3. Flow of Control

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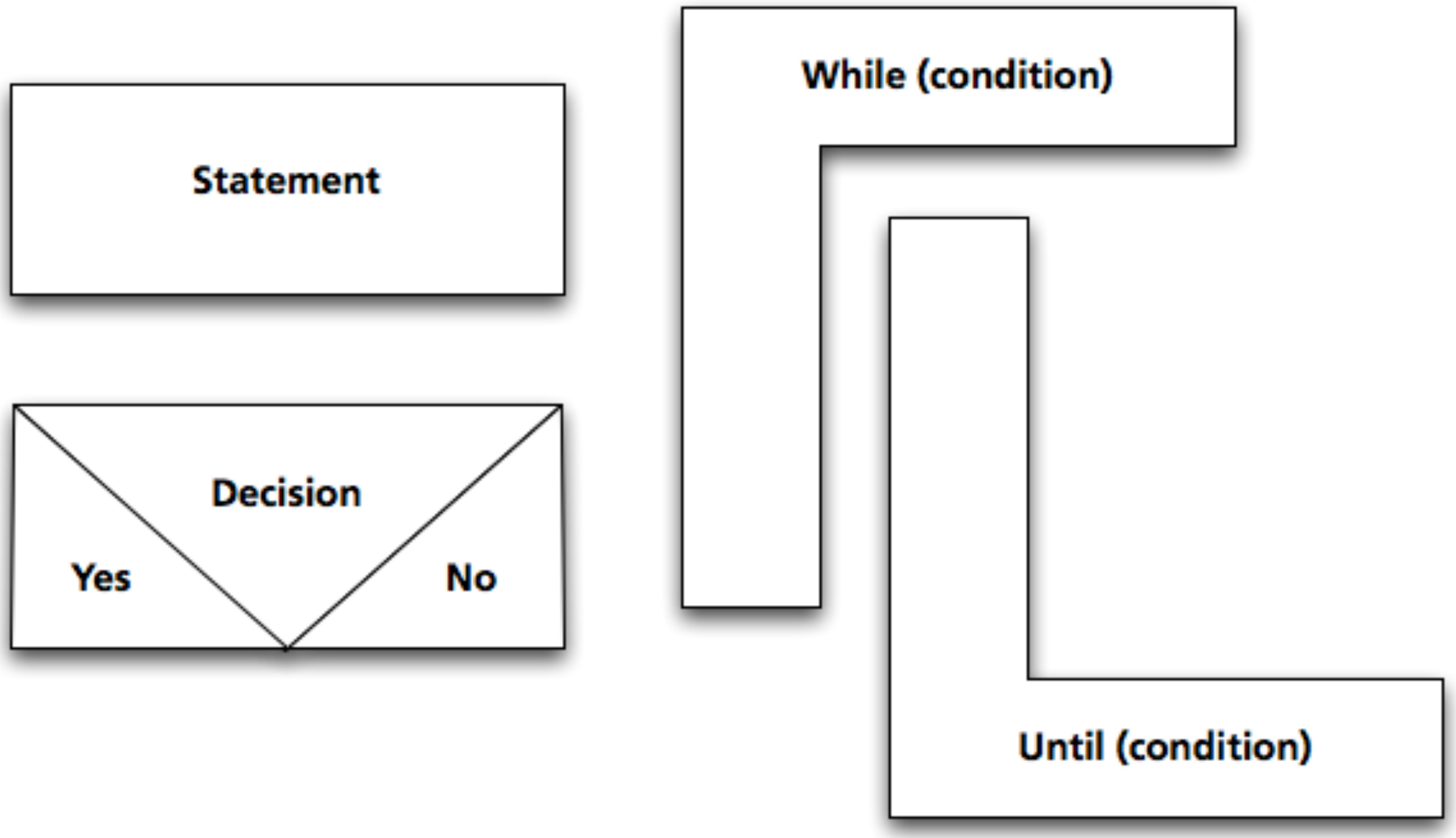
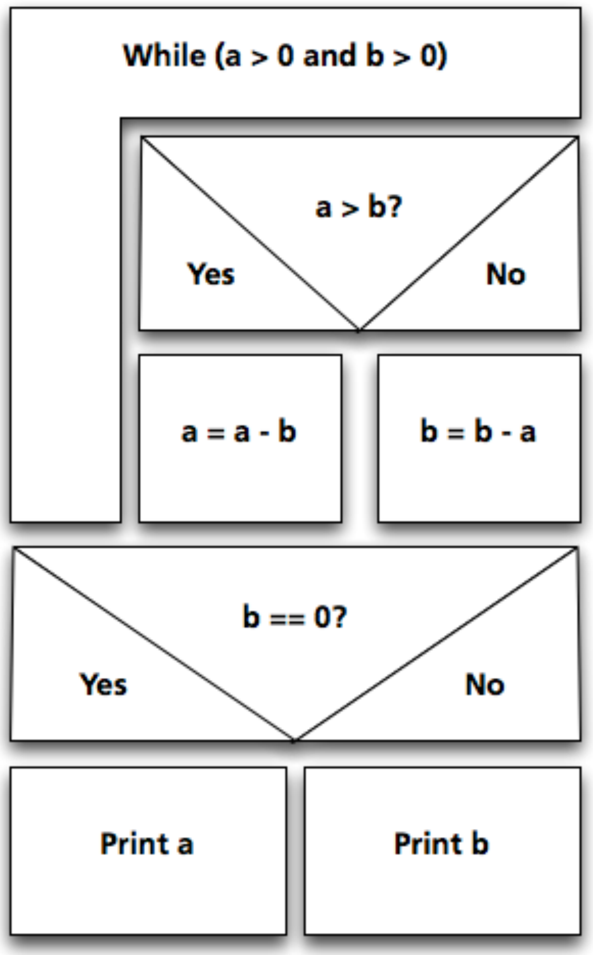
Flow of Control

- *Flow of control* is the order in which a program performs actions.
  - Up to this point, the order has been sequential.
- A *branching statement* chooses between two or more possible actions.
- A *loop statement* repeats an action until a stopping condition occurs.

Visualizing the Flow of Control



Example: Euclid's Algorithm



Outline

- The Type `boolean` and boolean Expressions
- The `if-else` Statement
- The `switch` statement

The Type boolean

- True or False
- Example use case:

  "The order can only be completed if the customer is already registered and has entered a valid credit card number."
- $\text{Order}_{\text{ok}} = \text{Account}_{\text{exists}}$ AND $\text{CreditCard}_{\text{valid}}$

The Type `boolean`

- The type `boolean` is a primitive type with only two values: `true` and `false`.
- Boolean variables can make programs more readable.

```
if (systemsAreOK)
```

instead of

```
if((temperature <= 100) && (thrust
  >= 12000) && (cabinPressure > 30)
  && …)
```

Naming Boolean Variables

- Choose names such as `isPositive` or `systemsAreOk`.
- Avoid names such as `numberSign` or `systemStatus`.

Input and Output of Boolean Values

- Example

```
boolean booleanVar = false;
System.out.println(booleanVar);
System.out.println("Enter a boolean value:");
Scanner keyboard = new Scanner(System.in);
booleanVar = keyboard.nextBoolean();
System.out.println("You entered " + booleanVar);
```

Input and Output of Boolean Values

- Dialog

```
false
Enter a boolean value: true
true
You entered true
```

Boolean Expressions and Variables

- Variables, constants, and expressions of type `boolean` all evaluate to either `true` or `false`.
- A boolean variable can be given the value of a boolean expression by using an assignment operator.

```
boolean isPositive = (number > 0);
...
if (isPositive) ...
```

Boolean Expressions

- The value of a *boolean expression* is either `true` or `false`.
- Examples

```
time < limit
balance < 0
```

Java Comparison Operators

Math Notation	Name	Java Notation	Java Examples

$=$	Equal to	`==`	`balance == 0`
			`answer == 'y'`

$\neq$	Not equal to	`!=`	`income != tax`
			`answer != 'y'`

$>$	Greater than	`>`	`expenses > income`
$\geq$	Greater than or equal to	`>=`	`points >= 60`
$<$	Less than	`<`	`pressure < max`
$\leq$	Less than or equal to	`<=`	`expenses <= income`

Using `==`

- `==` is appropriate for determining if two integers or characters have the same value.

  ```
  if (a == 3)
  ```

  where `a` is an integer type
- `==` is **not** appropriate for determining if two floating points values are equal. Use `<` and some appropriate tolerance instead.

  ```
  if (abs(b - c) < epsilon)
  ```

  where `b`, `c`, and `epsilon` are floating point types

Using ==, cont.

- `==` is not appropriate for determining if two objects have the same value.
  - `if (s1 == s2),` where `s1` and `s2` refer to strings, determines only if s1 and s2 refer the a common memory location.
  - If `s1` and `s2` refer to strings with identical sequences of characters, but stored in different memory locations, `(s1 == s2)` is false.

Using ==

- To test the equality of objects of class String, use method **`equals`**.

```
s1.equals(s2)
```

or

```
s2.equals(s1)
```

- To test for equality ignoring case, use method **`equalsIgnoreCase`**.

```
("Hello".equalsIgnoreCase("hello"))
```

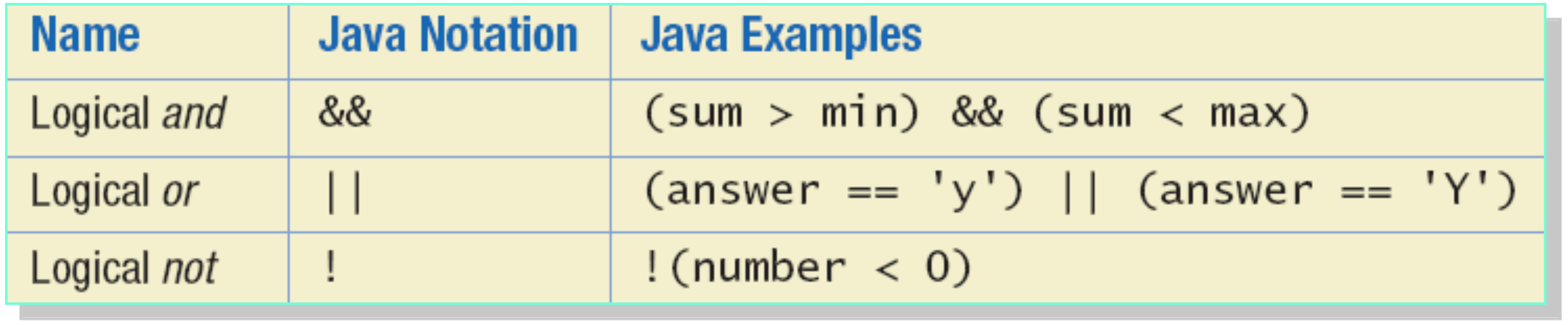
`equals` and `equalsIgnoreCase`

- Syntax

```
String.equals(Other_String)
String.equalsIgnoreCase(Other_String)
```

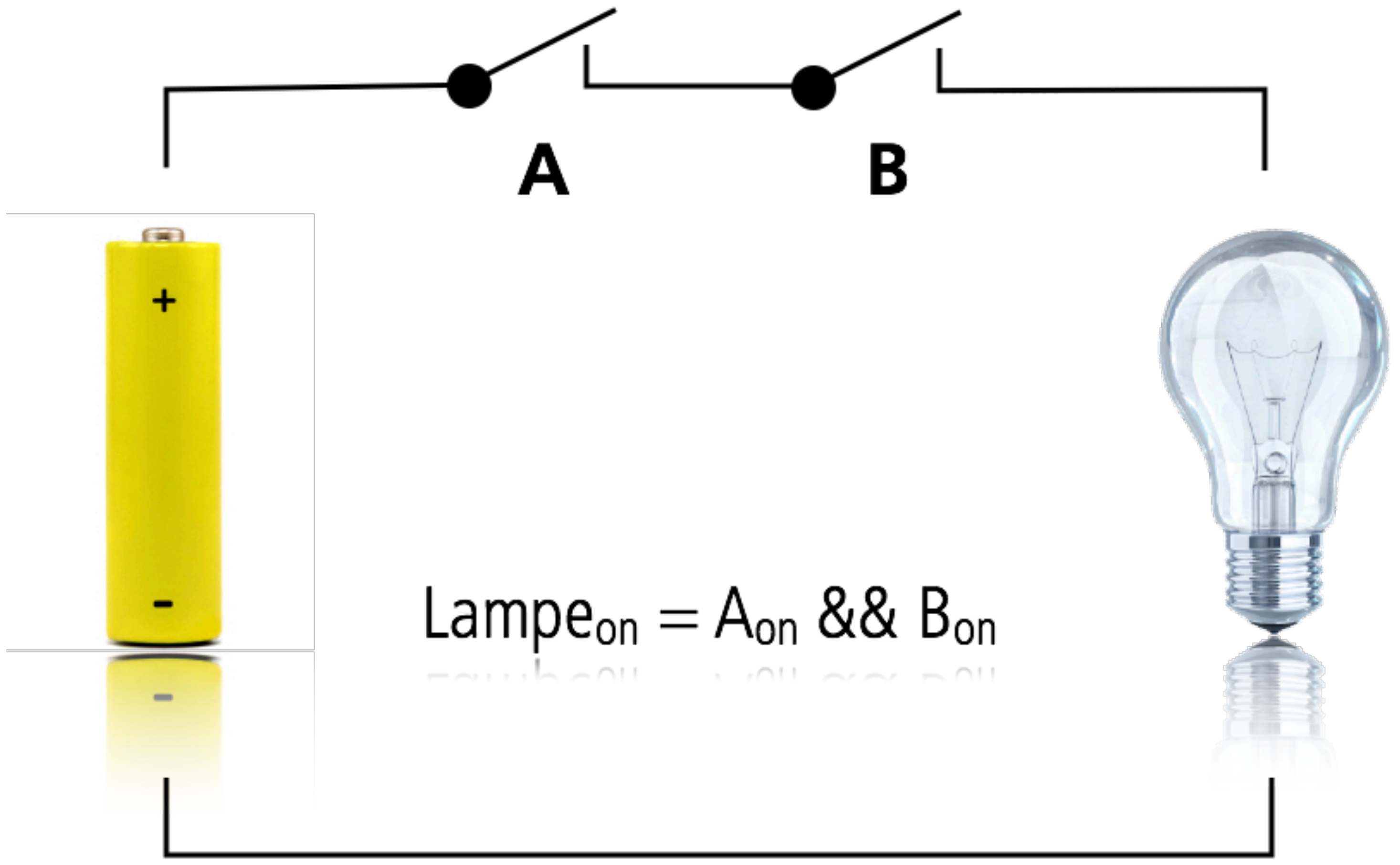
Java Logical Operators

- Figure 3.6



Name	Java Notation	Java Examples
Logical *and*	`&&`	`(sum > min) && (sum < max)`
Logical *or*	`||`	`(answer == 'y') || (answer == 'Y')`
Logical *not*	`!`	`!(number < 0)`

Boolean Expressions: AND



$$Lampe_{on} = A_{on} \&\& B_{on}$$

Compound Boolean Expressions

- Boolean expressions can be combined using the "and" `(&&)` operator.
- Example

```
if ((score > 0) && (score <= 100))
...
```

- Not allowed

```
if (0 < score <= 100)
...
```

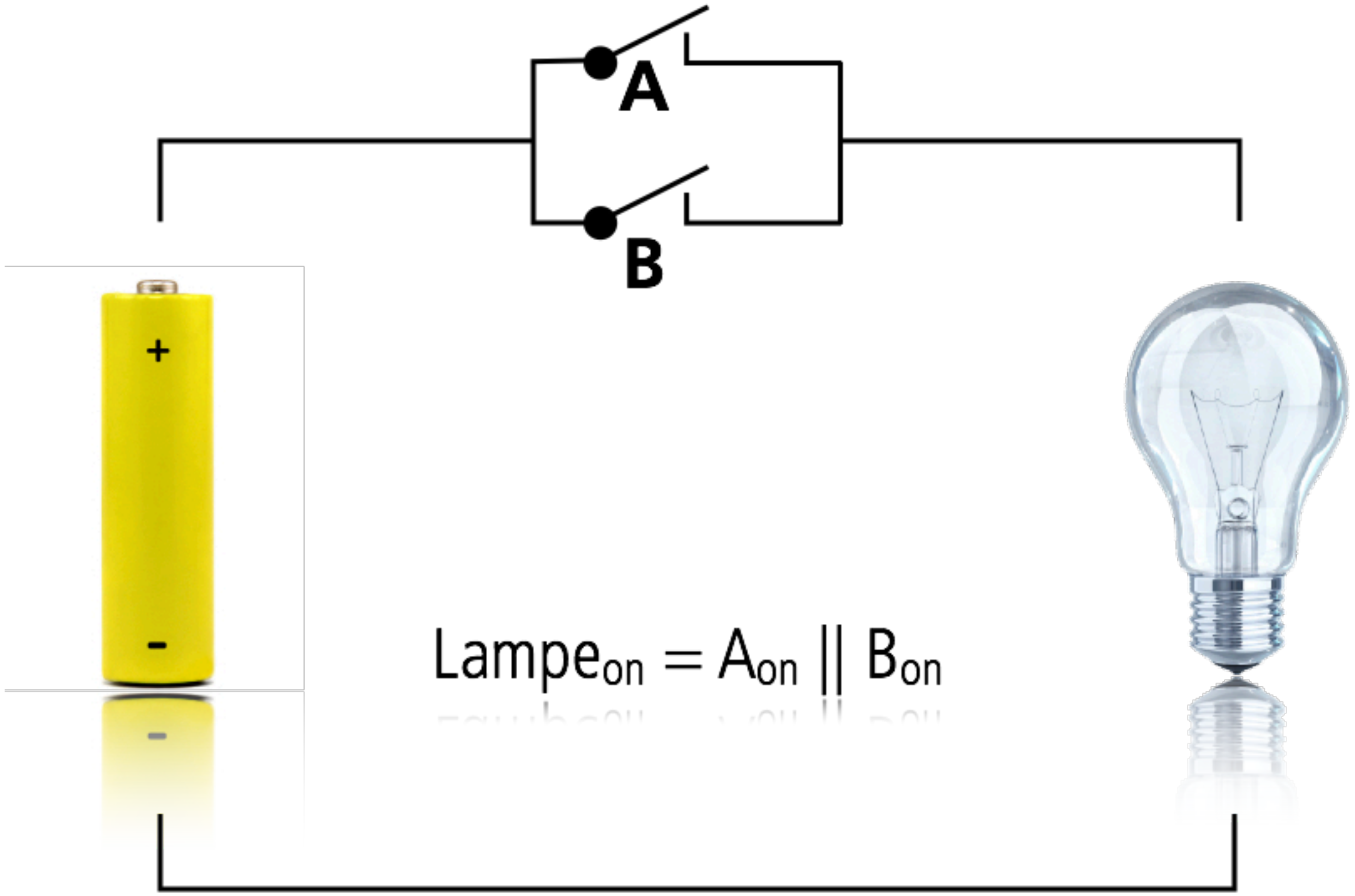
Compound Boolean Expressions

- Syntax

```
(Sub_Expression_1) &&
  (Sub_Expression_2)
```

- Parentheses often are used to enhance readability.
- The larger expression is true only when both of the smaller expressions are true.

Boolean Expressions: OR



$$\text{Lampe}_{\text{on}} = \text{A}_{\text{on}} \;||\; \text{B}_{\text{on}}$$

Compound Boolean Expressions, cont.

- Boolean expressions can be combined using the "or" `||` operator.
- Example

```
if ((quantity > 5) || (cost < 10))
…
```

- The Java version of “or” is the *inclusive or* which allows either or both to be true.
- The *exclusive or* allows one or the other, but not both to be true.

Compound Boolean Expressions, cont.

- The larger expression is true
  - when either of the smaller expressions is true
  - when both of the smaller expressions are true.
- The Java version of “or” is the *inclusive or* which allows either or both to be true.
- The *exclusive or* allows one or the other, but not both to be true.

Short-circuit Evaluation

- Sometimes only part of a boolean expression needs to be evaluated to determine the value of the entire expression.
  - If the first operand associated with an `||` is `true`, the expression is `true`.
  - If the first operand associated with an `&&` is `false`, the expression is `false`.
- This is called *short-circuit* or *lazy* evaluation.

Short-circuit Evaluation

- Short-circuit evaluation is not only efficient, sometimes it is essential!
- A run-time error can result, for example, from an attempt to divide by zero.

```
if ((number != 0) && (sum/number > 5))
```

- *Complete evaluation* can be achieved by substituting `&` for `&&` or `|` for `||`.

Negating a Boolean Expression

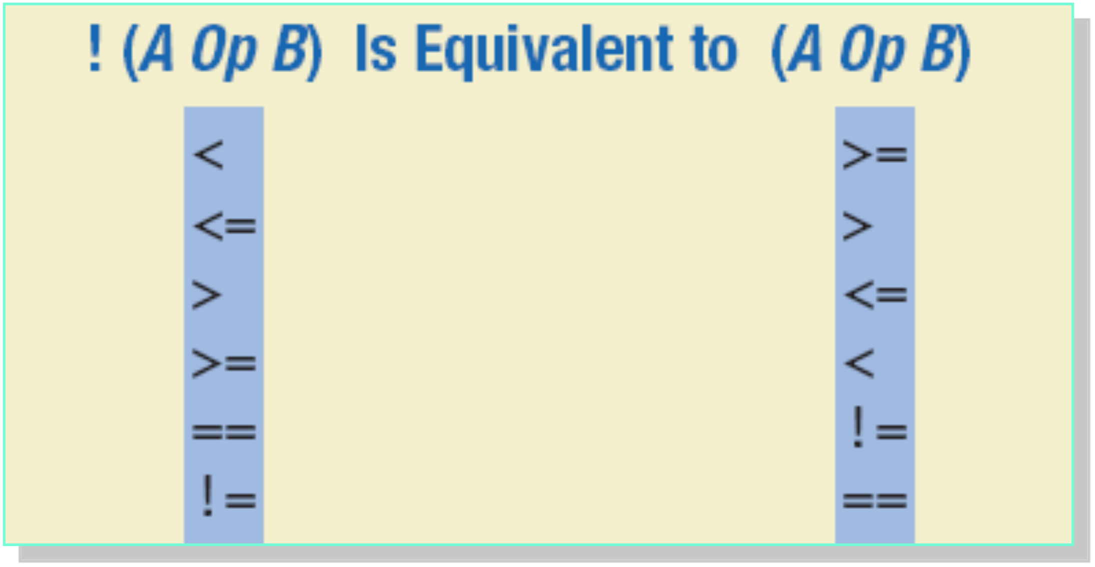
- A boolean expression can be negated using the "not" (`!`) operator.
- Example

```
(a || b) && !(a && b)
```

which is the *exclusive or*

Negating a Boolean Expression

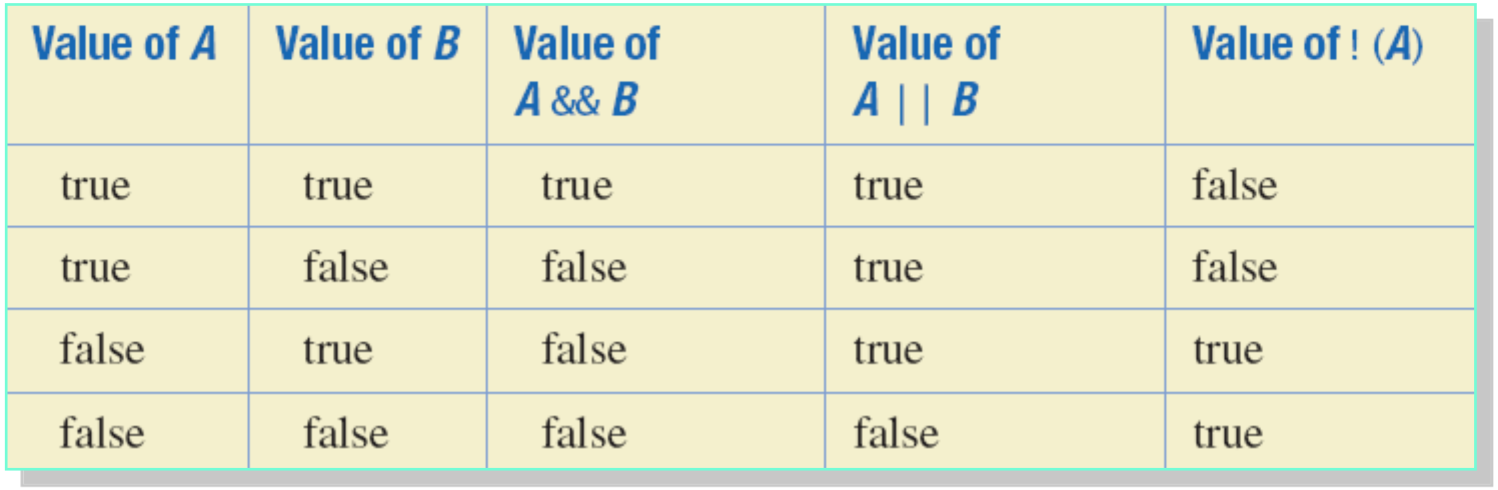
- Figure3.5 Avoiding the Negation Operator



! (*A Op B*)	Is Equivalent to (*A Op B*)
<	>=
<=	>
>	<=
>=	<
==	!=
!=	==

Boolean Operators

- FIGURE 3.7 The Effect of the Boolean Operators `&&` (and), `||` (or), and `!` (not) on Boolean values



Value of *A*	Value of *B*	Value of *A* && *B*	Value of *A* || *B*	Value of ! (*A*)
true	true	true	true	false
true	false	false	true	false
false	true	false	true	true
false	false	false	false	true

Precedence Rules

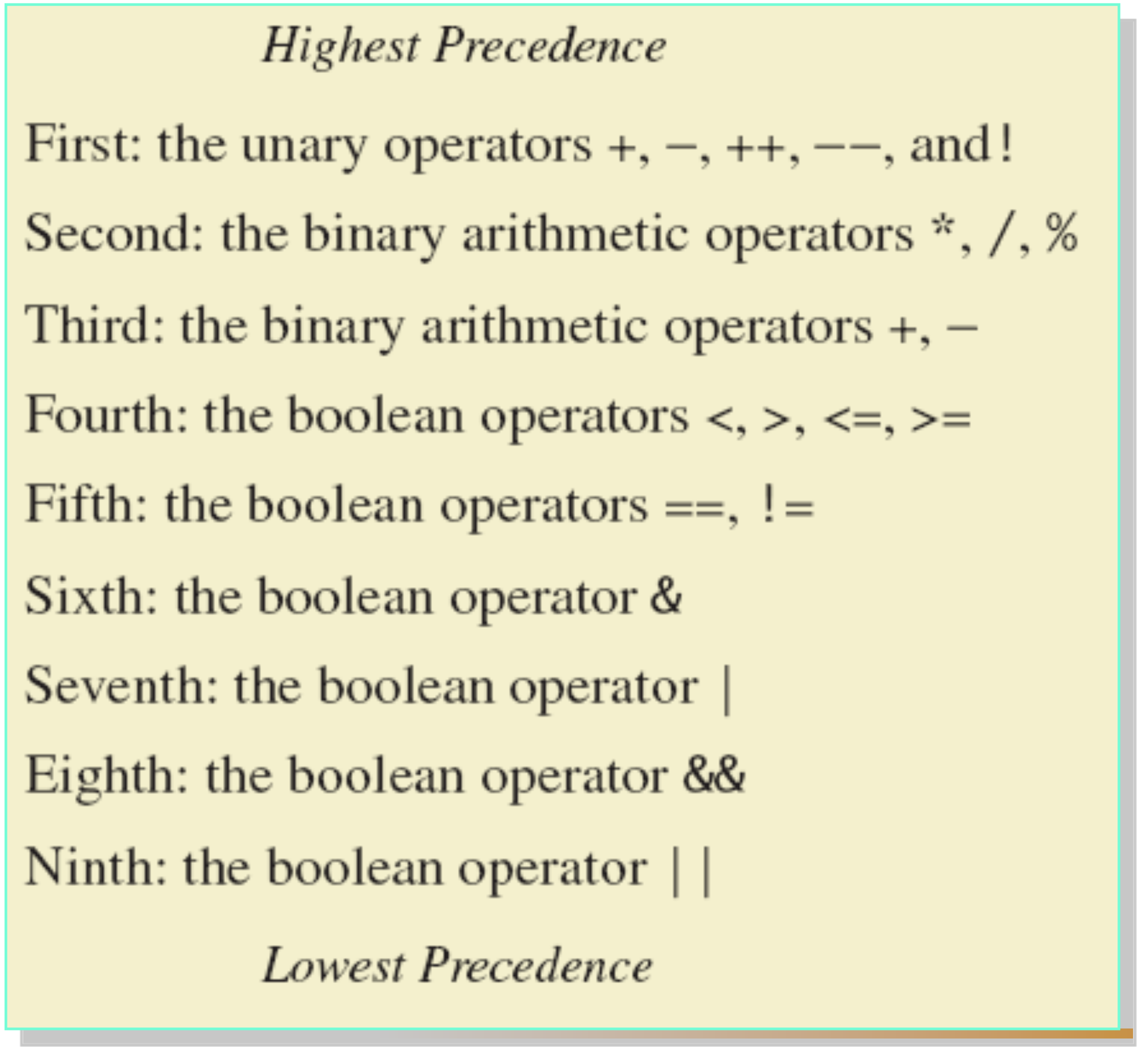
- Parentheses should be used to indicate the order of operations.
- When parentheses are omitted, the order of operation is determined by *precedence rules.*

Precedence Rules

- Operations with *higher precedence* are performed before operations with *lower precedence.*
- Operations with *equal precedence* are done left-to-right (except for unary operations which are done right-to-left).

Precedence Rules

- Figure 3.9



Highest Precedence

First: the unary operators +, −, ++, −−, and !

Second: the binary arithmetic operators *, /, %

Third: the binary arithmetic operators +, −

Fourth: the boolean operators <, >, <=, >=

Fifth: the boolean operators ==, !=

Sixth: the boolean operator &

Seventh: the boolean operator |

Eighth: the boolean operator &&

Ninth: the boolean operator ||

Lowest Precedence

Precedence Rules

- In what order are the operations performed?

```
score < min/2 - 10 || score > 90
score < (min/2) - 10 || score > 90
score < ((min/2) - 10) || score > 90
(score < ((min/2) - 10)) || score > 90
(score < ((min/2) - 10)) || (score > 90)
```

The `if-else` Statement

- A branching statement that chooses between two possible actions.
- syntax
  - `if (Boolean_Expression){`
  - ` Statement_1`
  - `} else {`
  - ` Statement_2`
  - `}`

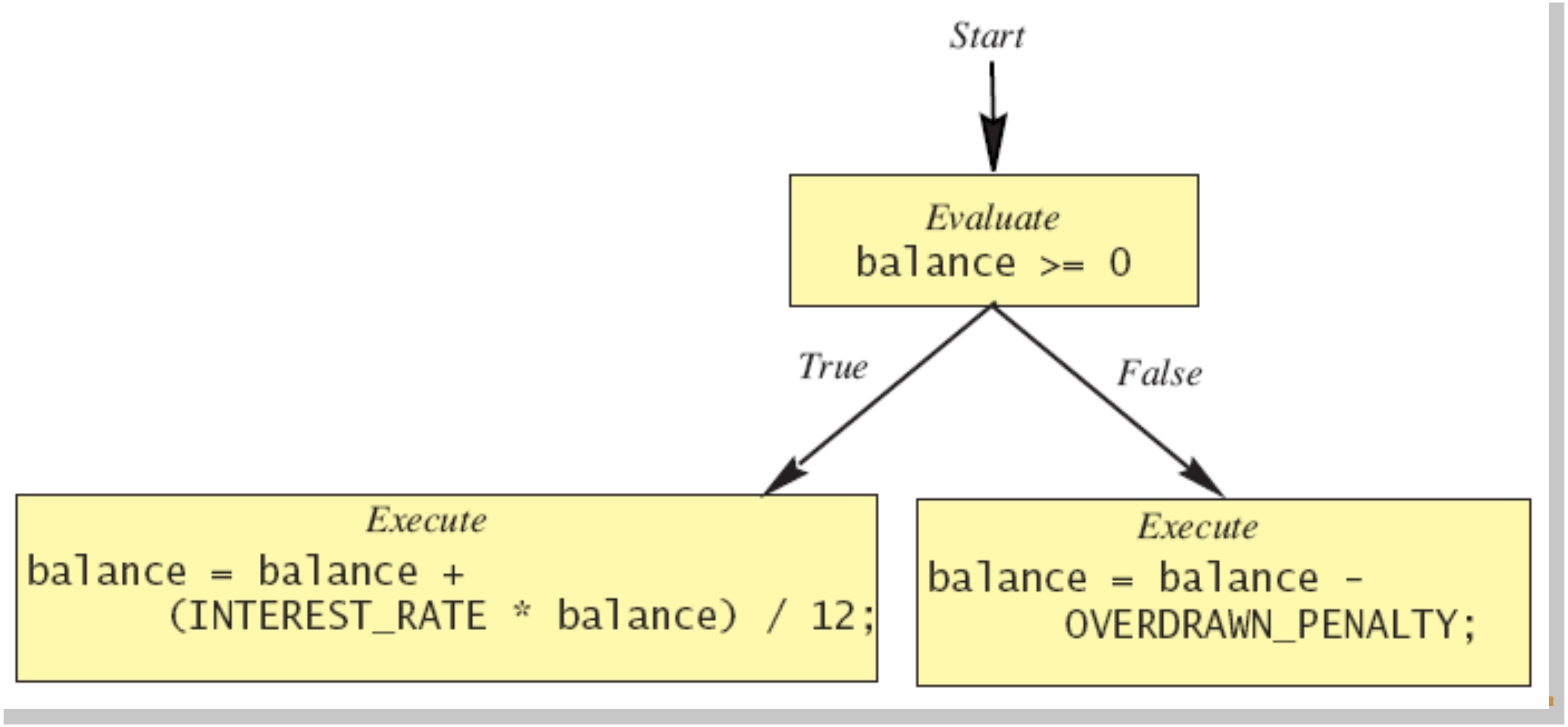
The `if-else` Statement, cont.

- Example

```
if (balance >= 0)
    balance = balance + (INTEREST_RATE * balance) / 12;
else
    balance = balance - OVERDRAWN_PENALTY;
```

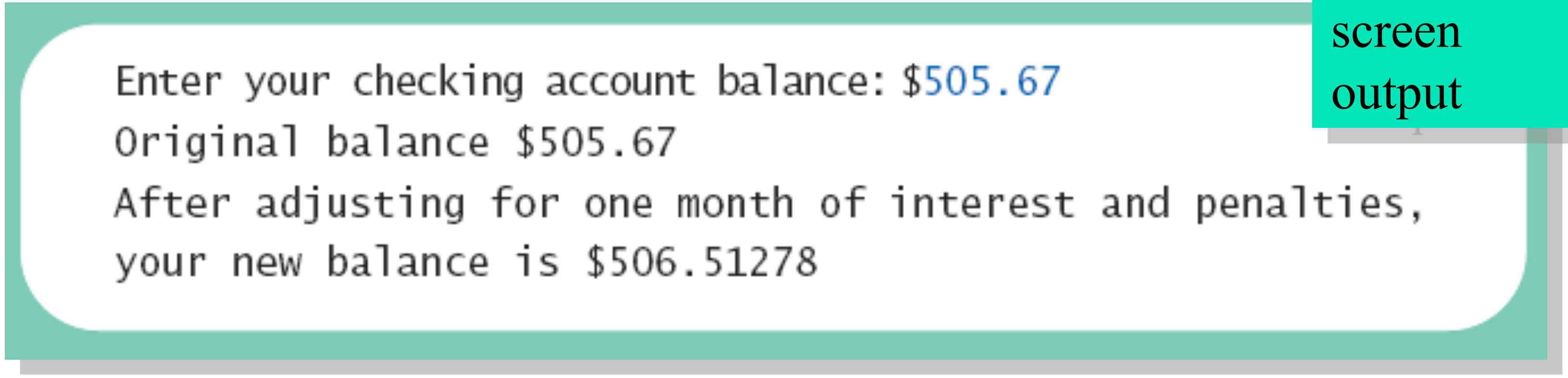
The `if-else` Statement

- Figure 3.1 The Action of the `if-else` Statement sample program Listing 3.1

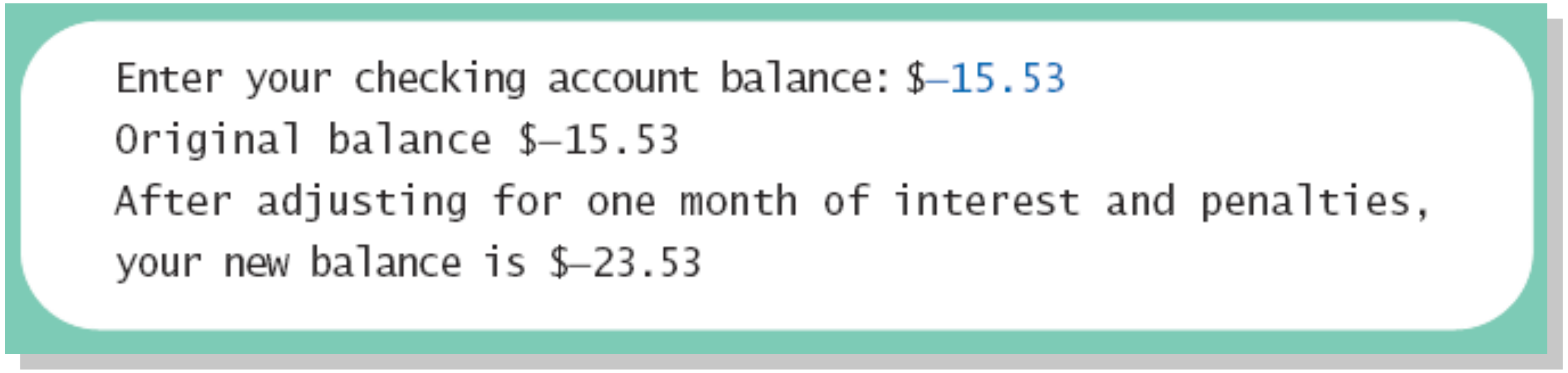


The `if-else` Statement

Sample screen output



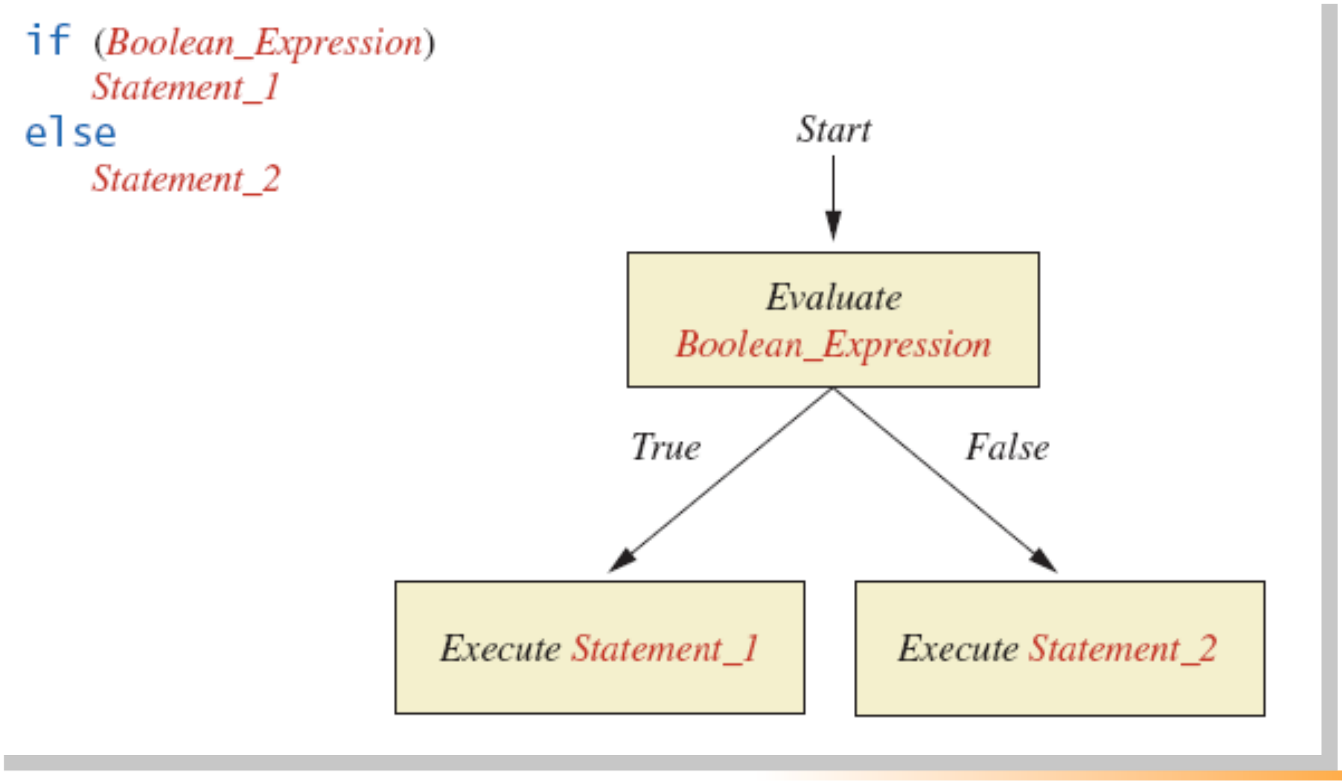
```
Enter your checking account balance: $505.67
Original balance $505.67
After adjusting for one month of interest and penalties,
your new balance is $506.51278
```



```
Enter your checking account balance: $–15.53
Original balance $–15.53
After adjusting for one month of interest and penalties,
your new balance is $–23.53
```

Semantics of the `if-else` Statement

- Figure 3.2



```
if (Boolean_Expression)
    Statement_1
else
    Statement_2
```

The `if-else` Statement, cont.

- `class BankBalance`

```
import java.util.*;

public class BankBalance
{
    public static final double OVERDRAWN_PENALTY = 8.00;
    public static final double INTEREST_RATE = 0.02;//2% annually

    public static void main(String[] args)
    {
        double balance;

        System.out.print("Enter your checking account balance: $");
        Scanner keyboard =  new Scanner(System.in);
        balance = keyboard.nextDouble();
        System.out.println("Original balance $" + balance);

        if (balance >= 0)
            balance = balance + (INTEREST_RATE * balance)/12;
        else
            balance = balance - OVERDRAWN_PENALTY;

        System.out.println("After adjusting for one month");
        System.out.println("of interest and penalties,");
        System.out.println("your new balance is $" + balance);
    }
}
```

Sample Screen Dialog 1

```
Enter your checking account balance: $505.67
Original balance $505.67
After adjusting for one month
of interest and penalties,
your new balance is $506.51278
```

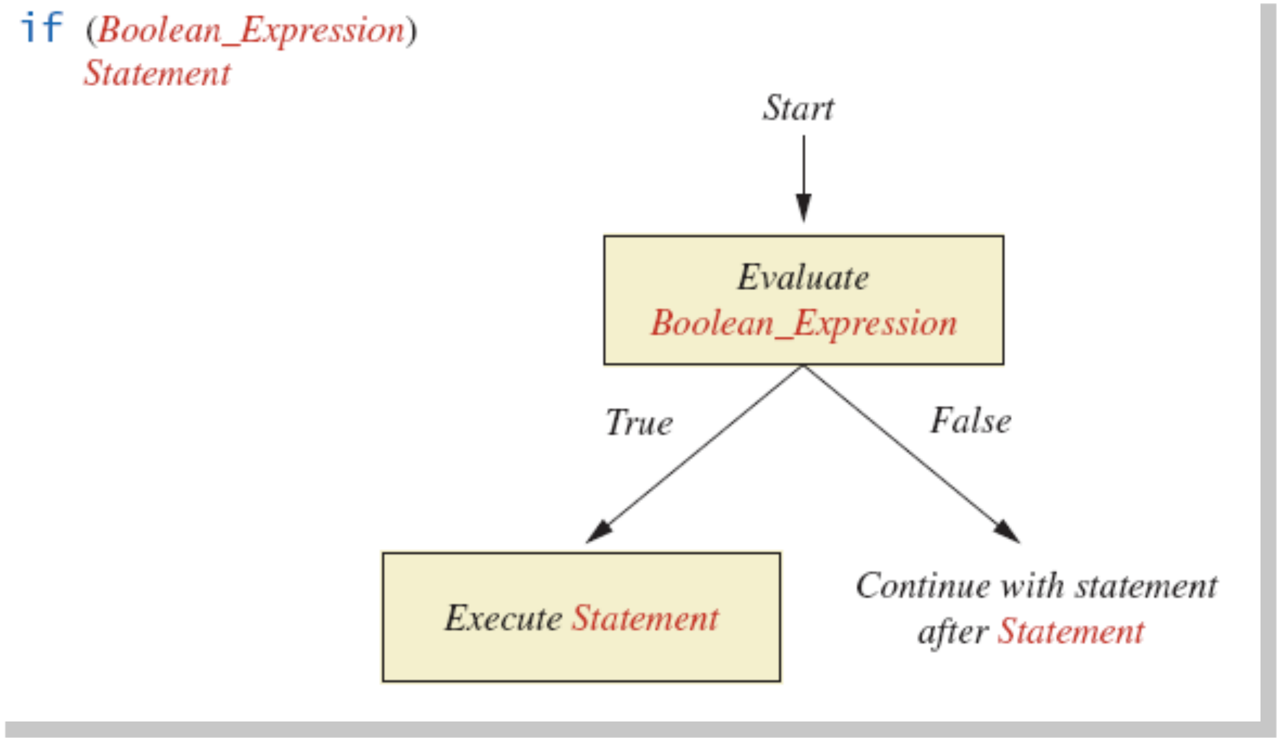
Sample Screen Dialog 2

```
Enter your checking account balance: $-15.53
Original balance $-15.53
After adjusting for one month
of interest and penalties,
your new balance is $-23.53
```

Display 3.1
A Program Using if-else

Omitting the `else` Part

- The Semantics of an `if` Statement without an `else`



if (Boolean_Expression)
Statement
Start
Evaluate Boolean_Expression
True
False
Execute Statement
Continue with statement after Statement

Omitting the `else` Part

- If the `else` part is omitted and the expression after the `if` is false, no action occurs.
- syntax

```
if (Boolean_Expression) {
    Statement
}
```

- example

```
if (weight > ideal) {
    caloriesPerDay -= 500;
}
```

Lexicographic Order

- Lexicographic order is similar to alphabetical order, but is it based on the order of the characters in the ASCII (and Unicode) character set.
  - All the digits come before all the letters.
  - All the uppercase letters come before all the lower case letters.

Lexicographic Order

- Strings consisting of alphabetical characters can be compared using method `compareTo` and method `toUpperCase` or method `toLowerCase`.

```
String s1 = "Hello";
String lowerS1 = s1.toLowerCase();
String s2 = "hello";
if (s1.compareTo(s2) == 0)
    System.out.println("Equal!");
```

Method `compareTo`

- Syntax

  `String_1.compareTo(String_2)`

- Method **`compareTo`** returns
  - a negative number if **`String_1`** precedes **`String_2`**
  - zero if the two strings are equal
  - a positive number of **`String_2`** precedes **`String_1`**.

Compound Statements

- To include multiple statements in a branch, enclose the statements in braces.

```
if (count < 3)
    {
        total = 0;
        count = 0;
    }
```

Compound Statements

- When a list of statements is enclosed in braces (`{ }`), they form a single *compound statement.*
- Syntax

```
{
      Statement_1;
      Statement_2;
   …
}
```

Compound Statements

- A compound statement can be used wherever a statement can be used.
- Example

```
if (total > 10)
{
   sum = sum + total;
   total = 0;
}
```

Nested `if-else` Statements

- An `if-else` statement can contain any sort of statement within it.
- In particular, it can contain another `if-else` statement.
  - An `if-else` may be nested within the "if" part.
  - An `if-else` may be nested within the "else" part.
  - An `if-else` may be nested within both parts.

Nested Statements

- Syntax

```
if (Boolean_Expression_1) {
     if (Boolean_Expression_2) {
         Statement_1;
     } else {
         Statement_2;
    }
} else {
    if (Boolean_Expression_3) {
         Statement_3;
    } else
         Statement_4;
    }
}
```

Nested Statements

- Each `else` is paired with the nearest unmatched `if`.
- **If used properly**, indentation communicates which `if` goes with which `else`.

Nested Statements

- Subtly different forms

First Form

```
if (a > b)
{
    if (c > d)
        e = f
}
    else
        g = h;
```

Second Form

```
if (a > b)
   if (c > d)
        e = f
    else
        g = h;

// oops
```

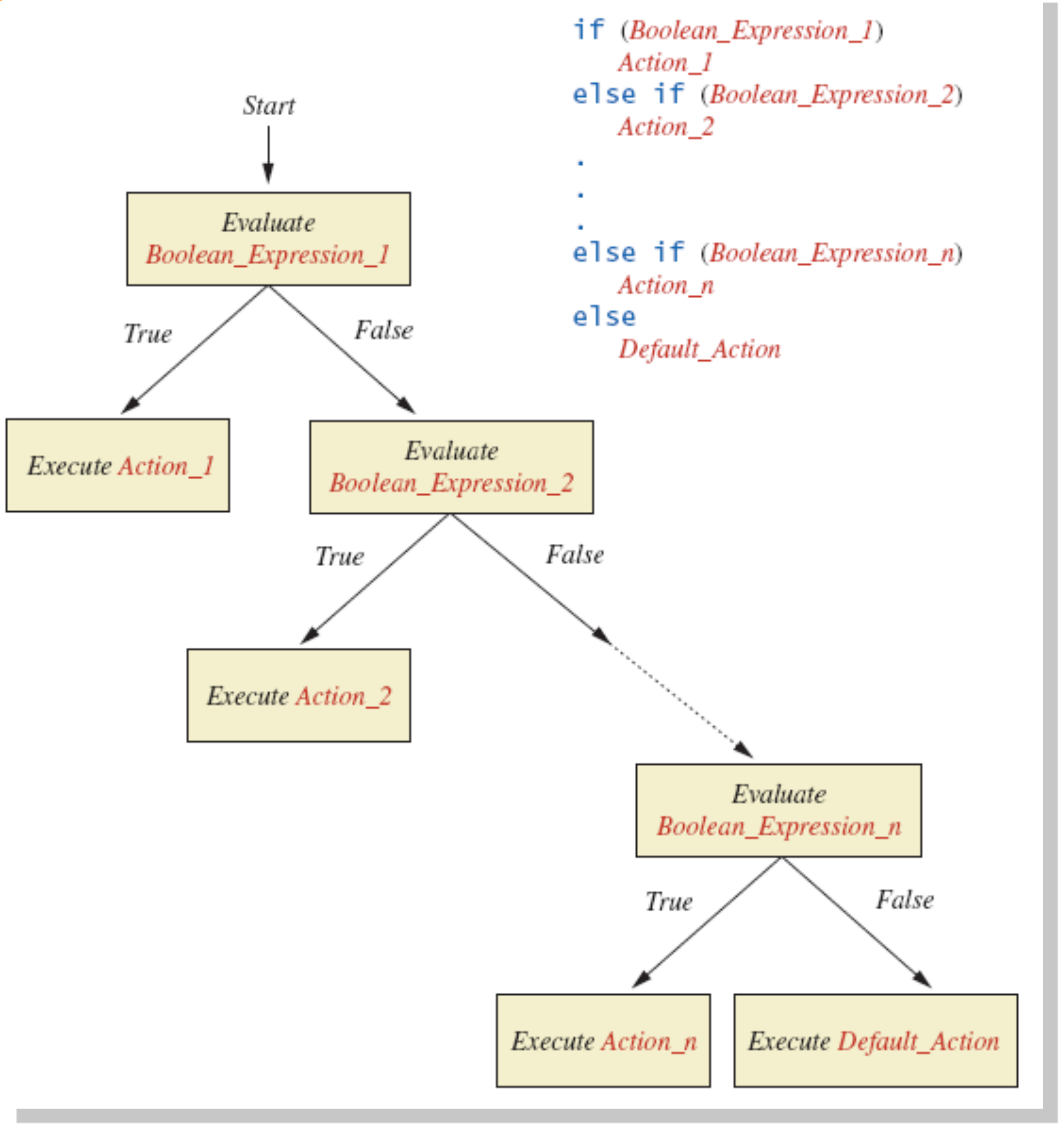
Multibranch `if-else` Statements

- Syntax

```
if (Boolean_Expression_1)
    Statement_1
else if (Boolean_Expression_2)
    Statement_2
else if (Boolean_Expression_3)
    Statement_3
else if …
else
    Default_Statement
```

Multibranch `if-else` Statements

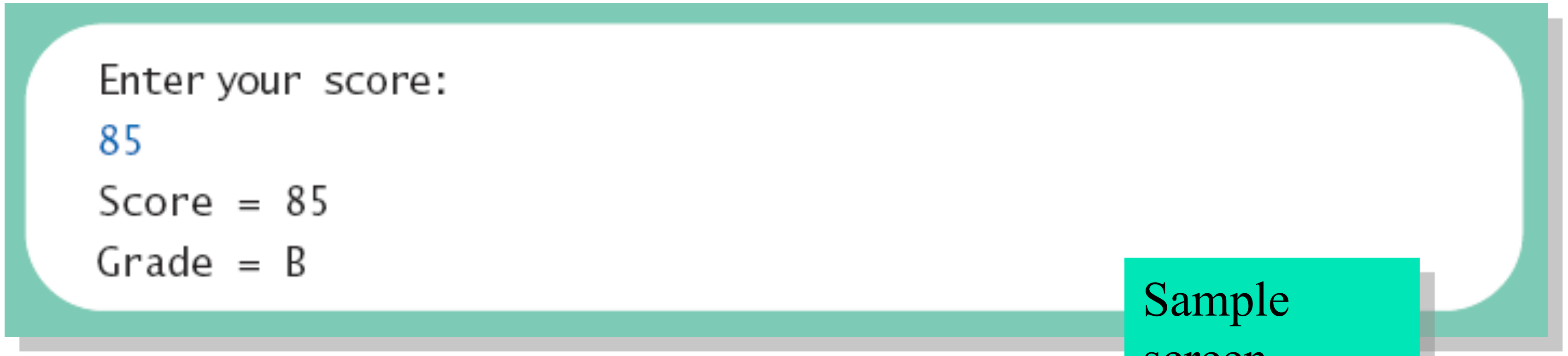
- Figure 3.8 Semantics



```
if (Boolean_Expression_1)
   Action_1
else if (Boolean_Expression_2)
   Action_2
.
.
.
else if (Boolean_Expression_n)
   Action_n
else
   Default_Action
```

Multibranch `if-else` Statements

- View sample program Listing 3.3
  `class Grader`



```
Enter your score:
85
Score = 85
Grade = B
```

Sample screen output

Multibranch `if-else` Statements

- Example:

```
if (score >= 90)
    grade = 'A';
else if ((score >= 80) && (score < 90))
    grade = 'B';
else if ((score >= 70) && (score < 80))
    grade = 'C';
else if ((score >= 60) && (score < 70))
    grade = 'D';
else
    grade = 'F';
```

The `switch` Statement

- The **`switch`** statement is a multiway branch that makes a decision based on an *integral* (integer or character) expression.
- The **`switch`** statement begins with the keyword **`switch`** followed by an integral expression in parentheses and called the *controlling expression.*

The `switch` Statement

- A list of cases follows, enclosed in braces.
- Each case consists of the keyword `case` followed by
  - A constant called the *case label*
  - A colon
  - A list of statements.
- The list is searched for a case label matching the controlling expression.

The `switch` Statement

- The action associated with a matching case label is executed.
- If no match is found, the case labeled `default` is executed.
  - The `default` case is optional, but recommended, even if it simply prints a message.
- Repeated case labels are not allowed.

The `switch` Statement

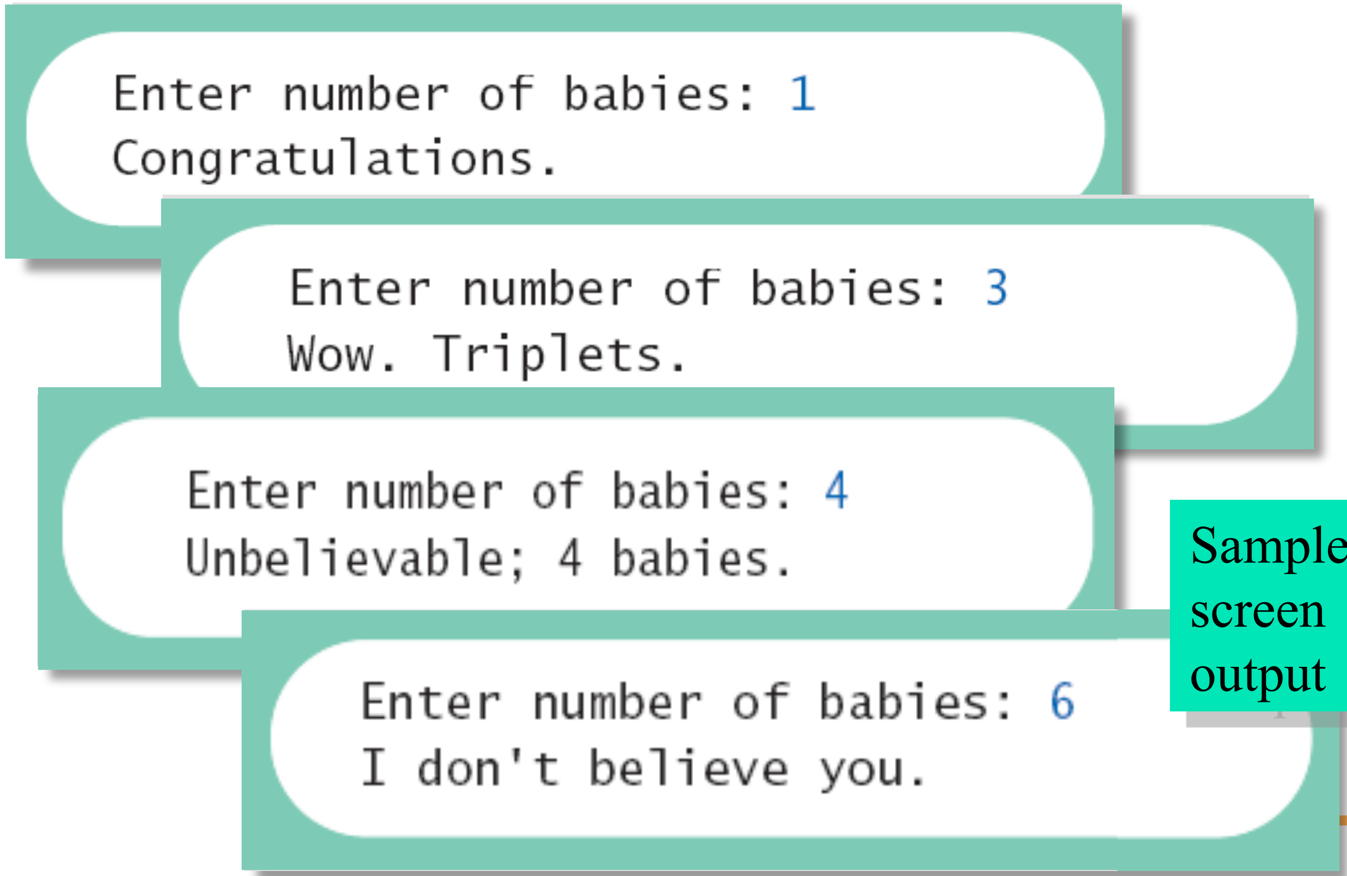
- Syntax

```
switch (Controlling_Expression)
{
    case Case_Label:
            Statement(s);
            break;
    case Case_Label:
    …
    default:
    …
}
```

The `switch` Statement

- View sample program Listing 3.4

`class MultipleBirths`



```
Enter number of babies: 1
Congratulations.
```

```
Enter number of babies: 3
Wow. Triplets.
```

```
Enter number of babies: 4
Unbelievable; 4 babies.
```

```
Enter number of babies: 6
I don't believe you.
```

Sample screen output

The `switch` Statement

- The action for each case typically ends with the word **`break`**.
- The optional **`break`** statement prevents the consideration of other cases.
- The controlling expression can be anything that evaluates to an integral type.

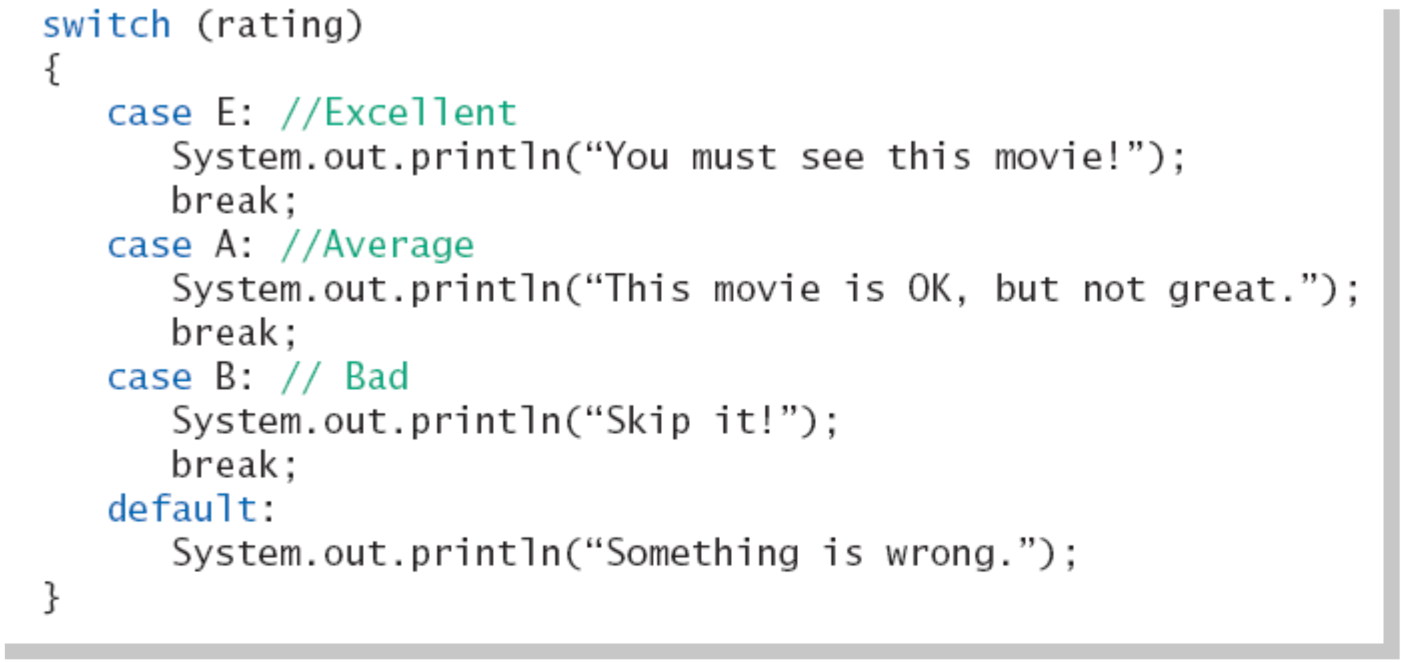
Enumerations

- Consider a need to restrict contents of a variable to certain values
- An enumeration lists the values a variable can have
- Example

```
enum MovieRating {E, A, B}
MovieRating rating;
rating = MovieRating.A;
```

Enumerations

- Now possible to use in a **`switch`** statement



```
switch (rating)
{
   case E: //Excellent
      System.out.println("You must see this movie!");
      break;
   case A: //Average
      System.out.println("This movie is OK, but not great.");
      break;
   case B: // Bad
      System.out.println("Skip it!");
      break;
   default:
      System.out.println("Something is wrong.");
}
```

Enumerations

- An even better choice of descriptive identifiers for the constants

```
enum MovieRating
      {EXCELLENT, AVERAGE, BAD}
rating = MovieRating.AVERAGE;

case EXCELLENT:   ...
```

The Conditional Operator

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

can be written as

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

- The `?` and `:` together are call the *conditional operator* or *ternary operator.*

The Conditional Operator

- The conditional operator is useful with print and println statements.

```
System.out.print("You worked " +
   ((hours > 1) ? "hours" ;
  "hour"));
```

Summary

- You have learned about Java branching statements.
- You have learned about the type **`boolean`**.