

ABSOLUTE JAVA™

SIXTH EDITION



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Chapter 3

Flow of Control

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PEARSON

Flow of Control

- As in most programming languages, *flow of control* in Java refers to its *branching* and *looping* mechanisms
- Java has several branching mechanisms: **if-else**, **if**, and **switch** statements
- Java has three types of loop statements: the **while**, **do-while**, and **for** statements
- Most branching and looping statements are controlled by Boolean expressions
 - A Boolean expression evaluates to either **true** or **false**
 - The primitive type **boolean** may only take the values **true** or **false**

if statement

```
if (isMoving){  
    // the "then" clause: decrease current speed  
    currentSpeed--;  
}
```

if-then-else

```
if (isMoving) {  
    currentSpeed--;  
} else {  
    System.err.println("The bicycle has already  
stopped!");  
}
```

nested if's

```
int testscore = 76;
char grade;
if (testscore >= 90) {
    grade = 'A';
} else if (testscore >= 80) {
    grade = 'B';
} else if (testscore >= 70) {
    grade = 'C';
}
else if (testscore >= 60) {
    grade = 'D';
} else {
    grade = 'F';
}
System.out.println("Grade = " + grade);
```

switch

```
int month = 8;
String monthString;
switch (month) {
    case 1: monthString = "January";
            break;
    case 2: monthString = "February";
            break;
    case 3: monthString = "March";
            break;
    // and so on
    case 12: monthString = "December";
            break;
    default: monthString = "Invalid month";
            break;
} // switch
System.out.println(monthString);
```

how to write the switch statement

- Always use “break”
- Do not use fall-through
 - don’t attempt to know what it is!
- Always have a default case.

while loop

```
while (expression) {  
    statement(s)  
}
```



```
int count = 1;
while (count < 11) {
    System.out.println("Count is: " + count);
    count++;
}
```

do-while

```
do {  
    statement(s)  
} while (expression);
```

```
int count = 1;
do {
    System.out.println("Count is: " + count);
    count++;
} while (count < 11);
```

for statement

```
for (initialization; termination; increment) {  
    statement(s)  
}
```

```
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

The break Statement

- An unlabeled break statement terminates the innermost switch, for, while, or do-while statement,
- but a labeled break terminates an outer statement.

unlabeled break

```
int i;  
boolean foundIt = false;  
for (i = 0; i < arrayOfInts.length; i++) {  
    if (arrayOfInts[i] == searchfor) {  
        foundIt = true;  
        break; // break the inner for- loop  
    }  
} // for
```

labeled break

search:

```
for (i = 0; i < arrayOfInts.length; i++) {  
    for (j = 0; j < arrayOfInts[i].length; j++) {  
        if (arrayOfInts[i][j] == searchfor) {  
            foundIt = true;  
            break search;  
        }  
    } // inner for-loop  
} // outer for-loop
```

the outer loop is labeled “search”

‘break search’ breaks the outer loop

The continue Statement

- The continue statement skips the current iteration of a for, while , or do-while loop.

unlabeled continue

```
String searchMe = "peter piper picked a " + "peck of pickled peppers";
int max = searchMe.length();
int numPs = 0;
for (int i = 0; i < max; i++) {
    // interested only in p's
    if (searchMe.charAt(i) != 'p')
        continue;
    // process p's
    numPs++;
} //for
System.out.println("Found " + numPs + " p's in the string.");
```

```
//Count the number of 'p' in a string
```

labeled continue

- A labeled continue statement skips the current iteration of an outer loop marked with the given label.

use of break and continue

- Whenever a normal flow of a loop is “interrupted” be a break or continue,
- the chance of undetected bug occurring is high
- Phone system of New York city went down for a day due to a wrong “continue”

Branching with an **if-else** Statement

- An **if-else** statement chooses between two alternative statements based on the value of a Boolean expression

```
if (Boolean_Expression)  
    Yes_Statement  
else  
    No_Statement
```

- The **Boolean_Expression** must be enclosed in parentheses
- If the **Boolean_Expression** is **true**, then the **Yes_Statement** is executed
- If the **Boolean_Expression** is false, then the **No_Statement** is executed

Compound Statements

- Each **Yes_Statement** and **No_Statement** branch of an **if-else** can be made up of a single statement or many statements
- *Compound Statement*: A branch statement that is made up of a list of statements
 - A compound statement must always be enclosed in a pair of braces (**{ }**)
 - A compound statement can be used anywhere that a single statement can be used

Compound Statements

```
if (myScore > your Score)
{
    System.out.println("I win!");
    wager = wager + 100;
}
else
{
    System.out.println
        ("I wish these were golf scores.");
    wager = 0;
}
```

Omitting the `else` Part

- The `else` part may be omitted to obtain what is often called an `if` statement

```
if (Boolean_Expression)
    Action_Statement
```

- If the `Boolean_Expression` is true, then the `Action_Statement` is executed
- The `Action_Statement` can be a single or compound statement
- Otherwise, nothing happens, and the program goes on to the next statement

```
if (weight > ideal)
    calorieIntake = calorieIntake - 500;
```


Nested Statements

- **if-else** statements and **if** statements both contain smaller statements within them
 - For example, single or compound statements
- In fact, any statement at all can be used as a subpart of an **if-else** or **if** statement, including another **if-else** or **if** statement
 - Each level of a nested **if-else** or **if** should be indented further than the previous level
 - Exception: *multiway* **if-else** statements

Multiway **if-else** Statements

- The multiway **if-else** statement is simply a normal **if-else** statement that nests another **if-else** statement at every **else** branch
 - It is indented differently from other nested statements
 - All of the **Boolean_Expressions** are aligned with one another, and their corresponding actions are also aligned with one another
 - The **Boolean_Expressions** are evaluated in order until one that evaluates to **true** is found
 - The final **else** is optional

Multiway **if-else** Statement

```
if (Boolean_Expression)
    Statement_1
else if (Boolean_Expression)
    Statement_2
    ⋮
else if (Boolean_Expression_n)
    Statement_n
else
    Statement_For_All_Other_Possibilities
```

The `switch` Statement

- The `switch` statement is the only other kind of Java statement that implements *multiway* branching
 - When a `switch` statement is evaluated, one of a number of different branches is executed
 - The choice of which branch to execute is determined by a *controlling expression* enclosed in parentheses after the keyword `switch`
 - The controlling expression must evaluate to a `char`, `int`, `short`, or `byte`

The `switch` Statement

- Each branch statement in a `switch` statement starts with the reserved word `case`, followed by a *constant* called a *case label*, followed by a colon, and then a sequence of statements
 - Each case label must be of the same type as the controlling expression
 - Case labels need not be listed in order or span a complete interval, but each one may appear only once
 - Each sequence of statements may be followed by a `break` statement (`break;`)

The `switch` Statement

- There can also be a section labeled `default`:
 - The `default` section is optional, and is usually last
 - Even if the case labels cover all possible outcomes in a given `switch` statement, it is still a good practice to include a `default` section
 - It can be used to output an error message, for example
- When the controlling expression is evaluated, the code for the case label whose value matches the controlling expression is executed
 - If no case label matches, then the only statements executed are those following the `default` label (if there is one)

The `switch` Statement

- The `switch` statement ends when it executes a `break` statement, or when the end of the `switch` statement is reached
 - When the computer executes the statements after a case label, it continues until a `break` statement is reached
 - If the `break` statement is omitted, then after executing the code for one case, the computer will go on to execute the code for the next case
 - If the `break` statement is omitted inadvertently, the compiler will not issue an error message

The **switch** Statement

```
switch (Controlling_Expression)
{
    case Case_Label_1:
        Statement_Sequence_1
        break;
    case Case_Label_2:
        Statement_Sequence_2
        break;
        :
    case Case_Label_n:
        Statement_Sequence_n
        break;
    default:
        Default_Statement_Sequence
        break;
}
```


The Conditional Operator

- The *conditional operator* is a notational variant on certain forms of the **if-else** statement
 - Also called the *ternary operator* or *arithmetic if*
 - The following examples are equivalent:

```
if (n1 > n2)    max = n1;  
else           max = n2;
```

vs.

```
max = (n1 > n2) ? n1 : n2;
```

- The expression to the right of the assignment operator is a *conditional operator expression*
- If the Boolean expression is true, then the expression evaluates to the value of the first expression (**n1**), otherwise it evaluates to the value of the second expression (**n2**)

Boolean Expressions

- A Boolean expression is an expression that is either **true** or **false**
- The simplest Boolean expressions compare the value of two expressions

`time < limit`

`yourScore == myScore`

- Note that Java uses two equal signs (`==`) to perform equality testing: A single equal sign (`=`) is used only for assignment
- A Boolean expression does not need to be enclosed in parentheses, unless it is used in an **if-else** statement

Java Comparison Operators

Display 3.3 Java Comparison Operators

| MATH NOTATION | NAME | JAVA NOTATION | JAVA EXAMPLES |
|---------------|--------------------------|---------------|---|
| = | Equal to | == | <code>x + 7 == 2*y</code> <code>answer == 'y'</code> |
| ≠ | Not equal to | != | <code>score != 0</code> <code>answer != 'y'</code> |
| > | Greater than | > | <code>time > limit</code> |
| ≥ | Greater than or equal to | >= | <code>age >= 21</code> |
| < | Less than | < | <code>pressure < max</code> |
| ≤ | Less than or equal to | <= | <code>time <=limit</code> |

Pitfall: Using `==` with Strings

- The equality comparison operator (`==`) can correctly test two values of a *primitive* type
- However, when applied to two *objects* such as objects of the **String** class, `==` tests to see if they are stored in the same memory location, not whether or not they have the same value
- In order to test two strings to see if they have equal values, use the method **equals**, or **equalsIgnoreCase**
`string1.equals(string2)`
`string1.equalsIgnoreCase(string2)`

Lexicographic and Alphabetical Order

- *Lexicographic* ordering is the same as *ASCII* ordering, and includes letters, numbers, and other characters
 - All uppercase letters are in alphabetic order, and all lowercase letters are in alphabetic order, but all uppercase letters come before lowercase letters
 - If **s1** and **s2** are two variables of type **String** that have been given **String** values, then **s1.compareTo(s2)** returns a negative number if **s1** comes before **s2** in lexicographic ordering, returns zero if the two strings are equal, and returns a positive number if **s2** comes before **s1**
- When performing an alphabetic comparison of strings (rather than a lexicographic comparison) that consist of a mix of lowercase and uppercase letters, use the **compareToIgnoreCase** method instead

Building Boolean Expressions

- When two Boolean expressions are combined using the "and" (`&&`) operator, the entire expression is true provided both expressions are true
 - Otherwise the expression is false
- When two Boolean expressions are combined using the "or" (`||`) operator, the entire expression is true as long as one of the expressions is true
 - The expression is false only if both expressions are false
- Any Boolean expression can be negated using the `!` operator
 - Place the expression in parentheses and place the `!` operator in front of it
- Unlike mathematical notation, strings of inequalities must be joined by `&&`
 - Use `(min < result) && (result < max)` rather than `min < result < max`

Evaluating Boolean Expressions

- Even though Boolean expressions are used to control branch and loop statements, Boolean expressions can exist independently as well
 - A Boolean variable can be given the value of a Boolean expression by using an assignment statement
- A Boolean expression can be evaluated in the same way that an arithmetic expression is evaluated
 - The only difference is that arithmetic expressions produce a number as a result, while Boolean expressions produce either **true** or **false** as their result

```
boolean madeIt = (time < limit) && (limit < max);
```

Truth Tables

Display 3.5 Truth Tables

| AND | | |
|--------------|--------------|------------------------------|
| <i>Exp_1</i> | <i>Exp_2</i> | <i>Exp_1</i> && <i>Exp_2</i> |
| true | true | true |
| true | false | false |
| false | true | false |
| false | false | false |

| OR | | |
|--------------|--------------|------------------------------|
| <i>Exp_1</i> | <i>Exp_2</i> | <i>Exp_1</i> <i>Exp_2</i> |
| true | true | true |
| true | false | true |
| false | true | true |
| false | false | false |

| NOT | |
|------------|-----------------|
| <i>Exp</i> | !(<i>Exp</i>) |
| true | false |
| false | true |

Short-Circuit and Complete Evaluation

- Java can take a shortcut when the evaluation of the first part of a Boolean expression produces a result that evaluation of the second part cannot change
- This is called *short-circuit evaluation* or *lazy evaluation*
 - For example, when evaluating two Boolean subexpressions joined by **&&**, if the first subexpression evaluates to **false**, then the entire expression will evaluate to **false**, no matter the value of the second subexpression
 - In like manner, when evaluating two Boolean subexpressions joined by **||**, if the first subexpression evaluates to **true**, then the entire expression will evaluate to **true**

Short-Circuit and Complete Evaluation

- There are times when using short-circuit evaluation can prevent a *runtime error*
 - In the following example, if the number of **kids** is equal to zero, then the second subexpression will not be evaluated, thus preventing a *divide by zero error*
 - Note that reversing the order of the subexpressions will not prevent this

```
if ((kids !=0) && ((toys/kids) >=2)) . . .
```

- Sometimes it is preferable to always evaluate both expressions, i.e., request complete evaluation
 - In this case, use the **&** and **|** operators instead of **&&** and **||**

Precedence and Associativity Rules

- Boolean and arithmetic expressions need not be fully parenthesized
- If some or all of the parentheses are omitted, Java will follow *precedence* and *associativity* rules (summarized in the following table) to determine the order of operations
 - If one operator occurs higher in the table than another, it has *higher precedence*, and is grouped with its operands before the operator of lower precedence
 - If two operators have the same precedence, then *associativity rules* determine which is grouped first

Precedence and Associativity Rules

*Highest
Precedence*



*Lowest
Precedence*

| PRECEDENCE | ASSOCIATIVITY |
|---|---------------|
| From highest at top to lowest at bottom. Operators in the same group have equal precedence. | |
| Dot operator, array indexing, and method invocation., [], () | Left to right |
| ++ (postfix, as in x++), -- (postfix) | Right to left |
| The unary operators: +, -, ++ (prefix, as in ++x), -- (prefix), and ! | Right to left |
| Type casts (Type) | Right to left |
| The binary operators *, /, % | Left to right |
| The binary operators +, - | Left to right |
| The binary operators <, >, <=, >= | Left to right |
| The binary operators ==, != | Left to right |
| The binary operator & | Left to right |
| The binary operator | Left to right |
| The binary operator && | Left to right |
| The binary operator | Left to right |
| The ternary operator (conditional operator) ?: | Right to left |
| The assignment operators =, *=, /=, %=, +=, -=, &=, = | Right to left |

Evaluating Expressions

- In general, parentheses in an expression help to document the programmer's intent
 - Instead of relying on precedence and associativity rules, it is best to include most parentheses, except where the intended meaning is obvious
- *Binding*: The association of operands with their operators
 - A fully parenthesized expression accomplishes binding for all the operators in an expression
- *Side Effects*: When, in addition to returning a value, an expression changes something, such as the value of a variable
 - The *assignment*, *increment*, and *decrement* operators all produce side effects

Rules for Evaluating Expressions

- Perform binding
 - Determine the equivalent fully parenthesized expression using the precedence and associativity rules
- Proceeding left to right, evaluate whatever subexpressions can be immediately evaluated
 - These subexpressions will be operands or method arguments, e.g., numeric constants or variables
- Evaluate each outer operation and method invocation as soon as all of its operands (i.e., arguments) have been evaluated

Loops

- *Loops* in Java are similar to those in other high-level languages
- Java has three types of loop statements: the **while**, the **do-while**, and the **for** statements
 - The code that is repeated in a loop is called the *body* of the loop
 - Each repetition of the loop body is called an *iteration* of the loop

while statement

- A **while** statement is used to repeat a portion of code (i.e., the loop body) based on the evaluation of a Boolean expression
 - The Boolean expression is checked *before* the loop body is executed
 - When false, the loop body is not executed at all
 - Before the execution of each following iteration of the loop body, the Boolean expression is checked again
 - If true, the loop body is executed again
 - If false, the loop statement ends
 - The loop body can consist of a single statement, or multiple statements enclosed in a pair of braces (**{ }**)

while Syntax

```
while (Boolean_Expression)  
Statement
```

Or

```
while (Boolean_Expression)  
{  
    Statement_1  
    Statement_2  
  
    Statement_Last  
}
```

do-while Statement

- A **do-while** statement is used to execute a portion of code (i.e., the loop body), and then repeat it based on the evaluation of a Boolean expression
 - The loop body is executed at least once
 - The Boolean expression is checked *after* the loop body is executed
 - The Boolean expression is checked after each iteration of the loop body
 - If true, the loop body is executed again
 - If false, the loop statement ends
 - Don't forget to put a semicolon after the Boolean expression
 - Like the while statement, the loop body can consist of a single statement, or multiple statements enclosed in a pair of braces ({ })

do-while Syntax

```
do  
    Statement  
while (Boolean_Expression);
```

Or

```
do  
{  
    Statement_1  
    Statement_2  
  
    Statement_Last  
} while (Boolean_Expression);
```

Equivalence of while and do-while loop

Given the following structure for a `do-while` loop:

```
do
{
    Statements;
} while (Boolean condition);
```

The equivalent while loop is:

```
Statements;
while (Boolean condition)
{
    Statements;
}
```

Equivalence of do-while and while loop

Given the following structure for a `while` loop:

```
while (Boolean condition)
{
    Statements;
}
```

The equivalent `do-while` loop is:

```
if (Boolean condition)
{
    do
    {
        Statements;
    } while (Boolean condition);
}
```

Algorithms and Pseudocode

- The hard part of solving a problem with a computer program is not dealing with the syntax rules of a programming language
- Rather, coming up with the underlying solution method is the most difficult part
- An *algorithm* is a set of precise instructions that lead to a solution
 - An algorithm is normally written in *pseudocode*, which is a mixture of programming language and a human language, like English
 - Pseudocode must be precise and clear enough so that a good programmer can convert it to syntactically correct code
 - However, pseudocode is much less rigid than code: One needn't worry about the fine points of syntax or declaring variables, for example

The `for` Statement

- The `for` statement is most commonly used to step through an integer variable in equal increments
- It begins with the keyword `for`, followed by three expressions in parentheses that describe what to do with one or more *controlling variables*
 - The first expression tells how the control variable or variables are *initialized or declared and initialized* before the first iteration
 - The second expression determines when the loop should *end*, based on the evaluation of a Boolean expression *before* each iteration
 - The third expression tells how the control variable or variables are *updated after* each iteration of the loop body

The **for** Statement Syntax

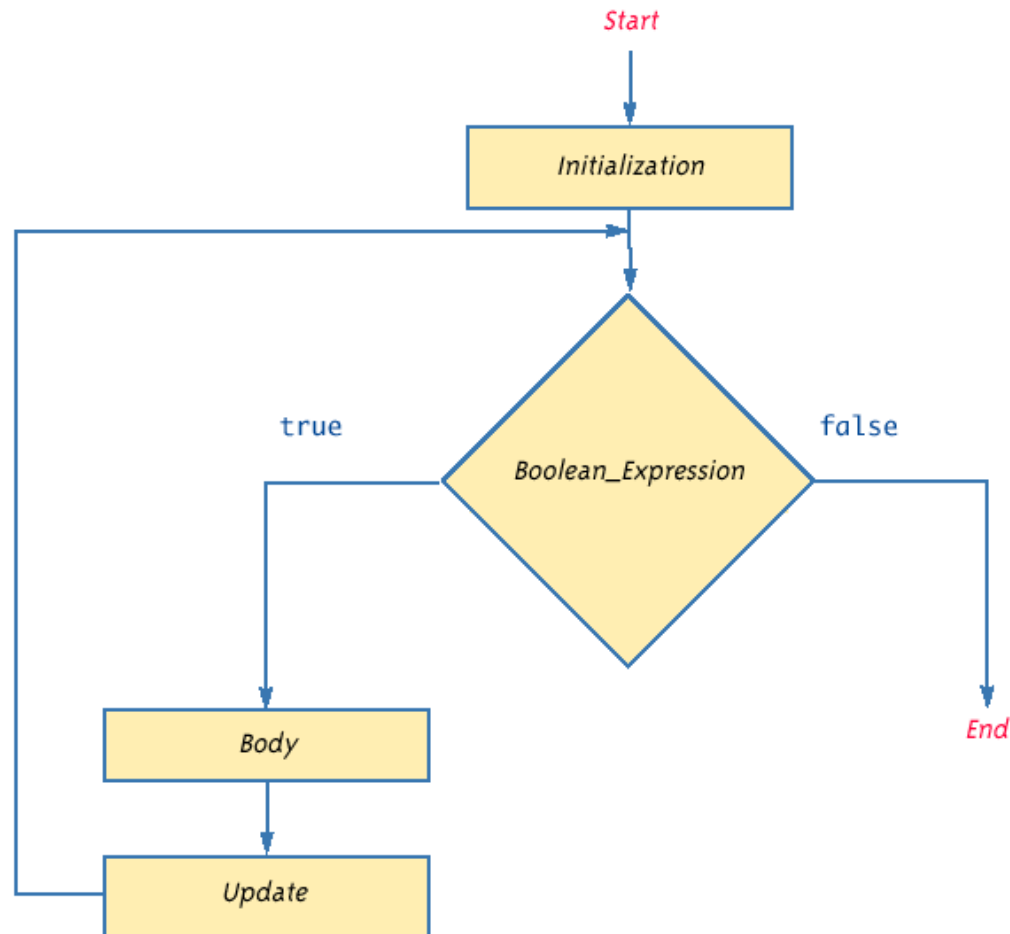
```
for (Initializing; Boolean_Expression; Update)  
  Body
```

- The **Body** may consist of a single statement or a list of statements enclosed in a pair of braces (**{ }**)
- Note that the three control expressions are separated by two, not three, semicolons
- Note that there is no semicolon after the closing parenthesis at the beginning of the loop

Semantics of the `for` Statement

Display 3.9 Semantics of the `for` Statement

```
for (Initialization; Boolean_Expression; Update)  
    Body
```



for Statement Syntax and Alternate Semantics

Display 3.10 for Statement Syntax and Alternate Semantics (Part 1 of 2)

for STATEMENT SYNTAX:

SYNTAX:

```
for (Initialization; Boolean_Expression; Update)  
    Body
```

EXAMPLE:

```
for (number = 100; number >= 0; number--)  
    System.out.println(number  
        + " bottles of beer on the shelf.");
```

for Statement Syntax and Alternate Semantics

Display 3.10 for Statement Syntax and Alternate Semantics (Part 2 of 2)

EQUIVALENT while LOOP:

EQUIVALENT SYNTAX:

```
Initialization;  
while (Boolean_Expression)  
{  
    Body  
    Update;  
}
```

EQUIVALENT EXAMPLE:

```
number = 100;  
while (number >= 0)  
{  
    System.out.println(number  
        + " bottles of beer on the shelf.");  
    number--;  
}
```

SAMPLE DIALOGUE

```
100 bottles of beer on the shelf.  
99 bottles of beer on the shelf.  
.  
.  
.  
0 bottles of beer on the shelf.
```

The Comma in **for** Statements

- A **for** loop can contain multiple initialization actions separated with commas
 - Caution must be used when combining a declaration with multiple actions
 - It is illegal to combine multiple type declarations with multiple actions, for example
 - To avoid possible problems, it is best to declare all variables outside the **for** statement
- A **for** loop can contain multiple update actions, separated with commas, also
 - It is even possible to eliminate the loop body in this way
- However, a **for** loop can contain only one Boolean expression to test for ending the loop

Infinite Loops

- A **while**, **do-while**, or **for** loop should be designed so that the value tested in the Boolean expression is changed in a way that eventually makes it false, and terminates the loop
- If the Boolean expression remains true, then the loop will run forever, resulting in an *infinite loop*
 - Loops that check for equality or inequality (**==** or **!=**) are especially prone to this error and should be avoided if possible

Nested Loops

- Loops can be *nested*, just like other Java structures
 - When nested, the inner loop iterates from beginning to end for each single iteration of the outer loop

```
int rowNum, columnNum;
for (rowNum = 1; rowNum <=3; rowNum++)
{
    for (columnNum = 1; columnNum <=2;
        columnNum++)
        System.out.print(" row " + rowNum +
            " column " + columnNum);
    System.out.println();
}
```

The **break** and **continue** Statements

- The **break** statement consists of the keyword **break** followed by a semicolon
 - When executed, the **break** statement ends the nearest enclosing switch or loop statement
- The **continue** statement consists of the keyword **continue** followed by a semicolon
 - When executed, the **continue** statement ends the current loop body iteration of the nearest enclosing loop statement
 - Note that in a **for** loop, the **continue** statement transfers control to the *update* expression
- When loop statements are nested, remember that any **break** or **continue** statement applies to the innermost, containing loop statement

The Labeled **break** Statement

- There is a type of **break** statement that, when used in nested loops, can end any containing loop, not just the innermost loop
- If an enclosing loop statement is labeled with an *Identifier*, then the following version of the break statement will exit the labeled loop, even if it is not the innermost enclosing loop:
break someIdentifier;
- To label a loop, simply precede it with an *Identifier* and a colon:
someIdentifier:

The `exit` Statement

- A `break` statement will end a loop or switch statement, but will not end the program
- The `exit` statement will immediately end the program as soon as it is invoked:
`System.exit(0);`
- The `exit` statement takes one integer argument
 - By tradition, a zero argument is used to indicate a normal ending of the program

Loop Bugs

- The two most common kinds of loop errors are unintended *infinite loops* and *off-by-one errors*
 - An off-by-one error is when a loop repeats the loop body one too many or one too few times
 - This usually results from a carelessly designed Boolean test expression
 - Use of `==` in the controlling Boolean expression can lead to an infinite loop or an off-by-one error
 - This sort of testing works only for characters and integers, and should never be used for floating-point

Tracing Variables

- *Tracing variables* involves watching one or more variables change value while a program is running
- This can make it easier to discover errors in a program and debug them
- Many *IDEs (Integrated Development Environments)* have a built-in utility that allows variables to be traced without making any changes to the program
- Another way to trace variables is to simply insert temporary output statements in a program

```
System.out.println("n = " + n); // Tracing n
```

- When the error is found and corrected, the trace statements can simply be commented out

General Debugging Techniques

- Examine the system as a whole – don't assume the bug occurs in one particular place
- Try different test cases and check the input values
- Comment out blocks of code to narrow down the offending code
- Check common pitfalls
- Take a break and come back later
- DO NOT make random changes just hoping that the change will fix the problem!

Debugging Example (1 of 9)

- The following code is supposed to present a menu and get user input until either 'a' or 'b' is entered.

```
String s = "";
char c = ' ';
Scanner keyboard = new Scanner(System.in);

do
{
    System.out.println("Enter 'A' for option A or 'B' for option B.");
    s = keyboard.next();
    s.toLowerCase();
    c = s.substring(0,1);
}
while ((c != 'a') || (c != 'b'));
```

Debugging Example (2 of 9)

Result: Syntax error:

```
c = s.substring(0,1);      : incompatible types  
found:   java.lang.String  
required: char
```

- Using the “random change” debugging technique we might try to change the data type of `c` to `String`, to make the types match
- This results in more errors since the rest of the code treats `c` like a `char`

Debugging Example (3 of 9)

- First problem: substring returns a String, use charAt to get the first character:

```
String s = "";
char c = ' ';
Scanner keyboard = new Scanner(System.in);

do
{
    System.out.println("Enter 'A' for option A or 'B' for option B.");
    s = keyboard.next();
    s.toLowerCase();
    c = s.charAt(0);
}
while ((c != 'a') || (c != 'b'));
```

Now the program compiles, but it is stuck in an infinite loop. Employ tracing:

Debugging Example (4 of 9)

```
do
{
    System.out.println("Enter 'A' for option A or 'B' for option B.");
    s = keyboard.next();
    System.out.println("String s = " + s);
    s.toLowerCase();
    System.out.println("Lowercase s = " + s);
    c = s.charAt(0);
    System.out.println("c = " + c);
}
while ((c != 'a') || (c != 'b'));
```

Sample output:

```
Enter 'A' for option A or 'B' for option B.
A
String s = A
Lowercase s = A
c = A
Enter 'A' for option A or 'B' for option B.
```

From tracing we can see that the string is never changed to lowercase. Reassign the lowercase string back to `s`.

Debugging Example (5 of 9)

- The following code is supposed to present a menu and get user input until either 'a' or 'b' is entered.

```
do
{
    System.out.println("Enter 'A' for option A or 'B' for option B.");
    s = keyboard.next();
    s = s.toLowerCase();
    c = s.charAt(0);
}
while ((c != 'a') || (c != 'b'));
```

However, it's still stuck in an infinite loop. What to try next?

Debugging Example (6 of 9)

- Could try the following “patch”

```
do
{
    System.out.println("Enter 'A' for option A or 'B' for option B.");
    s = keyboard.next();
    s = s.toLowerCase();
    c = s.charAt(0);
    if ( c == 'a')
        break;
    if (c == 'b')
        break;
}
while ((c != 'a') || (c != 'b'));
```

This works, but it is ugly! Considered a coding atrocity, it doesn't fix the underlying problem. The boolean condition after the while loop has also become meaningless. Try more tracing:

Debugging Example (7 of 9)

```
do
{
    System.out.println("Enter 'A' for option A or 'B' for option B.");
    s = keyboard.next();
    s = s.toLowerCase();
    c = s.charAt(0);
    System.out.println("c != 'a' is " + (c != 'a'));
    System.out.println("c != 'b' is " + (c != 'b'));
    System.out.println("(c != 'a' || (c != 'b')) is "
        + ((c != 'a' || (c != 'b'))));
}
while ((c != 'a') || (c != 'b'));
```

Sample output:

```
Enter 'A' for option A or 'B' for option B.
A
c != 'a' is false
c != 'b' is true
(c != 'a' || (c != 'b')) is true
```

From the trace we can see that the loop's boolean expression is true because `c` cannot be not equal to `'a'` and not equal to `'b'` at the same time.

Debugging Example (8 of 9)

- Fix: We use `&&` instead of `||`

```
do
{
    System.out.println("Enter 'A' for option A or 'B' for option B.");
    s = keyboard.next();
    s = s.toLowerCase();
    c = s.charAt(0);
}
while ((c != 'a') && (c != 'b'));
```

Debugging Example (9 of 9)

- Even better: Declare a boolean variable to control the do-while loop. This makes it clear when the loop exits if we pick a meaningful variable name.

```
boolean invalidKey;
do
{
    System.out.println("Enter 'A' for option A or 'B' for option B.");
    s = keyboard.next();
    s = s.toLowerCase();
    c = s.charAt(0);
    if (c == 'a')
        invalidKey = false;
    else if (c == 'b')
        invalidKey = false;
    else
        invalidKey = true;
}
while (invalidKey);
```

Assertion Checks

- An *assertion* is a sentence that says (asserts) something about the state of a program
 - An assertion must be either true or false, and should be true if a program is working properly
 - Assertions can be placed in a program as comments
- Java has a statement that can check if an assertion is true
assert Boolean_Expression;
 - If assertion checking is turned on and the **Boolean_Expression** evaluates to **false**, the program ends, and outputs an *assertion failed error message*
 - Otherwise, the program finishes execution normally

Assertion Checks

- A program or other class containing assertions is compiled in the usual way
- After compilation, a program can run with assertion checking turned on or turned off
 - Normally a program runs with assertion checking turned off
- In order to run a program with assertion checking turned on, use the following command (using the actual **ProgramName**):

```
java -enableassertions ProgramName
```

Preventive Coding

- Incremental Development
 - Write a little bit of code at a time and test it before moving on
- Code Review
 - Have others look at your code
- Pair Programming
 - Programming in a team, one typing while the other watches, and periodically switch roles

Generating Random Numbers

- The Random class can be used to generate pseudo-random numbers
 - Not truly random, but uniform distribution based on a mathematical function and good enough in most cases

- Add the following import

```
import java.util.Random;
```

- Create an object of type Random

```
Random rnd = new Random();
```

Generating Random Numbers

- To generate random numbers use the `nextInt()` method to get a random number from 0 to $n-1$

```
int i = rnd.nextInt(10);    // Random number from 0 to 9
```

- Use the `nextDouble()` method to get a random number from 0 to 1 (always less than 1)

```
double d = rnd.nextDouble();    // d is  $\geq 0$  and  $< 1$ 
```

Simulating a Coin Flip

Display 3.11

```
1 import java.util.Random;
2 public class CoinFlipDemo
3 {
4     public static void main(String[] args)
5     {
6         Random randomGenerator = new Random();
7         int counter = 1;
8
9         while (counter <= 5)
10        {
11            System.out.print("Flip number " + counter + ": ");
12            int coinFlip = randomGenerator.nextInt(2);
13            if (coinFlip == 1)
14                System.out.println("Heads");
15            else
16                System.out.println("Tails");
17            counter++;
18        }
19    }
20 }
```

Sample Dialogue (output will vary)

```
Flip number 1: Heads
Flip number 2: Tails
Flip number 3: Heads
Flip number 4: Heads
Flip number 5: Tails
```