

Chapter 3

Flow of Control

Slides prepared by Rose Williams,
Binghamton University

Kenrick Mock, University of Alaska
Anchorage

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**

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3-2

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

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3-3

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

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3-4

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		
Exp_1	Exp_2	Exp_1 && Exp_2
true	true	true
true	false	false
false	true	false
false	false	false

NOT	
Exp	!(Exp)
true	false
false	true

OR		
Exp_1	Exp_2	Exp_1 Exp_2
true	true	true
true	false	true
false	true	true
false	false	false

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

Display 3.6 Precedence and Associativity Rules

## Precedence and Associativity Rules

| 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);
```

## 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

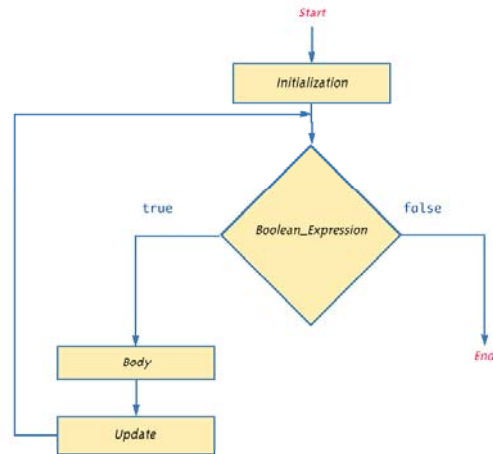
```
for (Initializing; Boolean_Expression; Update)
 Body
```

- 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 >=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
```