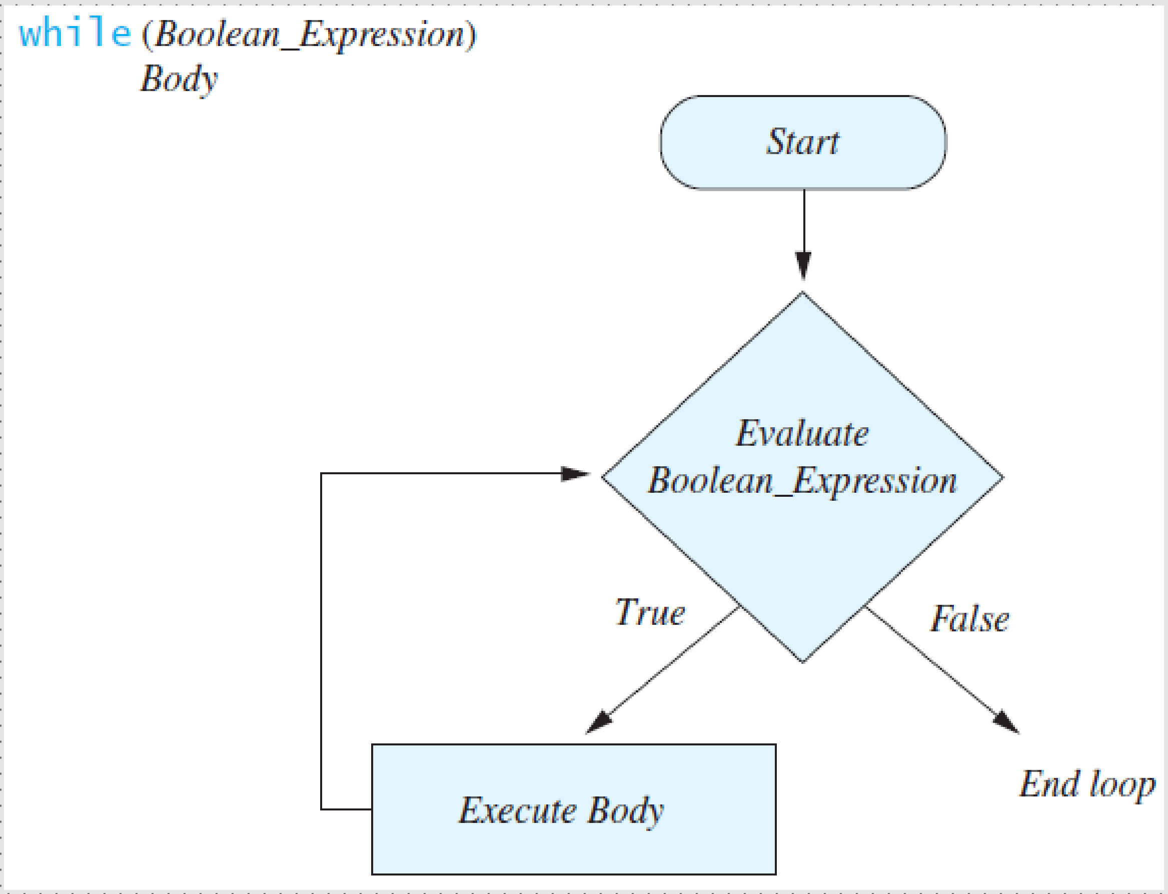
- Also called a `while` loop
- A `while` statement repeats while a controlling boolean expression remains true
- The loop body typically contains an action that ultimately causes the controlling boolean expression to become false.

Syntax of the `while` statement

- Syntax

```
while(Boolean_Expression)
  Body_Statement
or
while(Boolean_Expression)
{
  First_Statement
  Second_Statement
  …
}
```

Semantics of the `while` statement



```
while (Boolean_Expression)
      Body
```

Example

- Write a Java program that reads a positive number from the user and prints all numbers starting from 1 to the entered number.

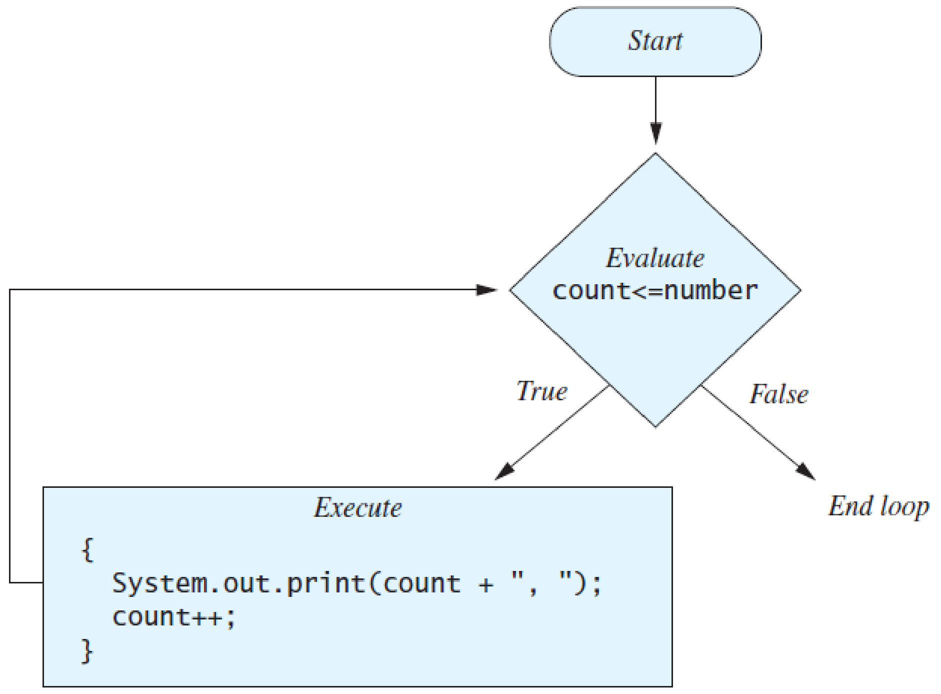
```
int number, count=1;
Scanner keyboard = new Scanner(System.in);
System.out.println("Enter a number:");
number = keyboard.nextInt();

while(count <= number)
{
   System.out.print(count + ", ");
   count++;
}
```

Sample Output

```
Enter a number:
5
1, 2, 3, 4, 5,
```

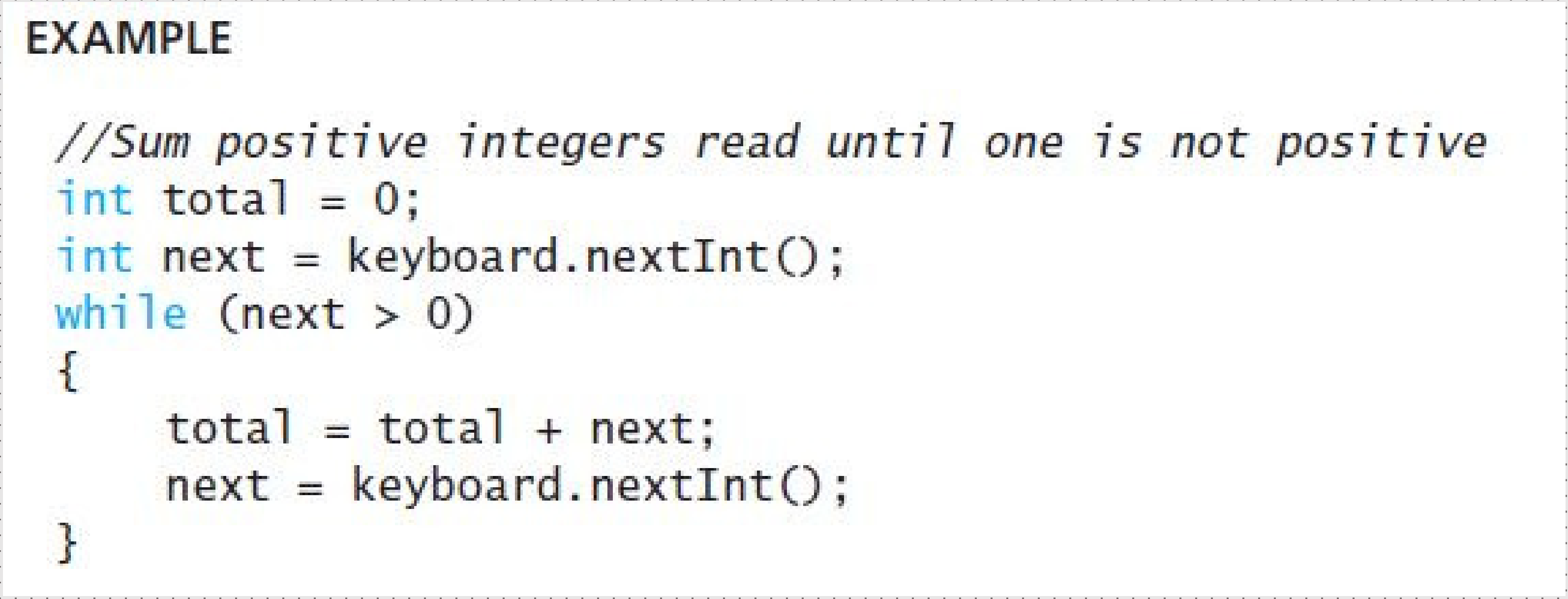
Action of the `while` statement

```
while (count <= number)
{
   System.out.print(count + ", ");
   count++;
}
```



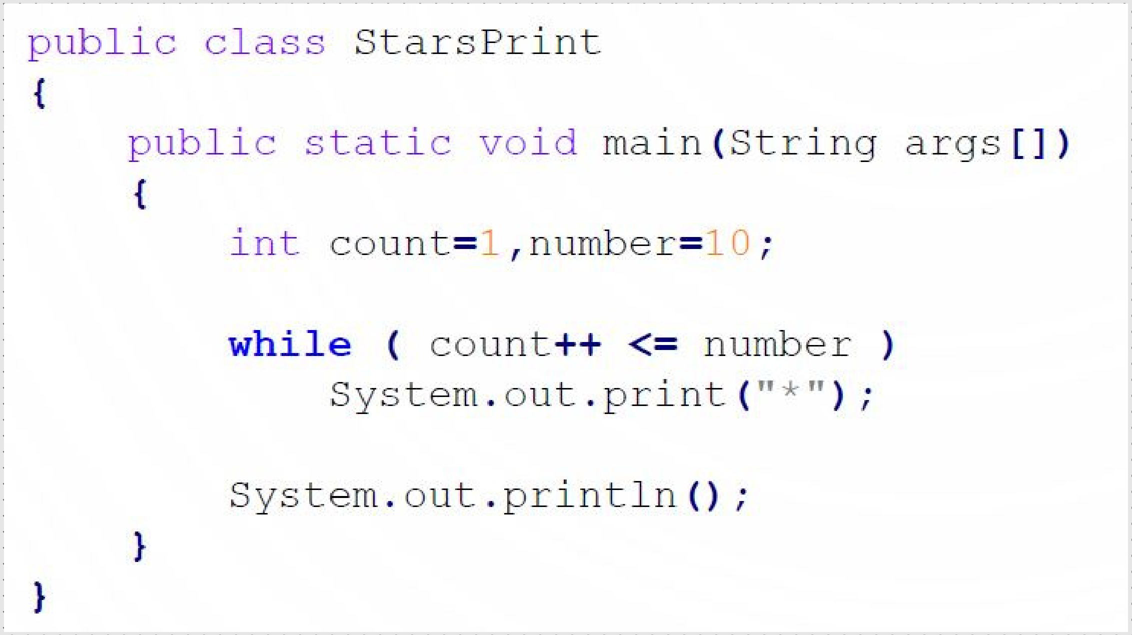
```
{
  System.out.print(count + ", ");
  count++;
}
```

Example

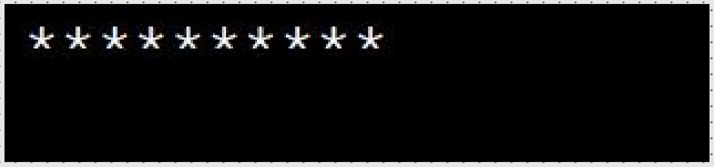

EXAMPLE

```
//Sum positive integers read until one is not positive
int total = 0;
int next = keyboard.nextInt();
while (next > 0)
{
    total = total + next;
    next = keyboard.nextInt();
}
```

Another example



```
public class StarsPrint
{
    public static void main(String args[])
    {
        int count=1,number=10;

        while ( count++ <= number )
            System.out.print("*");

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



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

Example

- Write Java statements that compute the product 1*2* … *10 and print its value

```java
int product = 1, number = 1;
while(number <= 10){
     product = product * number;
     number++;
}
System.out.println(product);
```

Output

```
3628800
```

Example

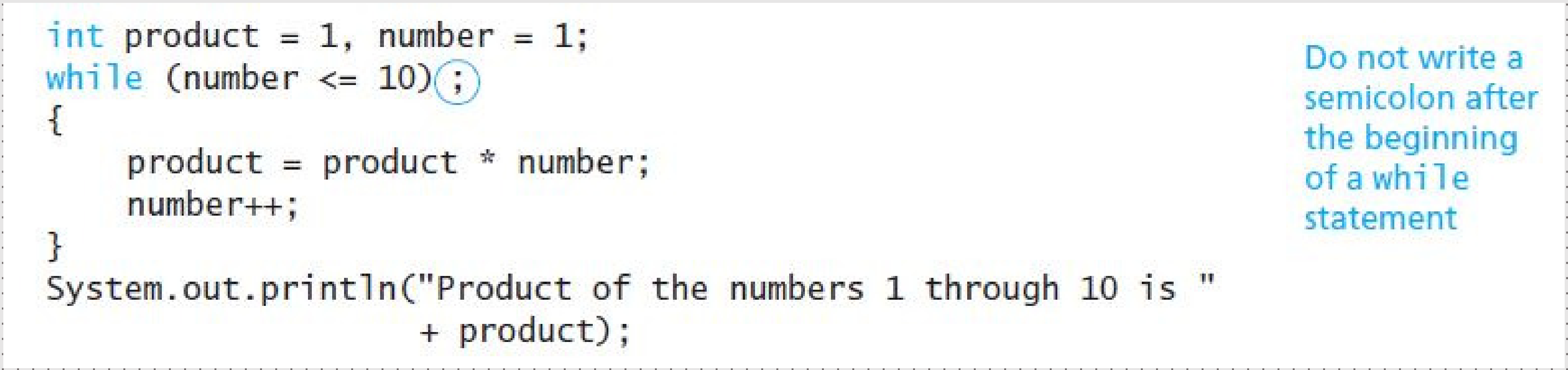
- Write Java statements that compute the sum 1+2+ … +10 and print its value

```
int sum = 0, number = 1;
while(number <= 10){
      sum = sum + number;
      number++;
}
System.out.println(sum);
```

Output

```
55
```

Caution



```
int product = 1, number = 1;
while (number <= 10);
{
    product = product * number;
    number++;
}
System.out.println("Product of the numbers 1 through 10 is "
                   + product);
```

Do not write a semicolon after the beginning of a `while` statement

Nested loops

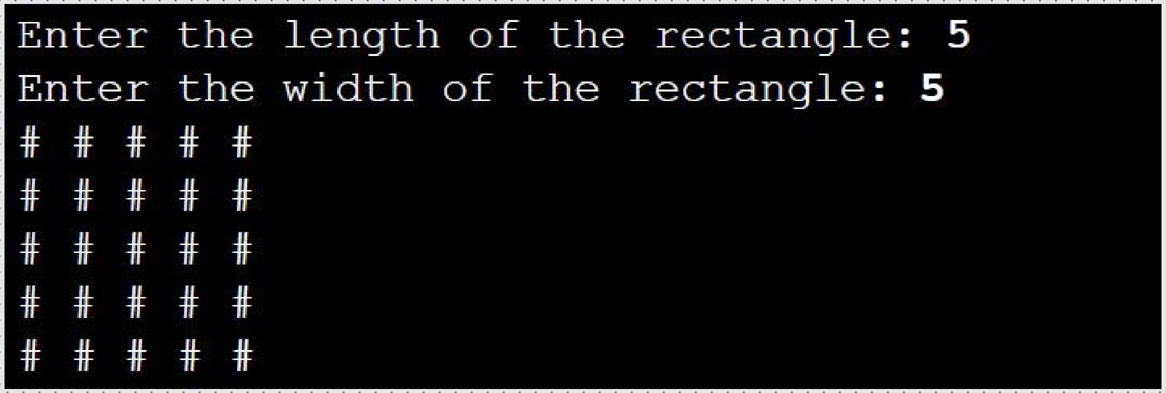
- The body of a loop can contain any kind of statements, including another loop.

- How many times will the string “Here” be printed?

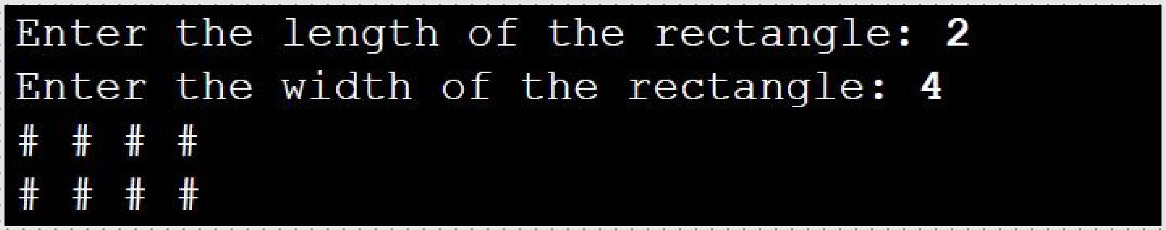
```
int count1 = 1, count2 = 1;
while(count1 <= 10){
        count2 = 1;
        while(count2 <= 20){
                System.out.println("Here");
                count2++;
        }
        count1++;
}
```

10 * 20 = 200

Rectangle drawing example



```
Enter the length of the rectangle: 5
Enter the width of the rectangle: 5
# # # # #
# # # # #
# # # # #
# # # # #
# # # # #
```



```
Enter the length of the rectangle: 2
Enter the width of the rectangle: 4
# # # #
# # # #
```

```java
import java.util.Scanner;
public class RectangleDrawing {
    public static void main(String[] args) {
        Scanner keyboard = new Scanner(System.in);
        int length, width, currentL=0, currentW=0;

        System.out.print("Enter the length of the rectangle: ");
        length = keyboard.nextInt();
        System.out.print("Enter the width of the rectangle: ");
        width = keyboard.nextInt();

        if(length>0 && width>0)
        {
            while(currentL<length)
            {
                currentW=0;
                while(currentW<width)
                {
                    System.out.print("# ");
                    currentW++;
                }
                System.out.println();
                currentL++;
            }
        }
    }
}
```

Equivalent Code

```java
import java.util.Scanner;
public class RectangleDrawing {
    public static void main(String[] args) {
        Scanner keyboard = new Scanner(System.in);
        int length, width, currentL=0, currentW=0;

        System.out.print("Enter the length of the rectangle: ");
        length = keyboard.nextInt();
        System.out.print("Enter the width of the rectangle: ");
        width = keyboard.nextInt();

        if(length>0 && width >0)
            while(currentL++<length)
            {
                currentW=0;
                while(currentW++<width)
                        System.out.print("# ");
                System.out.println();
            }
    }
}
```

The `do-while` statement

- Also called a `do-while` loop
- Similar to a `while` statement, except that the loop body is executed at least once
- Syntax

```
do
   Body_Statement
while (Boolean_Expression);
```

- Don’t forget the semicolon!

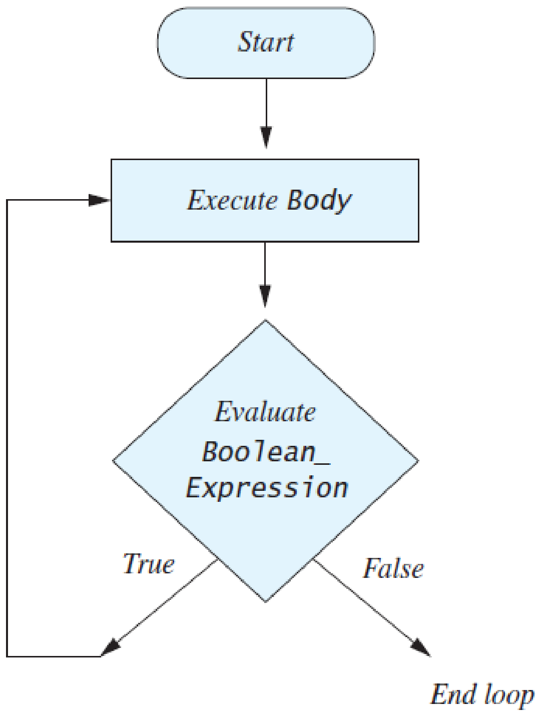
The **`do-while`** statement

- First, the loop body is executed.
- Then the boolean expression is checked.
  - As long as it is true, the loop is executed again.
  - If it is false, the loop is exited.
- Equivalent **`while`** statement

```
Statement(s)_S1
while (Boolean_Condition)
    Statement(s)_S1
```

Semantics of the `do-while` statement

```
do
    Body
while (Boolean_Expression)
```



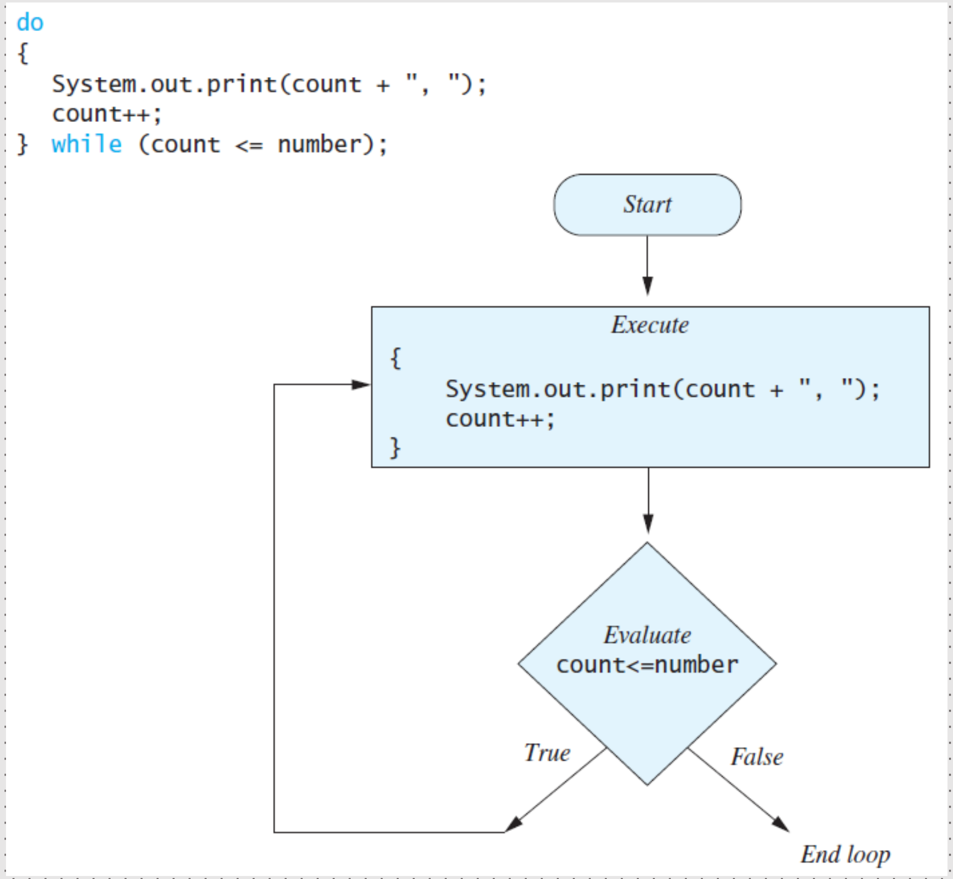
Example

```java
int number, count=1;
Scanner keyboard = new Scanner(System.in);
System.out.println("Enter a number:");
number = keyboard.nextInt();

do
{
   System.out.print(count + ", ");
   count++;
} while(count <= number);
```

Sample Output

```
Enter a number:
0
1,
```

Action of the **do-while** statement



```
do
{
   System.out.print(count + ", ");
   count++;
} while (count <= number);
```

Example

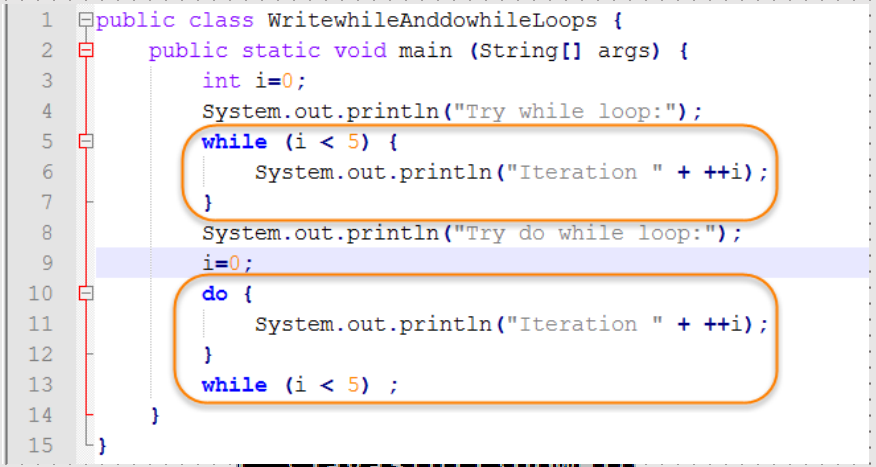
- A great use for the Do-While loop is the menu: The menu is displayed continuously until the end user picks a value. If they type a certain menu item, then the code stops.

```
***** MAIN MENU *****
1. Print Good Morning!
2. Print Good Evening!
3. Print Good Bye! and Exit the program

Select an Option:
1
Good Morning!
***** MAIN MENU *****
1. Print Good Morning!
2. Print Good Evening!
3. Print Good Bye! and Exit the program

Select an Option:
2
Good Evening!
***** MAIN MENU *****
1. Print Good Morning!
2. Print Good Evening!
3. Print Good Bye! and Exit the program

Select an Option:
3
Good Bye!
```

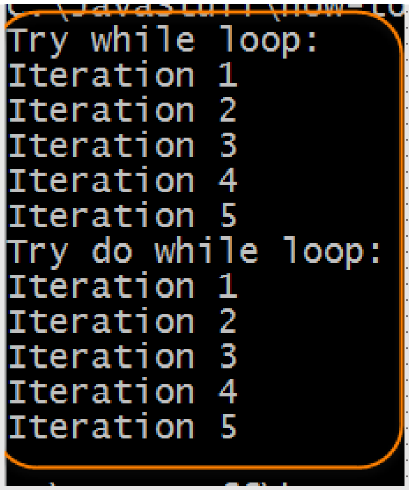
Example

```
int userOption;
Scanner keyboard = new Scanner(System.in);
    do {
        System.out.println("***** MAIN MENU *****");
        System.out.println("1. Print Good Morning!");
        System.out.println("2. Print Good Evening!");
        System.out.println("3. Print Good Bye! and Exit the program");
        System.out.println("\nSelect an Option: ");
        userOption = keyboard.nextInt();
        if(userOption == 1)
          System.out.println("Good Morning!");
        else
              if(userOption == 2)
                      System.out.println("Good Evening!");
               else
                      if(userOption == 3)
                             System.out.println("Good Bye!");

      } while(userOption != 3);
```

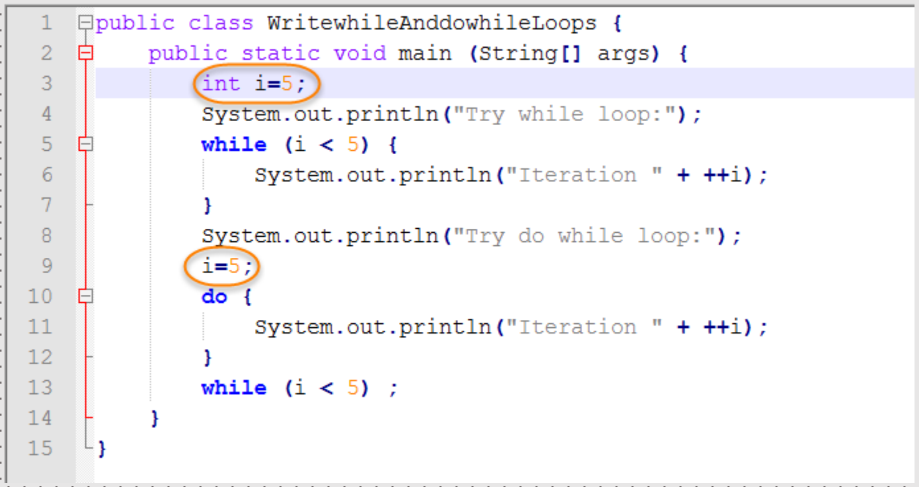
while vs. do-while



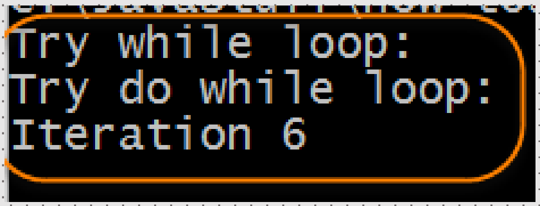
```java
public class WritewhileAnddowhileLoops {
    public static void main (String[] args) {
        int i=0;
        System.out.println("Try while loop:");
        while (i < 5) {
            System.out.println("Iteration " + ++i);
        }
        System.out.println("Try do while loop:");
        i=0;
        do {
            System.out.println("Iteration " + ++i);
        }
        while (i < 5) ;
    }
}
```



```
Try while loop:
Iteration 1
Iteration 2
Iteration 3
Iteration 4
Iteration 5
Try do while loop:
Iteration 1
Iteration 2
Iteration 3
Iteration 4
Iteration 5
```



```java
public class WritewhileAnddowhileLoops {
    public static void main (String[] args) {
        int i=5;
        System.out.println("Try while loop:");
        while (i < 5) {
            System.out.println("Iteration " + ++i);
        }
        System.out.println("Try do while loop:");
        i=5;
        do {
            System.out.println("Iteration " + ++i);
        }
        while (i < 5) ;
    }
}
```



```
Try while loop:
Try do while loop:
Iteration 6
```

Infinite loops

- A loop which repeats without ever ending is called an *infinite loop.*
- If the controlling boolean expression never becomes false, a **`while`** loop or a **`do-while`** loop will repeat without ending.

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

Exam average calculation example

- Compute the average of a list of (nonnegative) exam scores
- Repeats computation for more exams until the user says to stop

```
import java.util.Scanner;
/**
Computes the average of a list of (nonnegative) exam scores.
Repeats computation for more exams until the user says to stop.
*/
public class ExamAverager
{
    public static void main(String[] args)
    {
        System.out.println("This program computes the average of");
        System.out.println("a list of (nonnegative) exam scores.");
        double sum;
        int numberOfStudents;
        double next;
        String answer;
        Scanner keyboard = new Scanner(System.in);
        do
        {
            System.out.println();
            System.out.println("Enter all the scores to be averaged.");
            System.out.println("Enter a negative number after");
            System.out.println("you have entered all the scores.");
            sum = 0;
            numberOfStudents = 0;
            next = keyboard.nextDouble();
            while (next >= 0)
            {
               sum = sum + next;
               numberOfStudents++;
               next = keyboard.nextDouble();
            }
            if (numberOfStudents > 0)
                System.out.println("The average is " +
                                   (sum / numberOfStudents));
            else
                System.out.println("No scores to average.");

            System.out.println("Want to average another exam?");
            System.out.println("Enter yes or no.");
            answer = keyboard.next();
        } while (answer.equalsIgnoreCase("yes"));
    }
}
```

Sample Screen Output

```
This program computes the average of
a list of (nonnegative) exam scores.

Enter all the scores to be averaged.
Enter a negative number after
you have entered all the scores.
100
90
100
90
-1
The average is 95.0
Want to average another exam?
Enter yes or no.
yes

Enter all the scores to be averaged.
Enter a negative number after
you have entered all the scores.
90
70
80
-1
The average is 80.0
Want to average another exam?
Enter yes or no.
no
```

The `for` Statement

- A `for` statement executes the body of a loop a fixed number of times.
- Example

```
for (count = 1; count < 3; count++)
    System.out.println(count);
```

The `for` Statement

- Syntax

```
for (Initialization, Condition, Update)
        Body_Statement
```

- `Body_Statement` can be either a simple statement or a compound statement in `{ }` .

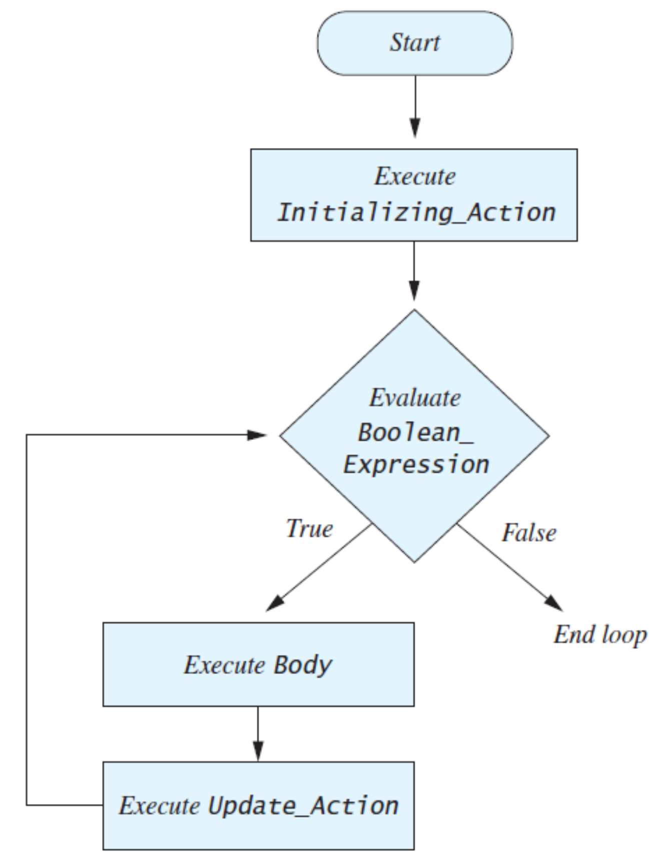
The `for` statement

- Corresponding `while` statement

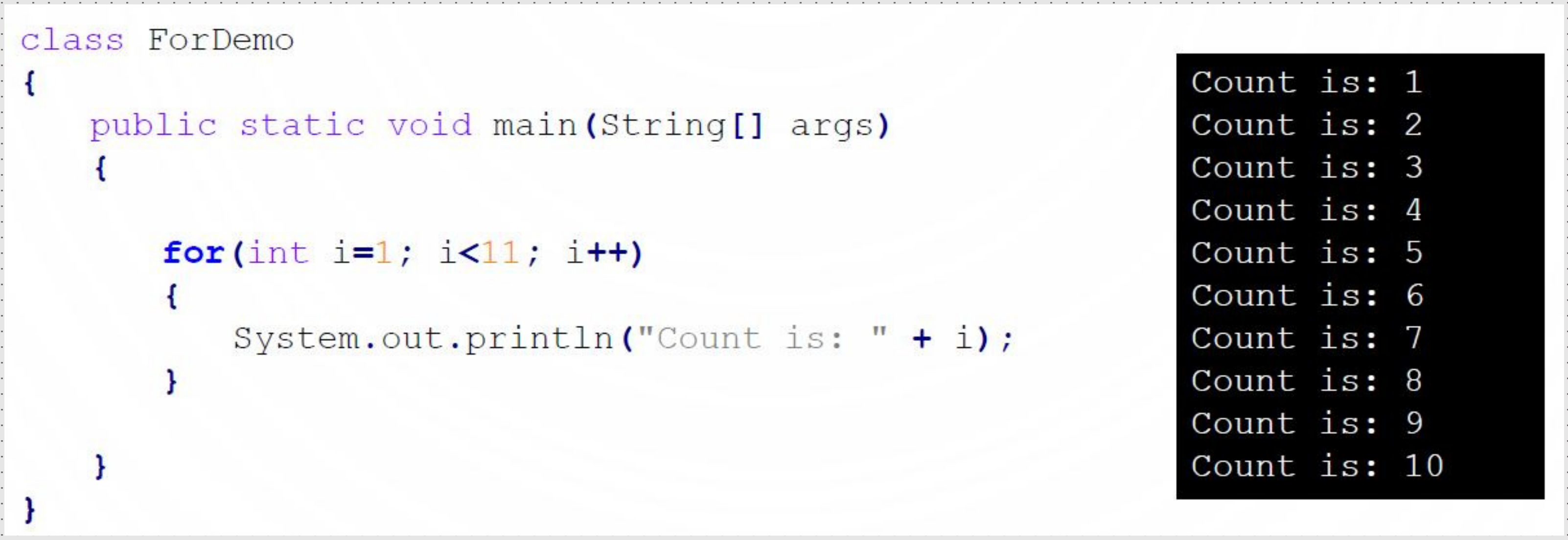
```
Initialization
while (Condition)
  Body_Statement_Including_Update
```

Semantic of the `for` statement

```
for (Initializing_Action; Boolean_Expression; Update_Action)
    Body
```



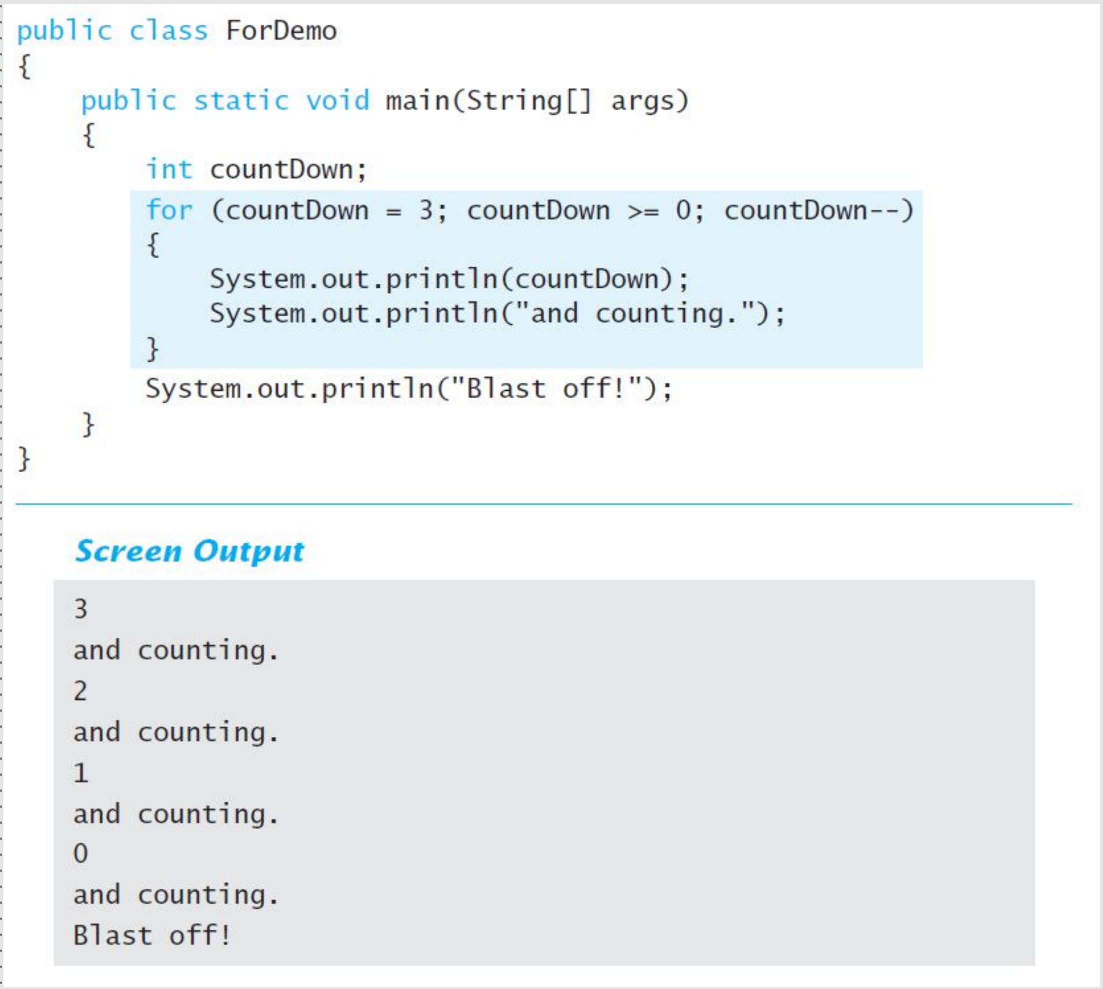
Example



```
class ForDemo
{
    public static void main(String[] args)
    {

        for(int i=1; i<11; i++)
        {
            System.out.println("Count is: " + i);
        }

    }
}
```

```
Count is: 1
Count is: 2
Count is: 3
Count is: 4
Count is: 5
Count is: 6
Count is: 7
Count is: 8
Count is: 9
Count is: 10
```

Example



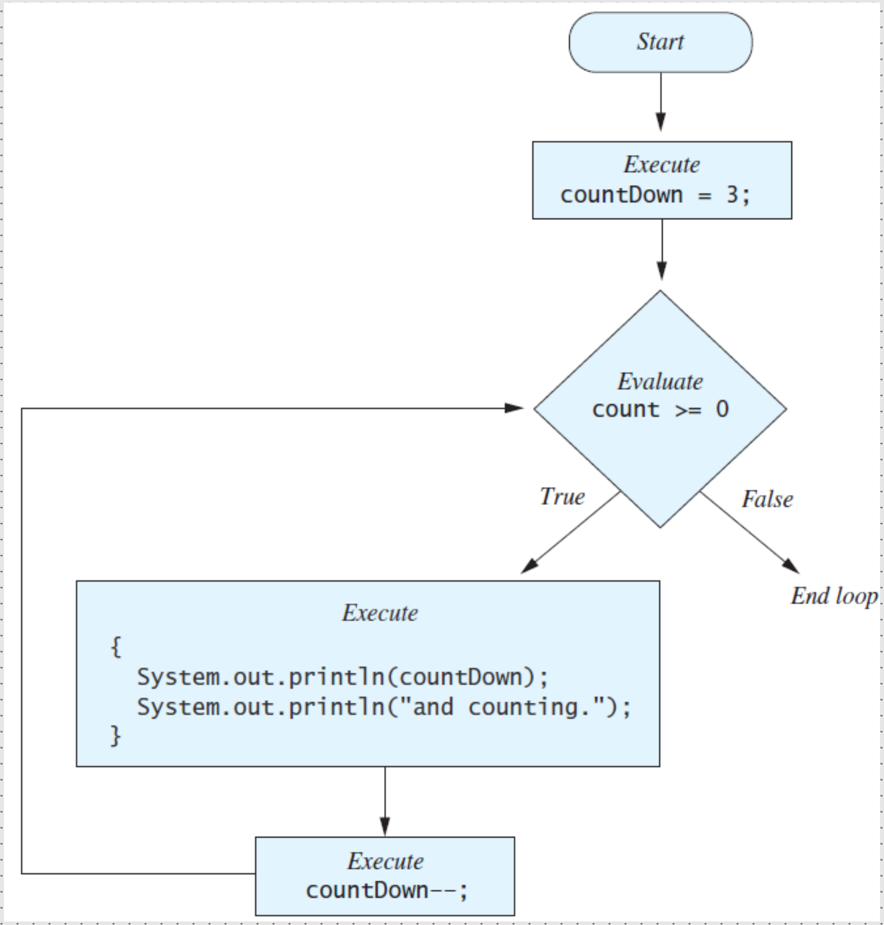
```java
public class ForDemo
{
    public static void main(String[] args)
    {
        int countDown;
        for (countDown = 3; countDown >= 0; countDown--)
        {
            System.out.println(countDown);
            System.out.println("and counting.");
        }
        System.out.println("Blast off!");
    }
}
```

Screen Output

```
3
and counting.
2
and counting.
1
and counting.
0
and counting.
Blast off!
```

Action of the `for` loop

```
for (countDown = 3; countDown >= 0; countDown--)
{
    System.out.println(countDown);
    System.out.println("and counting.");
}
```



The `for` statement

- Possible to declare variables within a `for` statement

```
int sum = 0;
for (int n = 1 ; n <= 10 ; n++)
    sum = sum + n * n;
```

- Note that variable `n` is local to the loop

The `for` statement

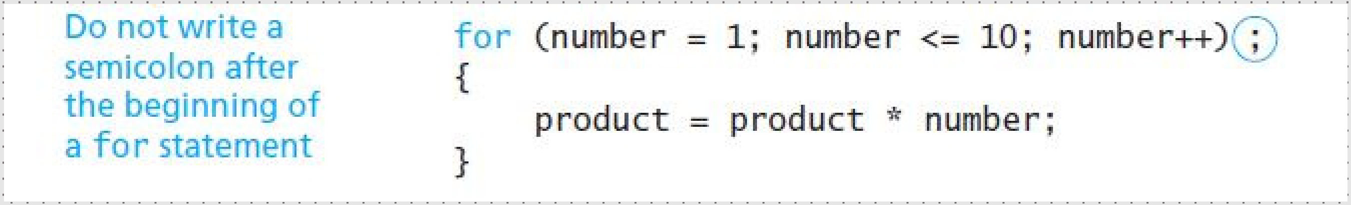
- A comma separates multiple initializations
- Example

```
for (n = 1, product = 1; n <= 10; n++)
    product = product * n;
```

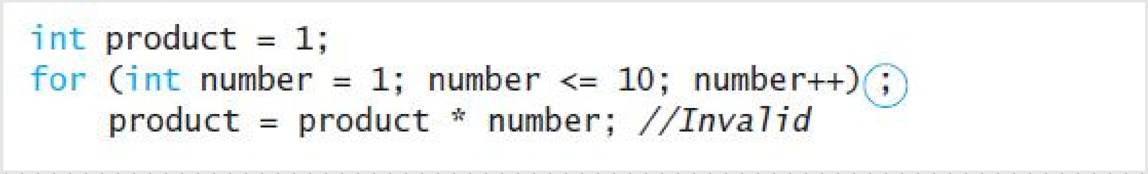
- Only one boolean expression is allowed, but it can consist of `&&`s, `||`s, and `!`s.
- Multiple update actions are allowed, too.

```
for (n = 1, product = 1; n <= 10;
        product = product * n, n++);
```

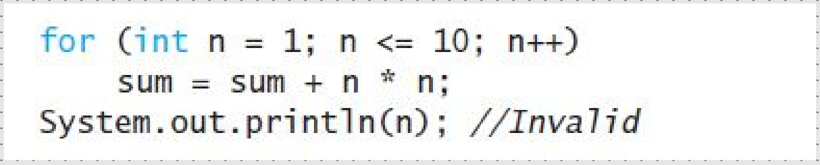
The `for` statement


Do not write a semicolon after the beginning of a for statement

```
for (number = 1; number <= 10; number++);
{
    product = product * number;
}
```

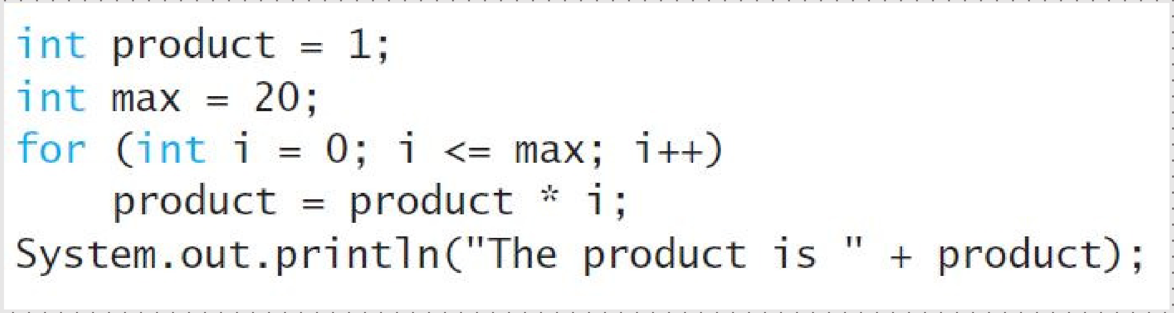


```
int product = 1;
for (int number = 1; number <= 10; number++);
    product = product * number; //Invalid
```

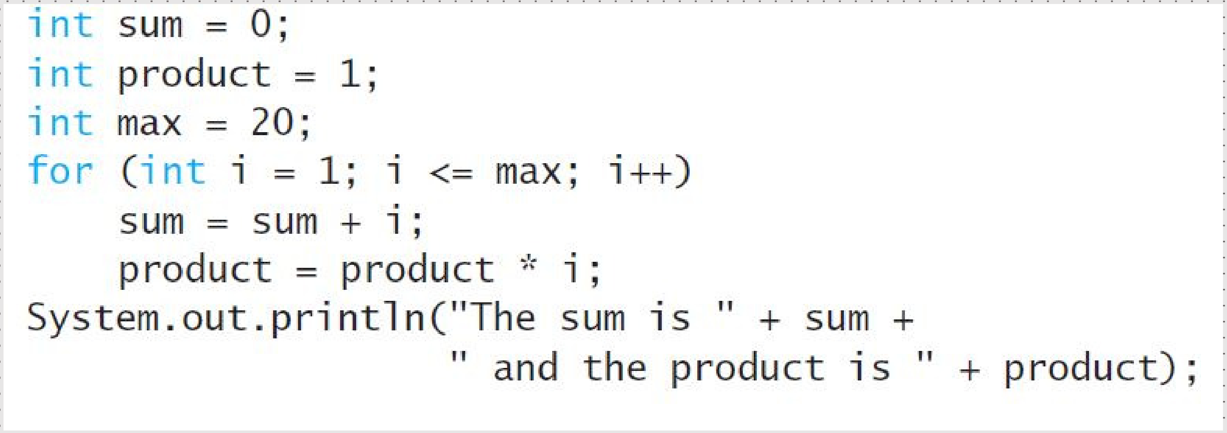


```
for (int n = 1; n <= 10; n++)
    sum = sum + n * n;
System.out.println(n); //Invalid
```

What does it display? How would you fix it?

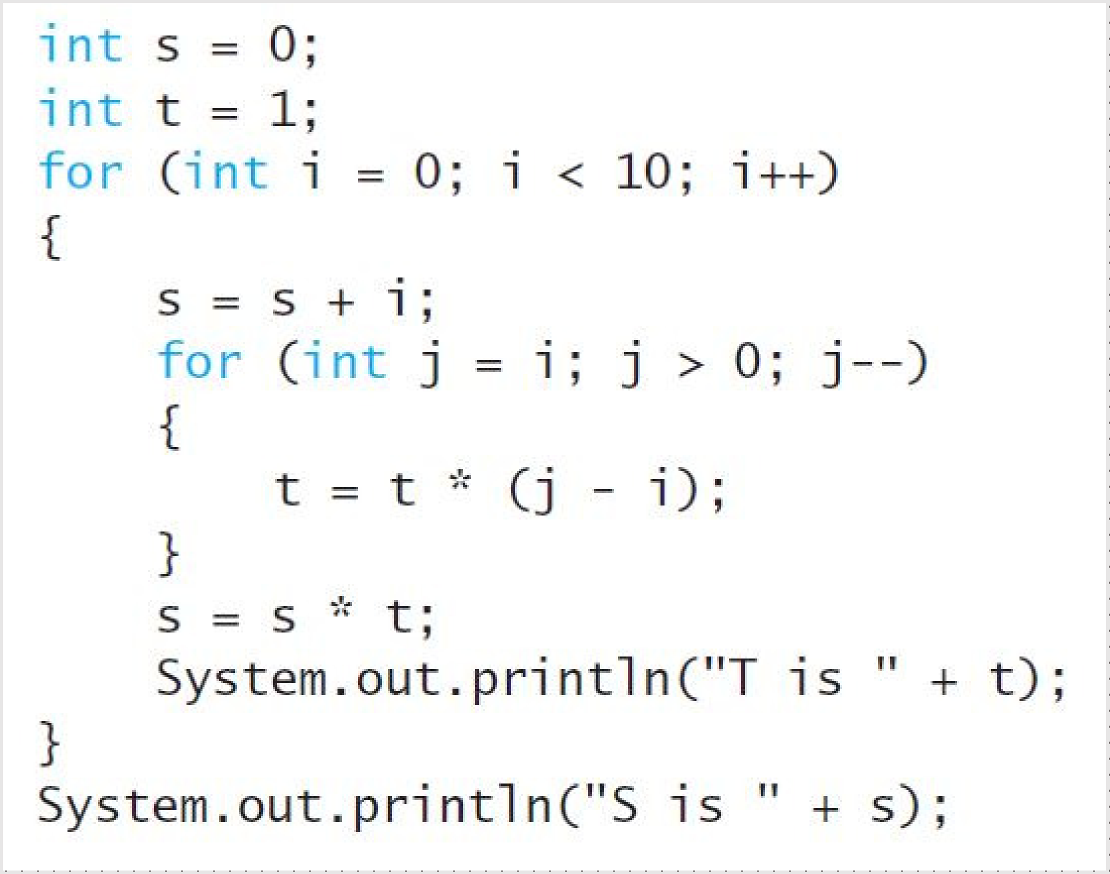


```java
int product = 1;
int max = 20;
for (int i = 0; i <= max; i++)
    product = product * i;
System.out.println("The product is " + product);
```



```java
int sum = 0;
int product = 1;
int max = 20;
for (int i = 1; i <= max; i++)
    sum = sum + i;
    product = product * i;
System.out.println("The sum is " + sum +
                   " and the product is " + product);
```

Convert it to while loop



```java
int s = 0;
int t = 1;
for (int i = 0; i < 10; i++)
{
    s = s + i;
    for (int j = i; j > 0; j--)
    {
        t = t * (j - i);
    }
    s = s * t;
    System.out.println("T is " + t);
}
System.out.println("S is " + s);
```

The loop body

- To design the loop body, write out the actions the code must accomplish.
- Then look for a repeated pattern.
  - The pattern need not start with the first action.
  - The repeated pattern will form the body of the loop.
  - Some actions may need to be done after the pattern stops repeating.

Initializing statements

- Some variables need to have a value before the loop begins.
  - Sometimes this is determined by what is supposed to happen after one loop iteration.
  - Often variables have an initial value of zero or one, but not always.
- Other variables get values only while the loop is iterating.

Controlling number of loop iterations

- If the number of iterations is known before the loop starts, the loop is called a *count-controlled loop.*
  - Use a `for` loop.
- Asking the user before each iteration if it is time to end the loop is called the *ask-before-iterating technique.*
  - Appropriate for a small number of iterations
  - Use a `while` loop or a `do-while` loop.

Controlling number of loop iterations

- For large input lists, a *sentinel value* can be used to signal the end of the list.
  - The sentinel value must be different from all the other possible inputs.
  - A negative number following a long list of nonnegative exam scores could be suitable.

```
90
0
10
-1
```

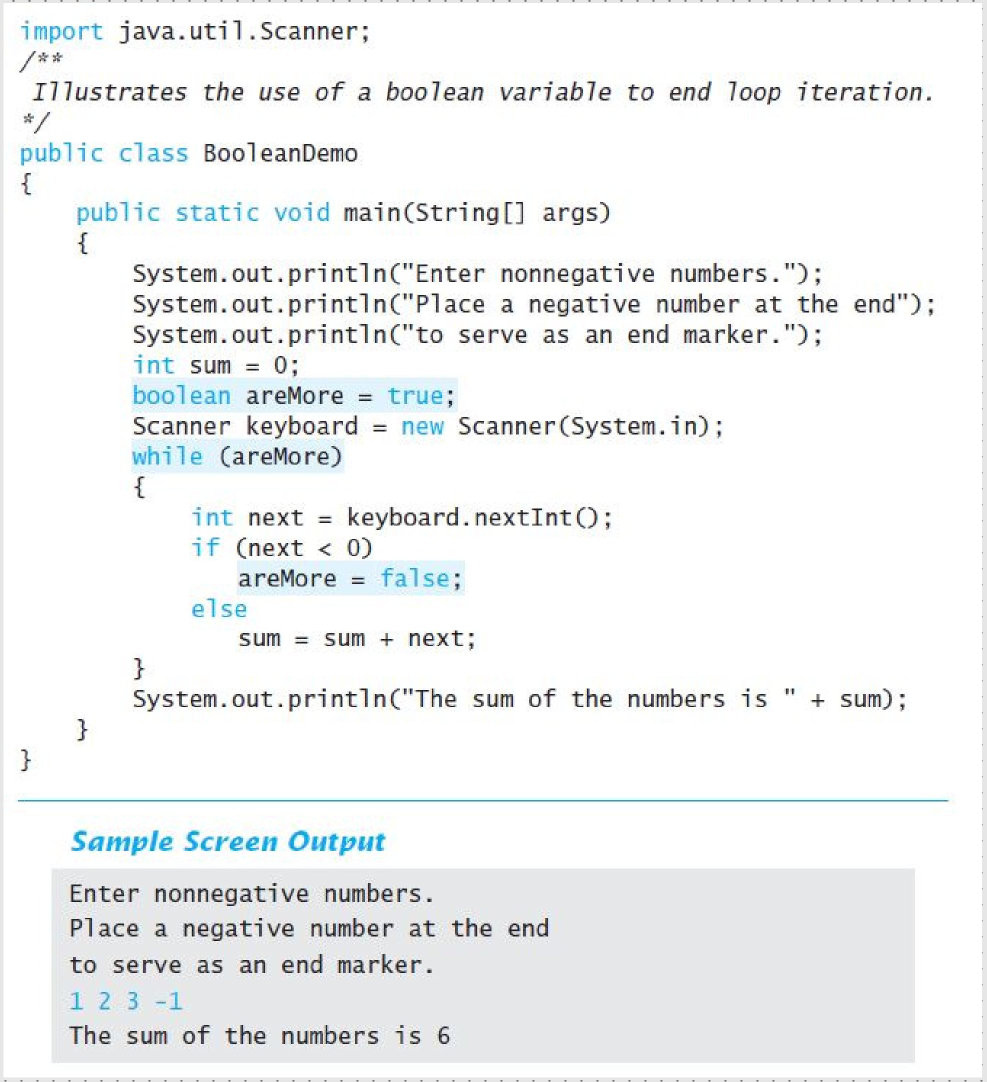
Controlling number of loop iterations

- Example - reading a list of scores followed by a sentinel value

```
int next = keyboard.nextInt();
while (next  >= 0)
{
  Process_The_Score
  next = keyboard.nextInt();
}
```

Controlling number of loop iterations

- Using a boolean variable to end the loop



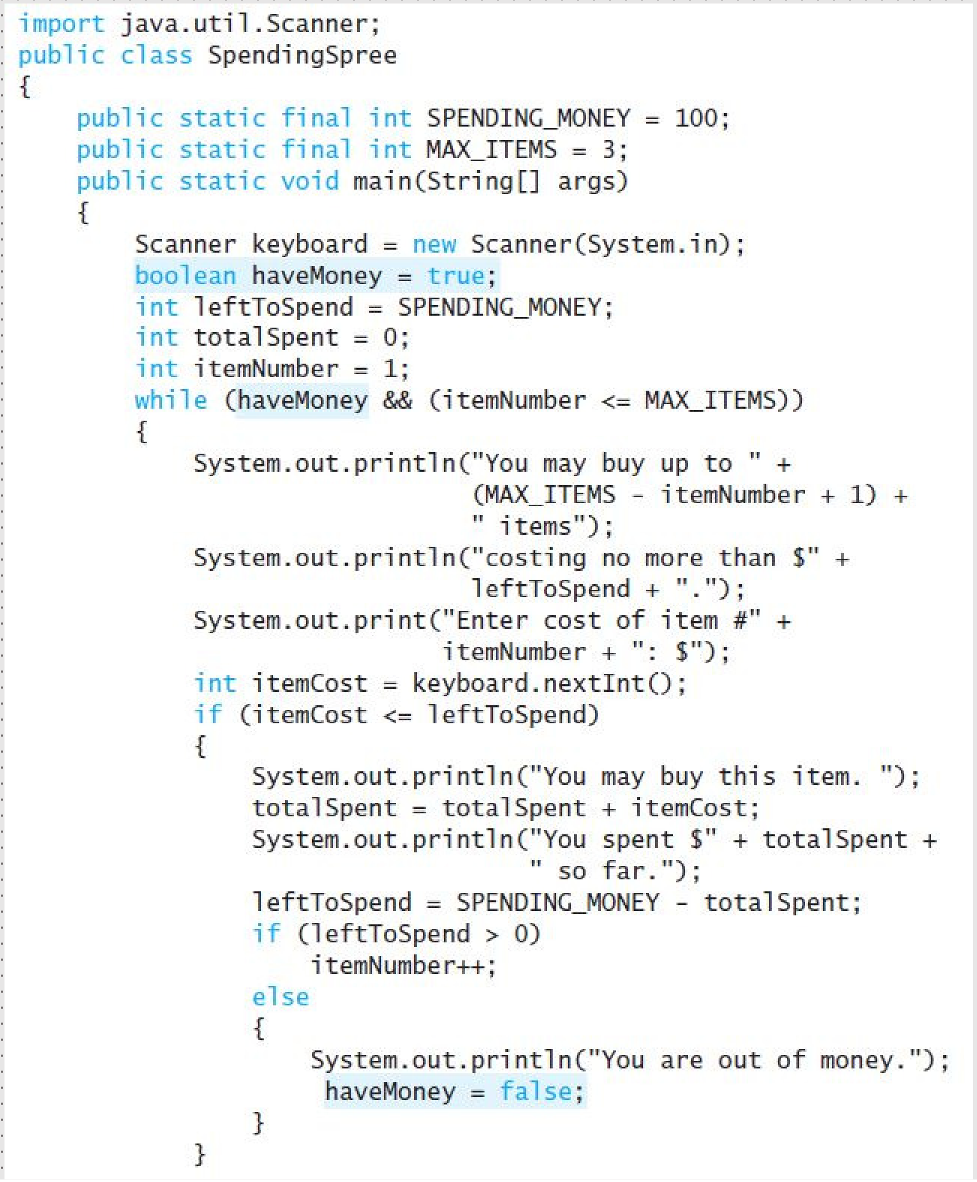
```java
import java.util.Scanner;
/**
 Illustrates the use of a boolean variable to end loop iteration.
*/
public class BooleanDemo
{
    public static void main(String[] args)
    {
        System.out.println("Enter nonnegative numbers.");
        System.out.println("Place a negative number at the end");
        System.out.println("to serve as an end marker.");
        int sum = 0;
        boolean areMore = true;
        Scanner keyboard = new Scanner(System.in);
        while (areMore)
        {
            int next = keyboard.nextInt();
            if (next < 0)
               areMore = false;
            else
               sum = sum + next;
        }
        System.out.println("The sum of the numbers is " + sum);
    }
}
```

Sample Screen Output

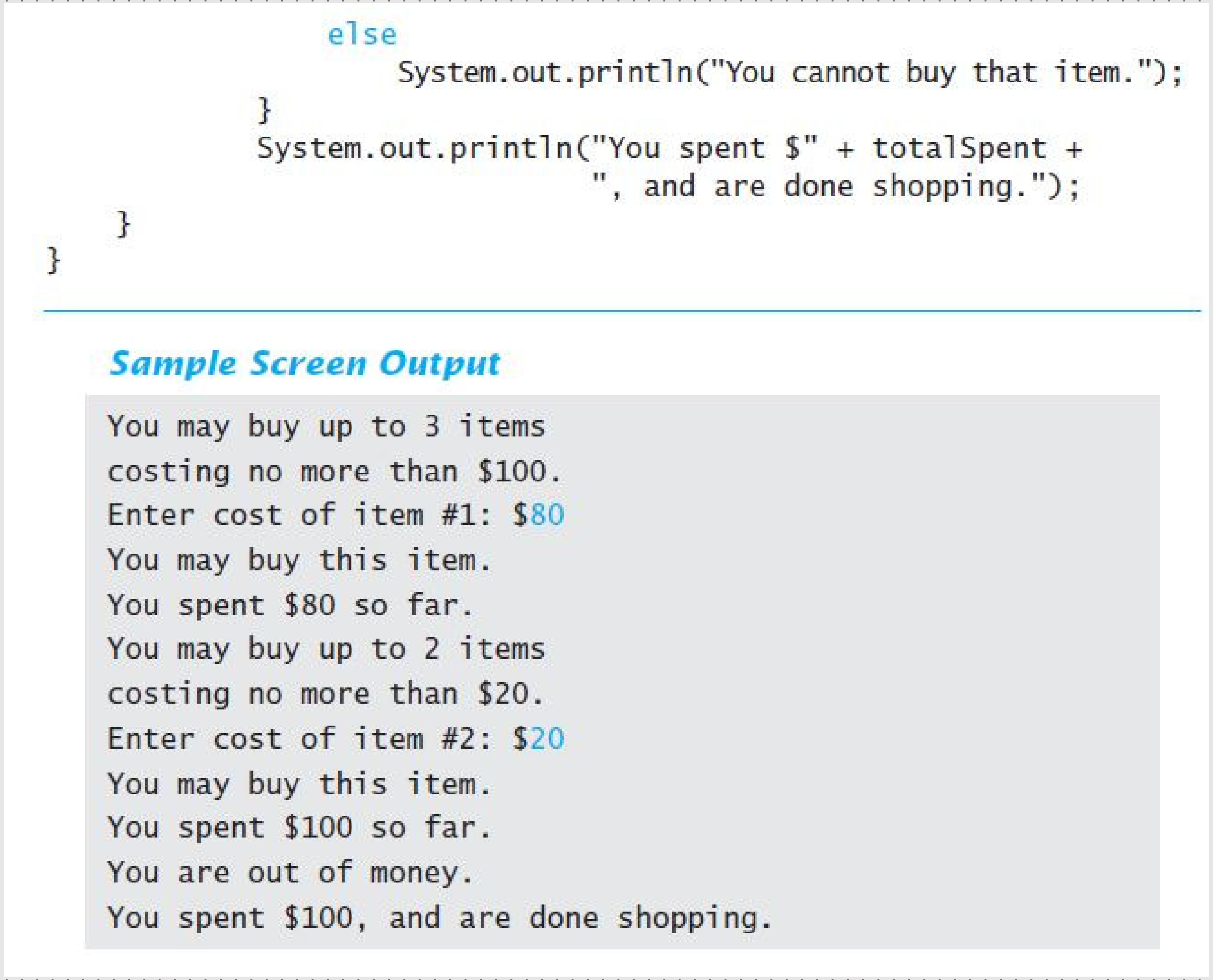
```
Enter nonnegative numbers.
Place a negative number at the end
to serve as an end marker.
1 2 3 -1
The sum of the numbers is 6
```

Programming example

- Spending Spree
  - You have $100 to spend in a store
  - Maximum 3 items
  - Computer tracks spending and item count
  - When item chosen, computer tells you whether or not you can buy it
- Client wants adaptable program
  - Able to change amount and maximum number of items



```java
import java.util.Scanner;
public class SpendingSpree
{
    public static final int SPENDING_MONEY = 100;
    public static final int MAX_ITEMS = 3;
    public static void main(String[] args)
    {
        Scanner keyboard = new Scanner(System.in);
        boolean haveMoney = true;
        int leftToSpend = SPENDING_MONEY;
        int totalSpent = 0;
        int itemNumber = 1;
        while (haveMoney && (itemNumber <= MAX_ITEMS))
        {
            System.out.println("You may buy up to " +
                               (MAX_ITEMS - itemNumber + 1) +
                               " items");
            System.out.println("costing no more than $" +
                               leftToSpend + ".");
            System.out.print("Enter cost of item #" +
                             itemNumber + ": $");
            int itemCost = keyboard.nextInt();
            if (itemCost <= leftToSpend)
            {
                System.out.println("You may buy this item. ");
                totalSpent = totalSpent + itemCost;
                System.out.println("You spent $" + totalSpent +
                                   " so far.");
                leftToSpend = SPENDING_MONEY - totalSpent;
                if (leftToSpend > 0)
                    itemNumber++;
                else
                {
                    System.out.println("You are out of money.");
                     haveMoney = false;
                }
            }
```



```
                else
                    System.out.println("You cannot buy that item.");
            }
            System.out.println("You spent $" + totalSpent +
                               ", and are done shopping.");
    }
}
```

Sample Screen Output

```
You may buy up to 3 items
costing no more than $100.
Enter cost of item #1: $80
You may buy this item.
You spent $80 so far.
You may buy up to 2 items
costing no more than $20.
Enter cost of item #2: $20
You may buy this item.
You spent $100 so far.
You are out of money.
You spent $100, and are done shopping.
```

Tracing variables

- *Tracing variables* means watching the variables change while the program is running.
  - Simply insert temporary output statements in your program to print of the values of variables of interest
  - Or, learn to use the debugging facility that may be provided by your system.

Loop bugs

- Common loop bugs
  - Unintended infinite loops
  - Off-by-one errors
  - Testing equality of floating-point numbers
- Subtle infinite loops
  - The loop may terminate for some input values, but not for others.
  - For example, you can’t get out of debt when the monthly penalty exceeds the monthly payment.