Control Structures

- A program can proceed:
  - Sequentially
  - Selectively (branch) - making a choice
  - Repetitively (iteratively) - looping

Conditional Execution

- `if` is a reserved word
- The most basic syntax for `if`:

```
if( condition )
    statement
```

- The statement is executed if the condition evaluates to `true`
- The statement is bypassed if the condition evaluates to `false`

`bool` Data Type and Conditions

- A condition can be a `bool` variable
- The data type `bool` has logical (Boolean) values `true` and `false`
- `bool`, `true`, and `false` are reserved words
- The identifier `true` has the value `1`
- The identifier `false` has the value `0`

`int` Data Type and Conditions

- Earlier versions of C++ did not provide built-in data types that had Boolean values
- Logical expressions evaluate to either 1 or 0
  - The value of a logical expression was stored in a variable of the data type `int`
- You can use the `int` data type as a condition

Logical Expressions

- General syntax for `if`:

```
if( logical-expression )
    statement
```

- A logical expression is any expression that evaluates to `true` or `false`
  - A literal (anything but `0` is true)
  - A variable (any built-in type)
  - A function (should return `bool` or `int`)
  - Any expression that evaluates to `bool` or `int`

Logical Expressions

- Arithmetic expressions
  - Built with arithmetic operators
  - Evaluate to numbers (integer or floating-point)

```
3 + 5
(7 / 2) * 4.0
```

- Logical expressions
  - Built with relational operators
  - Evaluate to `true` or `false`

```
3 == 3
“hello” < “goodbye”
```

Relational Operators

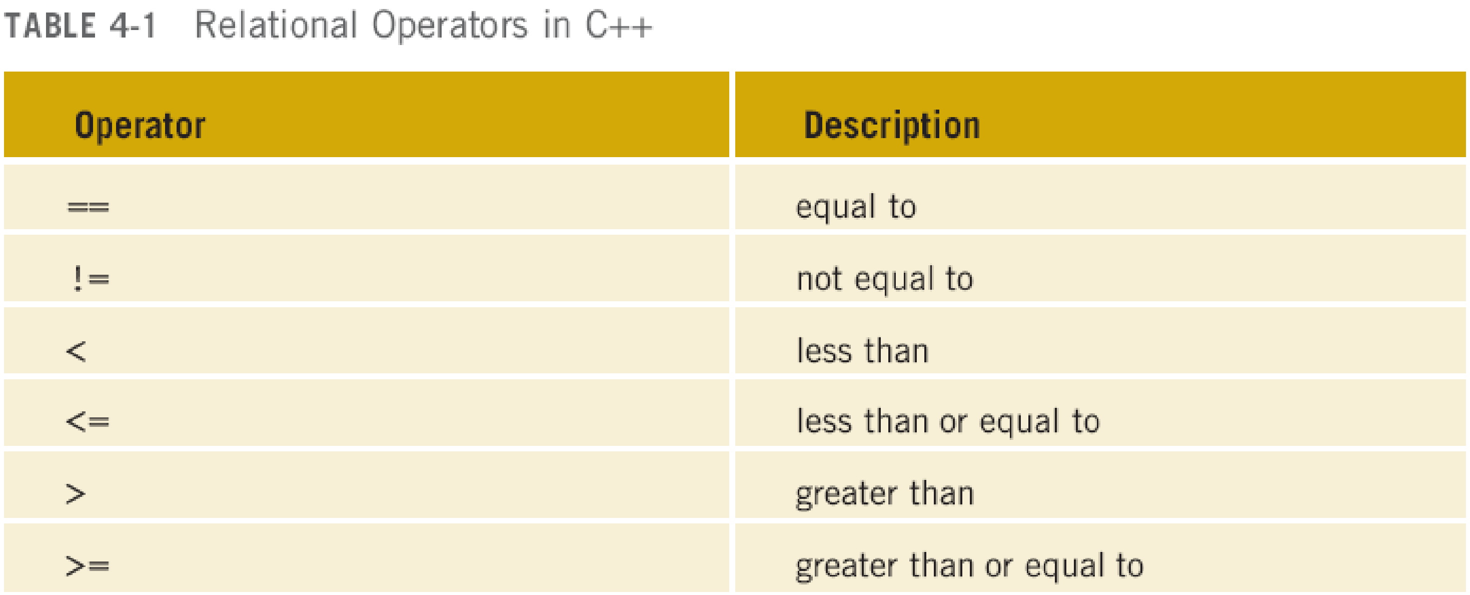


TABLE 4-1 Relational Operators in C++

Operator	Description
==	equal to
!=	not equal to
<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to

Comparing Numbers

- Integer and floating-point types can be compared
  - `8 < 15` evaluates to `true`
  - `6 != 6` evaluates to `false`
  - `2.5 > 5.8` evaluates to `false`
  - `5.9 <= 7` evaluates to `true`

Comparing Characters

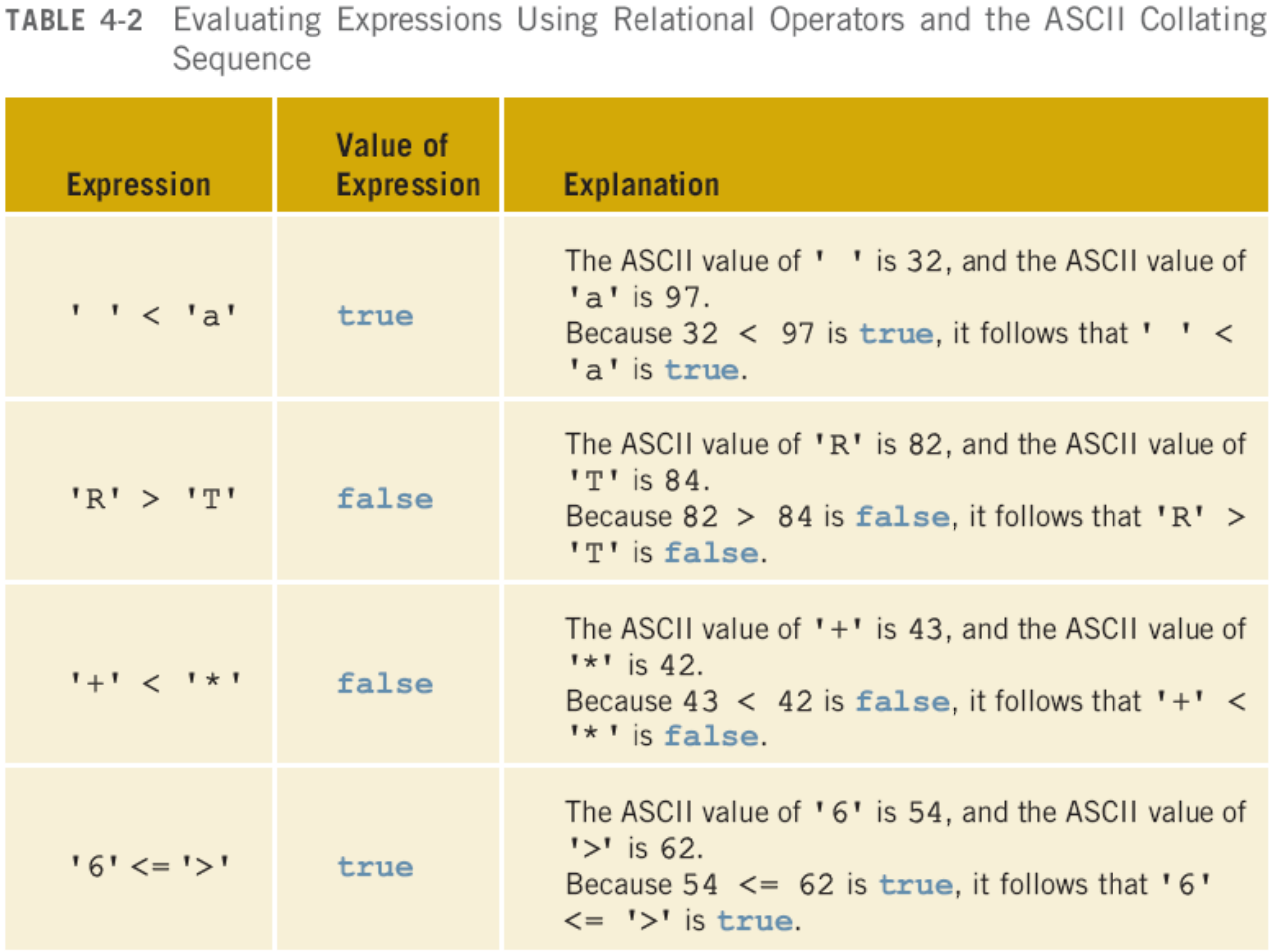


TABLE 4-2 Evaluating Expressions Using Relational Operators and the ASCII Collating Sequence

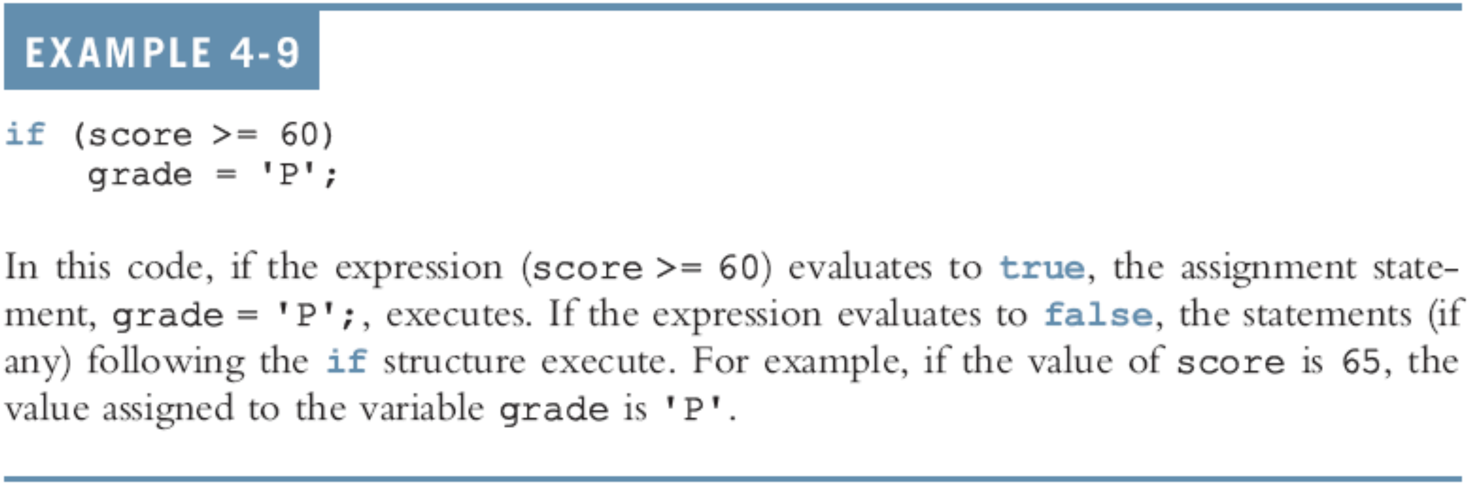
Expression	Value of Expression	Explanation
`' ' < 'a'`	`true`	The ASCII value of `' '` is 32, and the ASCII value of `'a'` is 97. Because 32 < 97 is `true`, it follows that `' ' < 'a'` is `true`.
`'R' > 'T'`	`false`	The ASCII value of `'R'` is 82, and the ASCII value of `'T'` is 84. Because 82 > 84 is `false`, it follows that `'R' > 'T'` is `false`.
`'+' < '*'`	`false`	The ASCII value of `'+'` is 43, and the ASCII value of `'*'` is 42. Because 43 < 42 is `false`, it follows that `'+' < '*'` is `false`.
`'6'<='>'`	`true`	The ASCII value of `'6'` is 54, and the ASCII value of `'>'` is 62. Because 54 <= 62 is `true`, it follows that `'6' <= '>'` is `true`.

Comparing `strings`

- Relational operators can be applied to strings
- Strings are compared character by character, starting with the first character
- Comparison continues until either a mismatch is found or all characters are found equal
- If two strings of different lengths are compared and the comparison is equal to the last character of the shorter string
  - The shorter string is less than the larger string

- Note: this does not work for comparing 2 string literals!

Examples



EXAMPLE 4-9

```
if (score >= 60)
    grade = 'P';
```

In this code, if the expression (`score >= 60`) evaluates to `true`, the assignment statement, `grade = 'P';`, executes. If the expression evaluates to `false`, the statements (if any) following the `if` structure execute. For example, if the value of `score` is `65`, the value assigned to the variable `grade` is `'P'`.

EXAMPLE 4-10

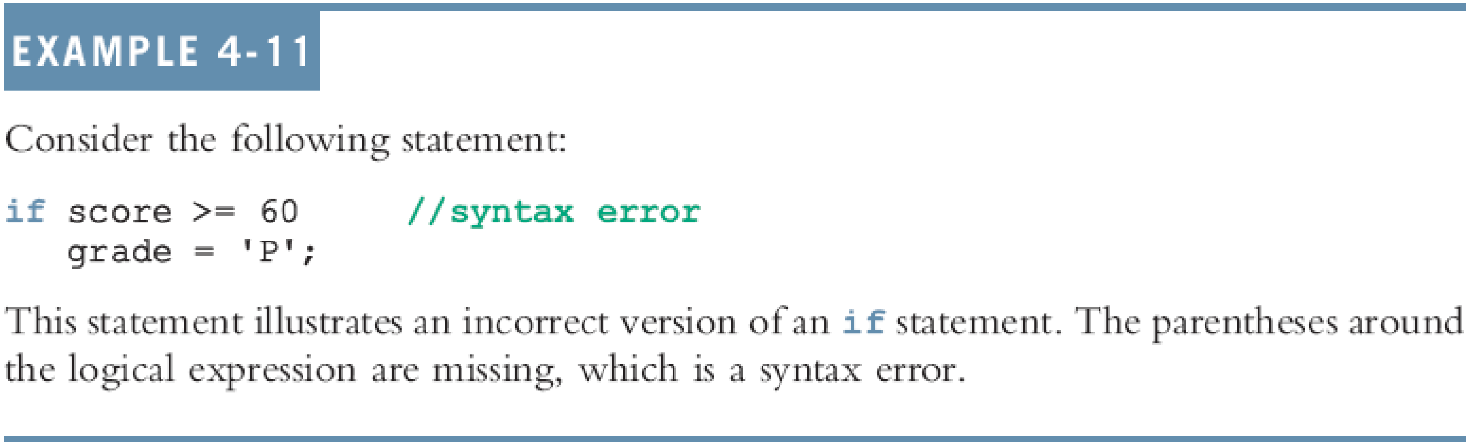
The following C++ program finds the absolute value of an integer:

```
//Program: Absolute value of an integer

#include <iostream>

using namespace std;

int main()
{
    int number, temp;

    cout << "Line 1: Enter an integer: ";         //Line 1
    cin >> number;                                //Line 2
    cout << endl;                                 //Line 3

    temp = number;                                //Line 4

    if (number < 0)                               //Line 5
        number = -number;                         //Line 6

    cout << "Line 7: The absolute value of "
         << temp << " is " << number << endl;     //Line 7

    return 0;
}
```

Sample Run: In this sample run, the user input is shaded.

```
Line 1: Enter an integer: -6734
Line 7: The absolute value of -6734 is 6734
```

Common Syntax Errors

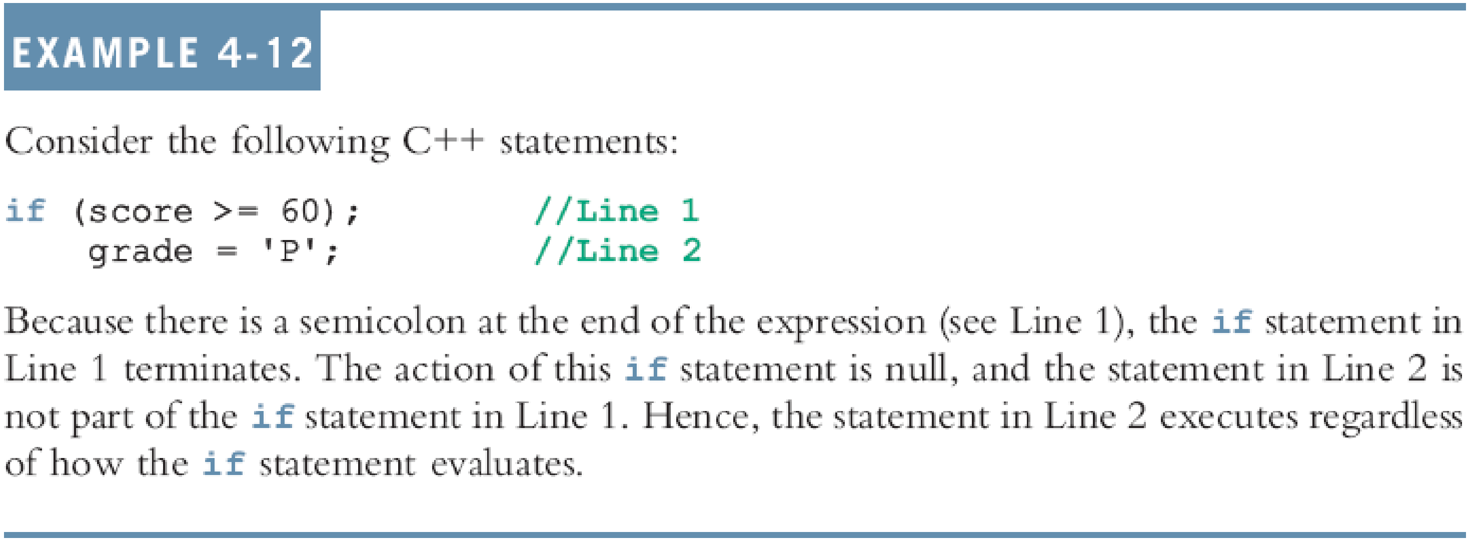


EXAMPLE 4-11

Consider the following statement:

```
if score >= 60      //syntax error
   grade = 'P';
```

This statement illustrates an incorrect version of an `if` statement. The parentheses around the logical expression are missing, which is a syntax error.



EXAMPLE 4-12

Consider the following C++ statements:

```
if (score >= 60);          //Line 1
    grade = 'P';           //Line 2
```

Because there is a semicolon at the end of the expression (see Line 1), the `if` statement in Line 1 terminates. The action of this `if` statement is null, and the statement in Line 2 is not part of the `if` statement in Line 1. Hence, the statement in Line 2 executes regardless of how the `if` statement evaluates.

Two-way Conditional Execution

- `if` can be paired with `else`

```
if( logical-expression )
    statement1
else
    statement2
```

- If the condition is `true`, statement1 is executed
- If the condition is `false`, statement2 is executed

One-Way Selection

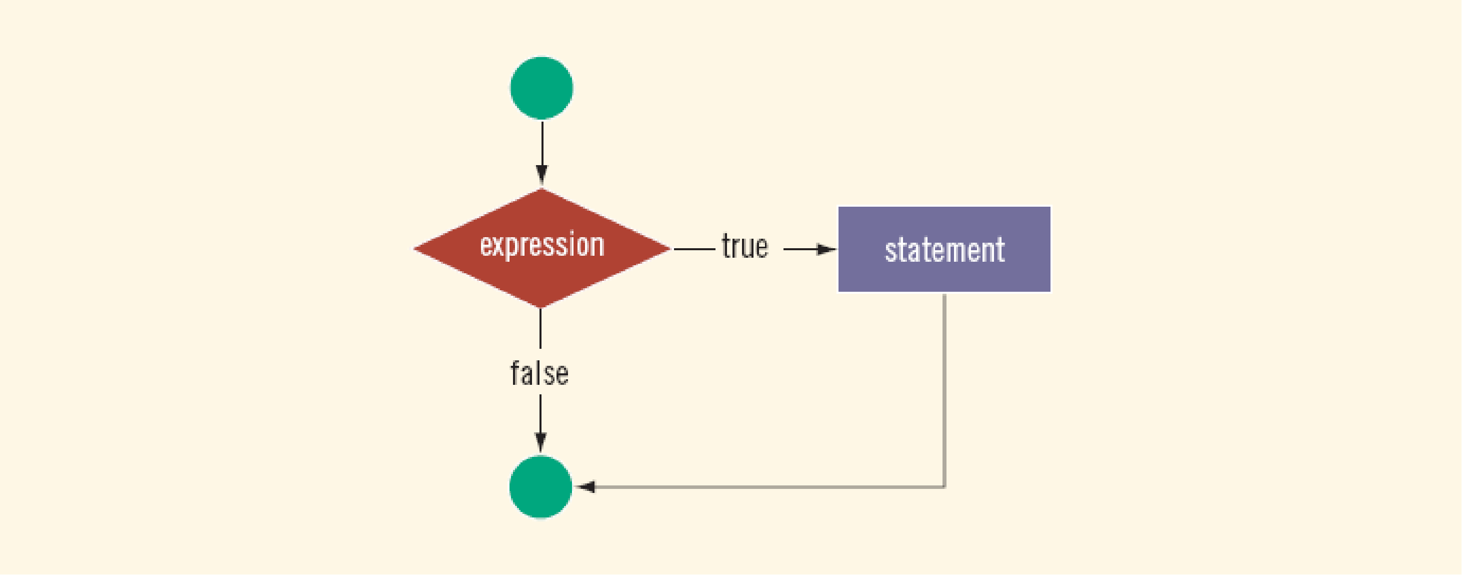


FIGURE 4-2 One-way selection

Two-Way Selection

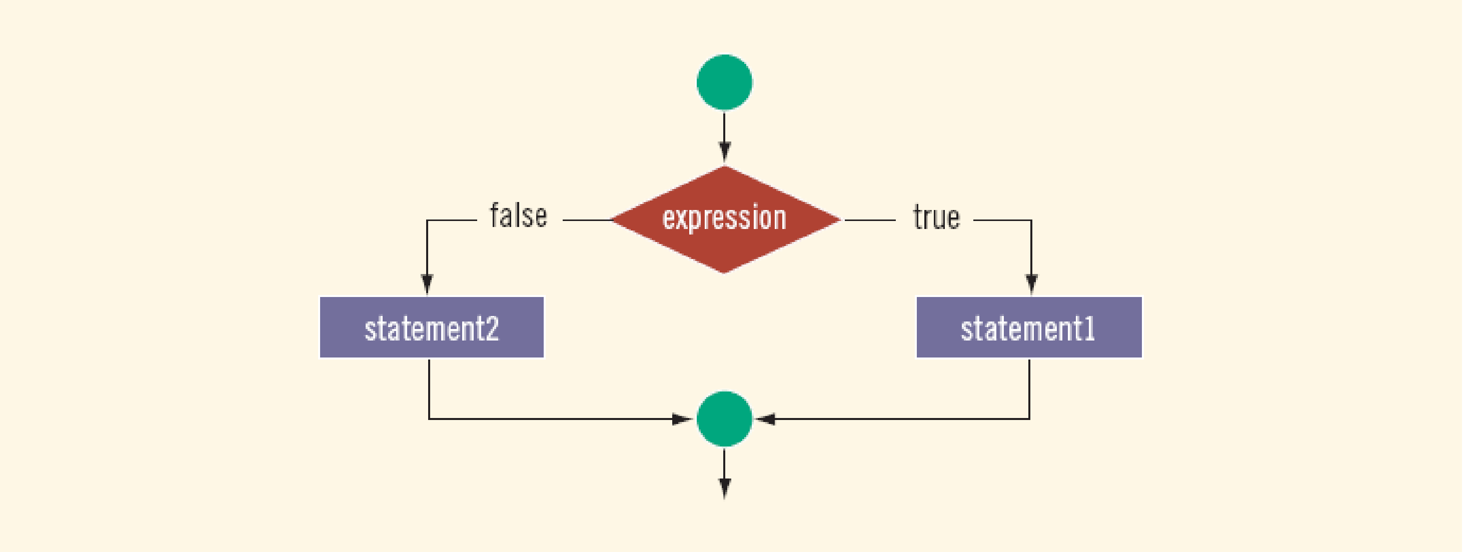
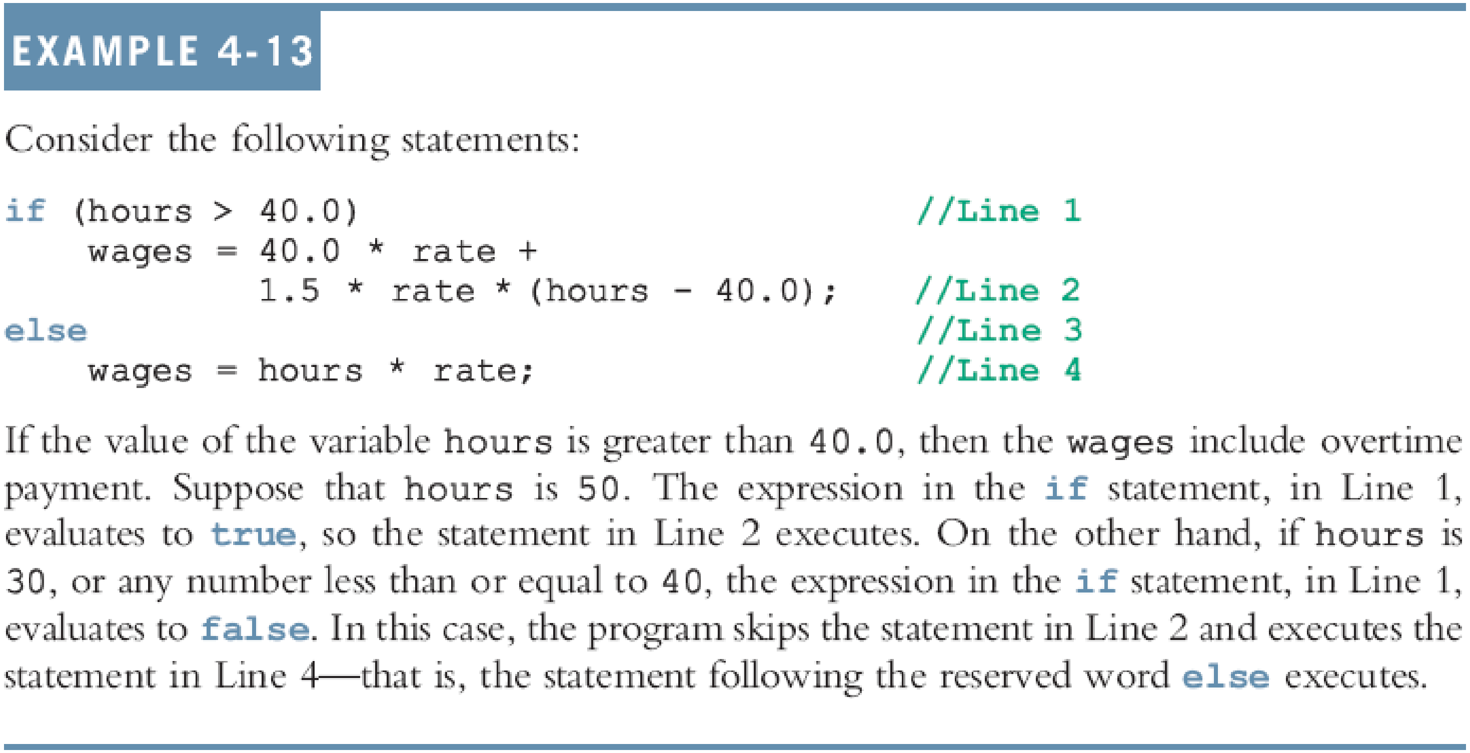


FIGURE 4-3 Two-way selection

Example



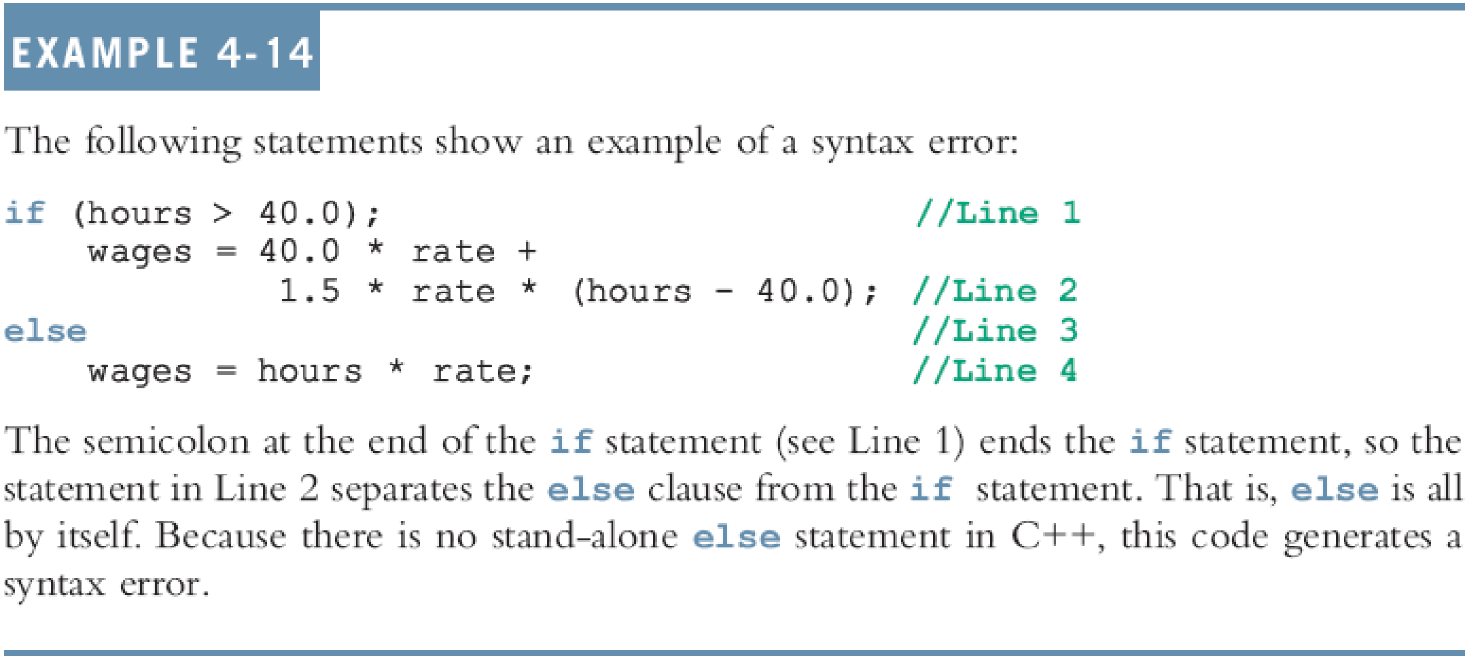
EXAMPLE 4-13

Consider the following statements:

```
if (hours > 40.0)                           //Line 1
    wages = 40.0 * rate +
            1.5 * rate * (hours - 40.0);    //Line 2
else                                        //Line 3
    wages = hours * rate;                   //Line 4
```

If the value of the variable hours is greater than 40.0, then the wages include overtime payment. Suppose that hours is 50. The expression in the if statement, in Line 1, evaluates to true, so the statement in Line 2 executes. On the other hand, if hours is 30, or any number less than or equal to 40, the expression in the if statement, in Line 1, evaluates to false. In this case, the program skips the statement in Line 2 and executes the statement in Line 4—that is, the statement following the reserved word else executes.

Common Syntax Errors



EXAMPLE 4-14

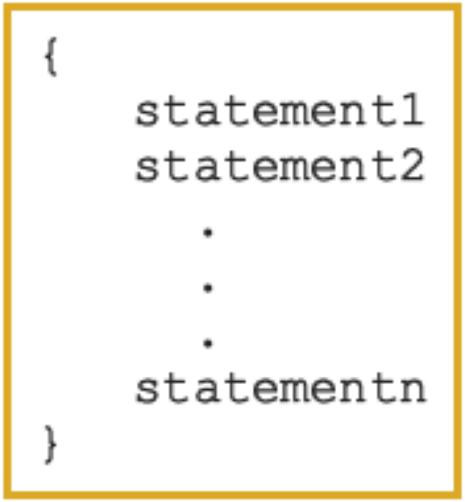
The following statements show an example of a syntax error:

```
if (hours > 40.0);                              //Line 1
    wages = 40.0 * rate +
             1.5 * rate * (hours - 40.0);       //Line 2
else                                            //Line 3
    wages = hours * rate;                       //Line 4
```

The semicolon at the end of the `if` statement (see Line 1) ends the `if` statement, so the statement in Line 2 separates the `else` clause from the `if` statement. That is, `else` is all by itself. Because there is no stand-alone `else` statement in C++, this code generates a syntax error.

Block Statements

- A block (or compound) statement looks like:



```
{
     statement1
     statement2
         .
         .
         .
     statementn
}
```

- A block can be used anywhere a statement can be used

Conditional Block Statements

```
if (age > 18)
  cout << "No longer a minor." << endl;
else
  cout << "Still a minor." << endl;
```

Conditional Block Statements

```
if (age > 18)
{
  cout << "No longer a minor." << endl;
}
else
{
  cout << "Still a minor." << endl;
}
```

Conditional Block Statements

```
if (age > 18)
{
  cout << "No longer a minor." << endl;
  cout << "Eligible to vote." << endl;
}
else
{
  cout << "Still a minor." << endl;
  cout << "Not eligible to vote." << endl;
}
```

More Than 2 Choices

- Series of `if` statements:

```
if( logical-expression1 )
{
    statement1
}
if( logical-expression2 )
{
    statement2
}
if( logical-expression3 )
{
    statement3
}
```

  - Checks all three conditions
  - Can’t have a default `else` condition
  - Used for statements that are not mutually exclusive

More Than 2 Choices

- For mutually exclusive conditions, use an `if…else` tree
  - Stops when a condition is true
  - Can have a default `else` condition

```
if( logical-expression1 )
{
    statement1
}
else if( logical-expression2 )
{
    statement2
}
else if( logical-expression3 )
{
    statement3
}
else
{
    statement4
}
```

Example: Date Conversion

- Input
  - Date in the form *yyyy-mm-dd*
  - (e.g. 2009-09-24)
- Output
  - Date in the form *month day, year*
  - (e.g. September 24, 2009)

Example: Large Joe’s

Write a simple fast food drive-through ordering program for Large Joe’s restaurant. The menu is:

Triple Burger:	$4.99
Fried Chicken	$6.99
French Fries	$2.29

Sample run (user input in **bold**):

```
== Welcome to Large Joe's, can I take your order? ==
For a triple burger, press 1
For a heap of fried chicken, press 2
Your order: 1

Would you like fries with that? (y/n): y

Your total is $7.28, please drive through.
```

Example: Large Joe’s

- Large Joe’s now has bacon!
  - Adding bacon to your burger costs $0.99
  - Modify the program so that if the customer orders a burger, the program asks them:

```
Would you like bacon on your burger? (y/n): y
```

  - If they answer yes, add the cost to their order
  - Don’t ask about bacon if they didn’t order a burger!

A Repetitive Task

- Get six numbers from the user
- Add them all together
- Print the result to the screen

- Requires:
  - Six variables to hold input (e.g. num1, num2, num3, etc.)
  - Six input statements

- Repetitive and inefficient
  - Worse, what if it was 1000 numbers (perhaps from a file rather than from a user)?

Repetitive Execution

- A better solution:
  - Tell the computer to *iterate*, to do the same thing six times
    - Get a number from the user
    - Add it to a running total
  - Then print the result

- Requires:
  - Two variables (input and total)
  - One input statement for each *iteration*

- Pretty much any real program involves iteration

Conditional Execution

- `if…else` is used to control conditional execution

```
if( condition )
{
   // do some stuff only if condition is true


}
```

- Conditional execution happens 0 or 1 time
- Condition is a logical expression
  – Evaluates to `true` (`1`) or `false` (`0`)
  – Can be a literal, a variable, a function or an expression

Iterative Execution

- `while` used to control iterative execution (looping)

```
while( condition )
{
   // do some stuff repeatedly as long
   //  as condition is true
}
```

- Iterative execution happens 0 or more times
- Condition is a logical expression
  - Evaluates to `true` (`1`) or `false` (`0`)
  - Can be a literal, a variable, a function or an expression

while Looping (Repetition) Structure

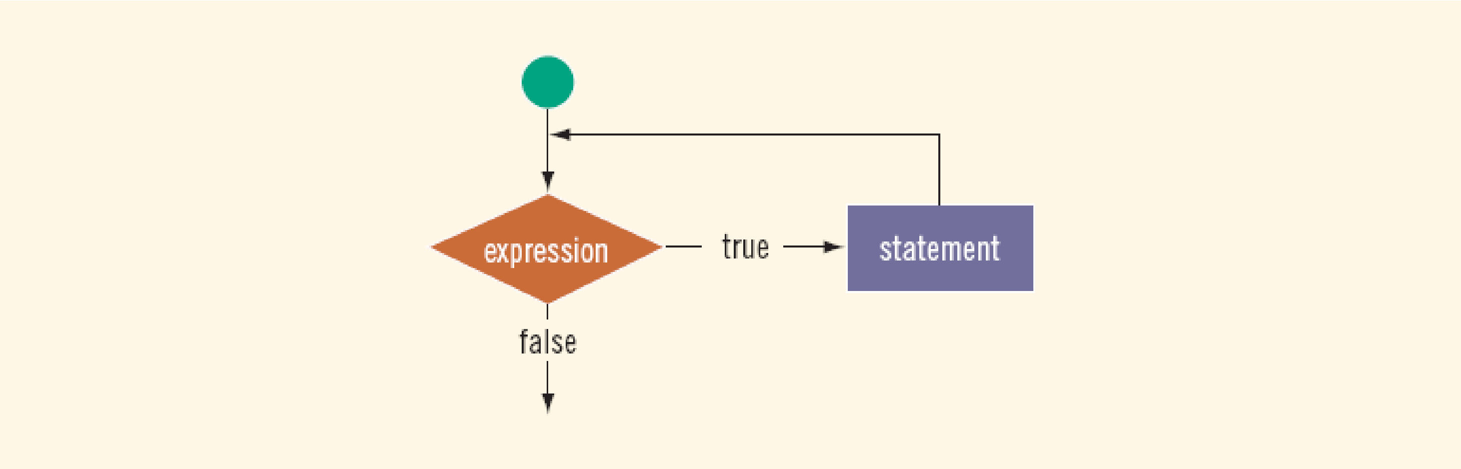


FIGURE 5-1 while loop

- Infinite loop: continues to execute endlessly
  - Avoided by including statements in loop body that assure exit condition is eventually false

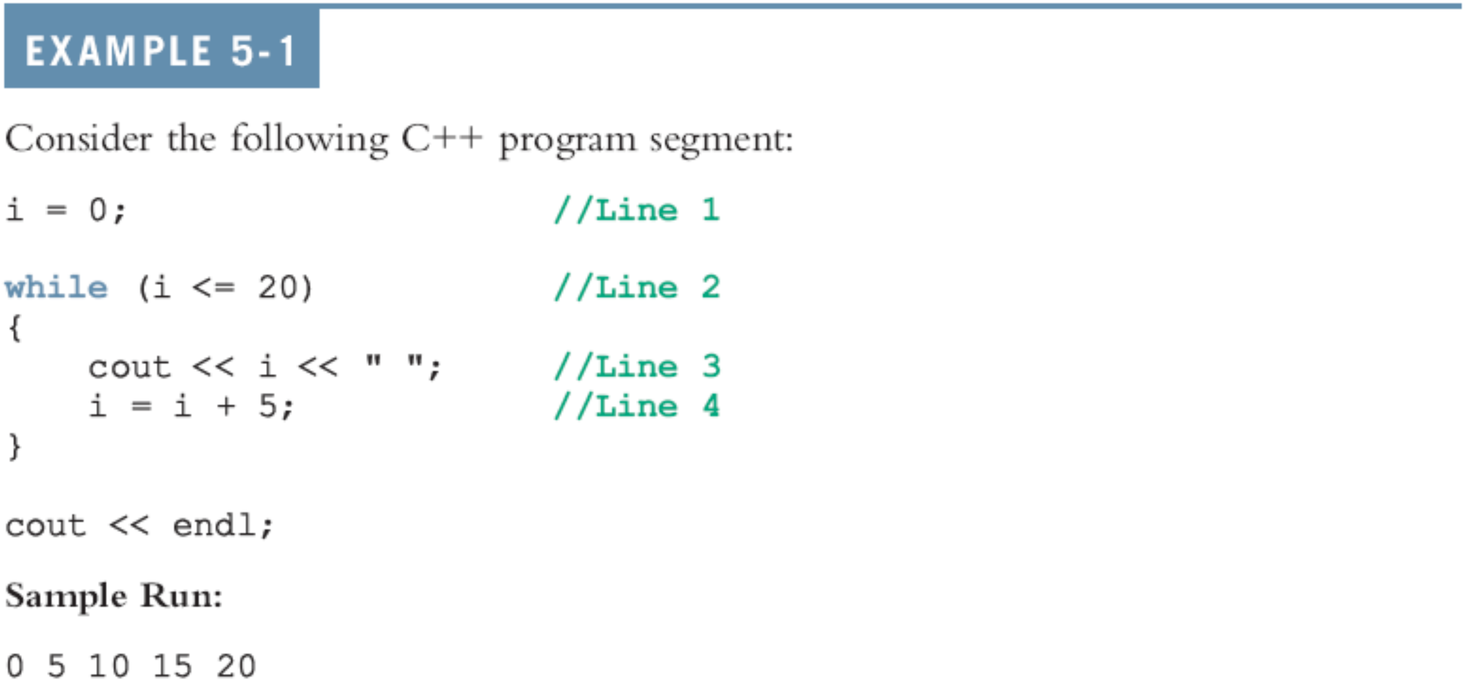
Elements of an Iterative Statement

- There are three key parts to an iterative statement:
  - Initialization (before the loop)
    - What are the values of variables set to before the loop starts?
  - Condition (the while condition)
    - When does the loop quit?
  - Update (in the body of the loop)
    - How are those values changed in the loop?

Example Case: Counter Loop

- Use a `while` loop to do something a predetermined number of times
  1. Initialization (before the loop)
     - Declare a variable to use as a counter
     - Assign it the value to start counting at
  2. Condition (the while condition)
     - Check to see if the counter value has reached the target count
       - If it has, quit the loop
  3. Update (in the body of the loop)
     - Increment or decrement the counter value
     - Do the other repetitive tasks as well
  4. Steps 2 and 3 repeat

while Looping (Repetition) Structure (continued)



EXAMPLE 5-1

Consider the following C++ program segment:

```
i = 0;                        //Line 1

while (i <= 20)               //Line 2
{
    cout << i << " ";         //Line 3
    i = i + 5;                //Line 4
}

cout << endl;
```

Sample Run:

```
0 5 10 15 20
```

The Rest of the Loop

- The body of a counter loop must update the counter
  - But it also does whatever repetitive tasks you are trying to accomplish
    - Update other variables
    - Get input
    - Print output
    - Etc…

Exercise

```
int i = 0, j = 0;
while( i < 5 )
{
     j = j + 10;
     i++;
}
```

- Initialization:
  - Both `i` and `j` are set to 0 before the loop
- Update:
  - Both `i` and `j` are assigned new values in the body of the loop
- Condition:
  - The loop stops based on the value of `i`

Exercise

- What are the values of `i`, `j` at the beginning of each iteration of this loop?

```
int i = 0, j = 0;
while( i < 5 )
{
    j = j + 10;
    i++;
}
```

Iteration	`i`	`j`
first		
second		
third		
…		

Exercise

- Write the output of the following loops:

a:

```
int i = 0;
while ( i < 5 )
{
    cout << i << “ ”;
    cout << endl;
    i++;
}
```

b:

```
int i = 0;
while ( i < 5 )
{
    i++;
    cout << i << “ ”;
}
cout << endl;
```

Example Case: Input Condition

- Use a while loop to do something until input (user, file, etc) tells us to stop

1. Initialization (before the loop)
    - Declare a variable to hold the user input
    - Assign it an initial value
2. Condition (the while condition)
    - Check to see if the input variable matches the target value
        - If it does, quit the loop
3. Update (in the body of the loop)
    - Get new input
4. Steps 2 and 3 repeat

Exercise

- Write a while loop that:
  - Asks the user to enter a number
  - If the number is -99 it quits
  - Otherwise, adds that number to a running total
  - And repeat
  - Initialization
    - Variables to hold user input and the accumulated total
      - Initial values?
  - Condition
    - Is the latest input equal to -99?
  - Update
    - Add the last number to the total
    - Get the next user input

Combining Conditions

- A loop may depend on multiple conditions, just like with `if…else`
  - Can use a complex logical statement (using `&&`, `||`)
  - Can also use an intermediate boolean *flag* variable

Example Case: Flag Variable

- Use a `while` loop to do something until a certain boolean variable becomes false

1. Initialization (before the loop)
   - Declare a boolean *flag* variable
   - Assign it an initial value of true
2. Condition (the while condition)
   - Check to see if the flag is true
     - If it is not, quit the loop
3. Update (in the body of the loop)
   - Do the repetitive tasks
   - Something in the body must potentially set the flag to false, otherwise the loop will never end
4. Steps 2 and 3 repeat

`do…while` Loop

- `while` loop executes 0 or more times
- `do…while` loop executes 1 or more times

```
do
{
   // do some stuff then repeat
   //  as long as condition is true
}
while( condition )
```

while vs. do…while Loop

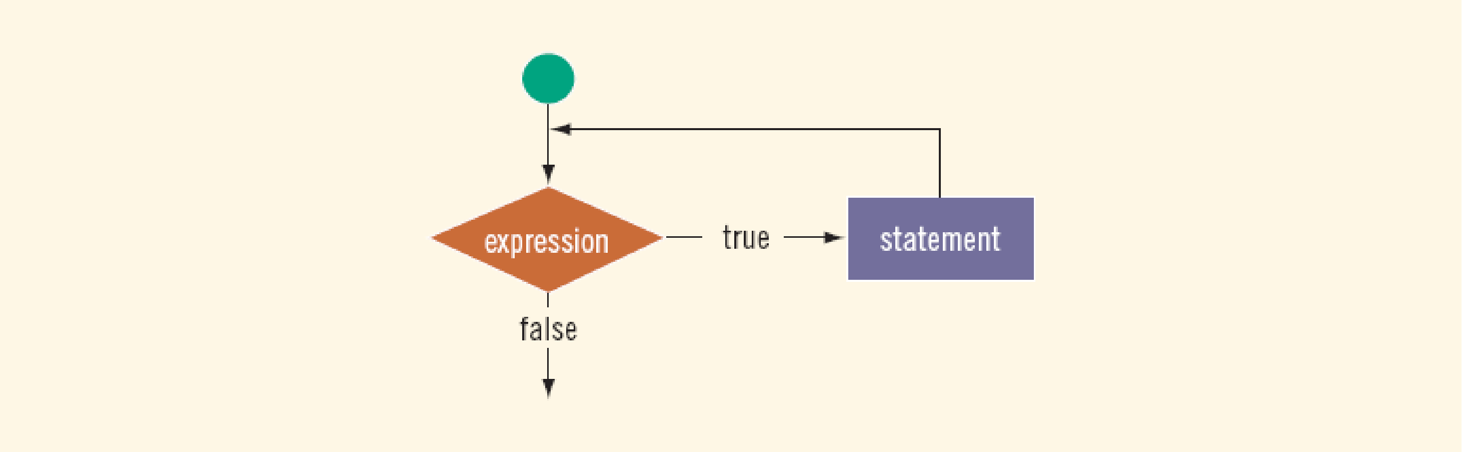


FIGURE 5-1 while loop

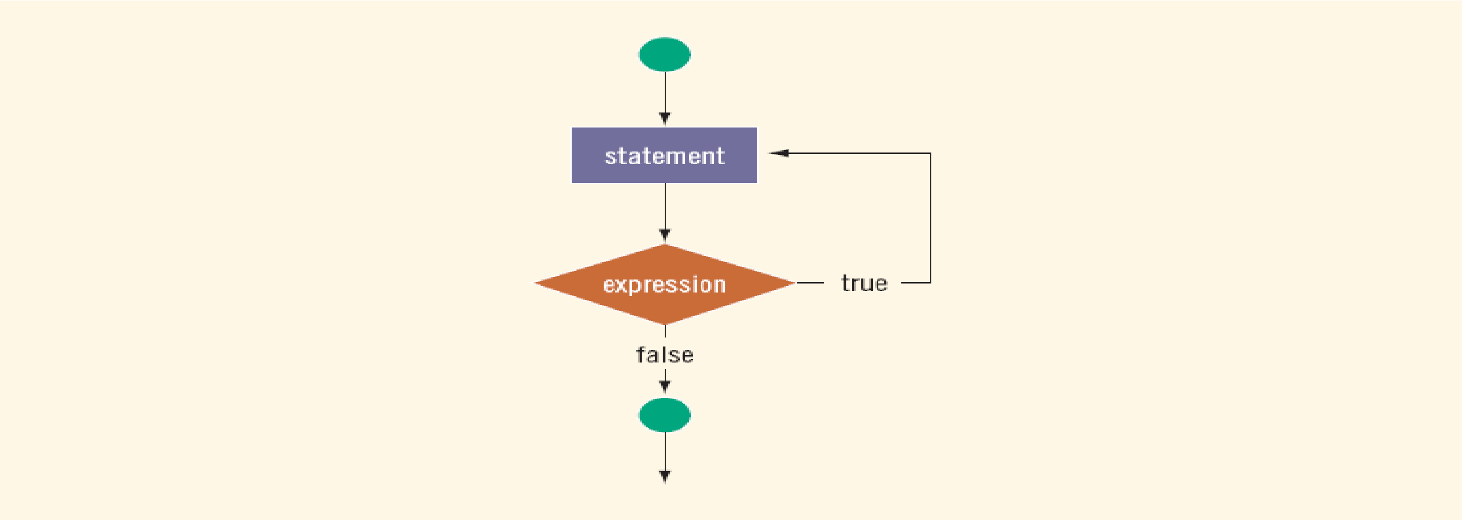


FIGURE 5-3 do...while loop