Week 5 Lecture Notes: Loops and Files Objectives

Concepts covered in this lesson:

- Looping ; The Increment and Decrement Operators
- Introduction to Loops: The while Loop
- Using the while Loop for Input Validation
- Counters
- The do-while Loop ; The for Loop
- Sentinels
- Using a Loop to Read Data from a File
- Deciding Which Loop to Use
- Nested Loops
- Breaking Out of a Loop
- The continue Statement

The Increment and Decrement Operators

- ++ is the increment operator.
  It adds one to a variable.

  `val++;` is the same as `val = val + 1;`
- ++ can be used before (prefix) or after (postfix) a variable:

```
++val;      val++;
```

The Increment and Decrement Operators

- `--` is the decrement operator.
  It subtracts one from a variable.

  `val--;` is the same as `val = val - 1;`
- `--` can be also used before (prefix) or after (postfix) a variable:

```
--val;      val--;
```

Increment and Decrement Operators in Program 5-1

Program 5-1

```
1  // This program demonstrates the ++ and -- operators.
2  #include <iostream>
3  using namespace std;
4
5  int main()
6  {
7     int num = 4;    // num starts out with 4.
8
9     // Display the value in num.
10    cout << "The variable num is " << num << endl;
11    cout << "I will now increment num.\n\n";
12
13    // Use postfix ++ to increment num.
14    num++;
15    cout << "Now the variable num is " << num << endl;
16    cout << "I will increment num again.\n\n";
17
18    // Use prefix ++ to increment num.
19    ++num;
20    cout << "Now the variable num is " << num << endl;
21    cout << "I will now decrement num.\n\n";
22
23    // Use postfix -- to decrement num.
24    num--;
25    cout << "Now the variable num is " << num << endl;
26    cout << "I will decrement num again.\n\n";
27
```

Continued…

Increment and Decrement Operators in Program 5-1

Program 5-1 *(continued)*

```
28      // Use prefix -- to increment num.
29      --num;
30      cout << "Now the variable num is " << num << endl;
31      return 0;
32  }
```

Program Output

```
The variable num is 4
I will now increment num.

Now the variable num is 5
I will increment num again.

Now the variable num is 6
I will now decrement num.

Now the variable num is 5
I will decrement num again.

Now the variable num is 4
```

Prefix vs. Postfix

- `++` and `--` operators can be used in complex statements and expressions
- In prefix mode (`++val, --val`) the operator increments or decrements, *then* returns the value of the variable
- In postfix mode (`val++, val--`) the operator returns the value of the variable, *then* increments or decrements

Prefix vs. Postfix - Examples

```
int num, val = 12;
cout << val++; // displays 12,
               // val is now 13;
cout << ++val; // sets val to 14,
                 // then displays it
num = --val;    // sets val to 13,
               // stores 13 in num
num = val--;    // stores 13 in num,
               // sets val to 12
```

Notes on Increment and Decrement

- Can be used in expressions:

```
result = num1++ + --num2;
```

- Must be applied to something that has a location in memory. Cannot have:

```
result = (num1 + num2)++;
```

- Can be used in relational expressions:

```
if (++num > limit)
```

  pre- and post-operations will cause different comparisons

5.2

Introduction to Loops: The `while` Loop

Introduction to Loops: The `while` Loop

- Loop: a control structure that causes a statement or statements to repeat
- General format of the `while` loop:

```
while (expression)
      statement;
```

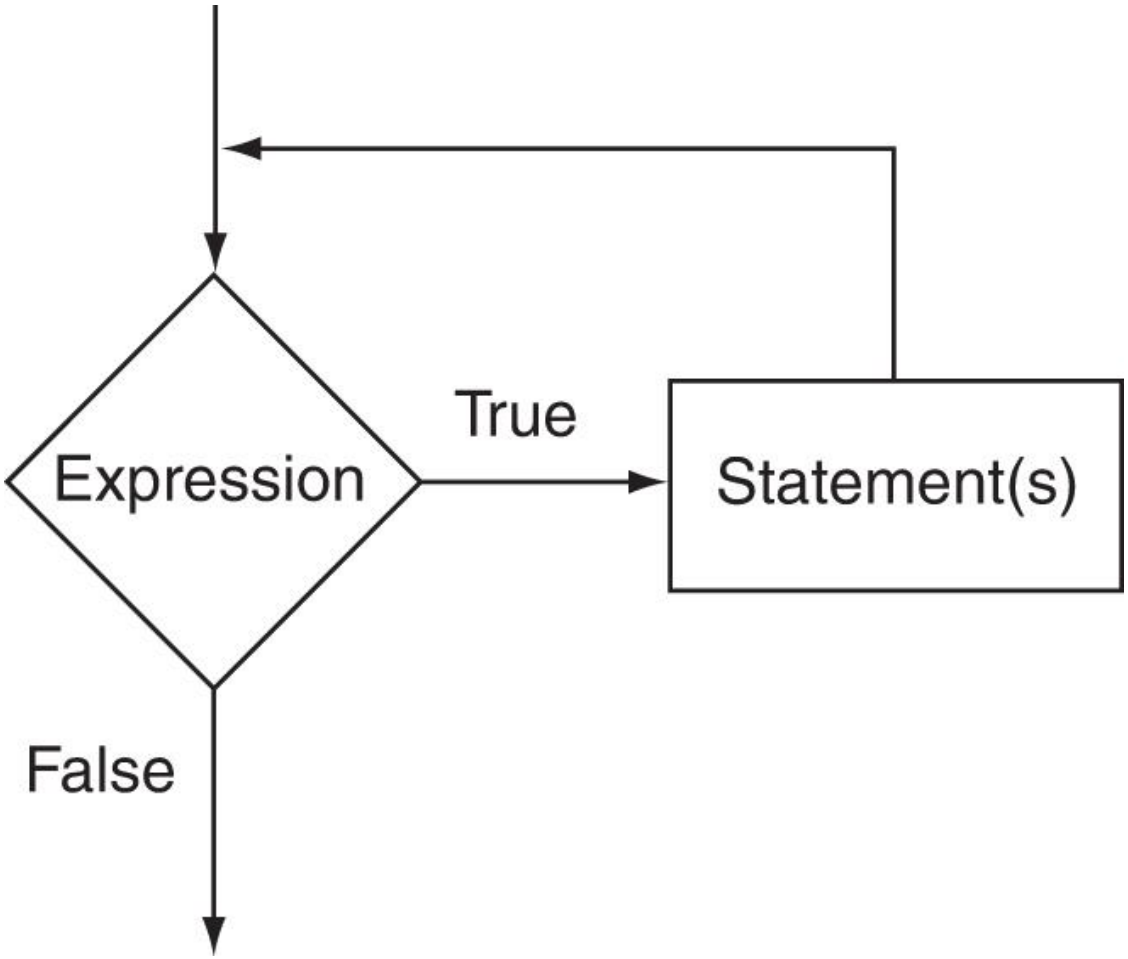
- *`statement;`* can also be a block of statements enclosed in `{ }`

The `while` Loop – How It Works

```
while (expression)
      statement;
```

- *`expression`* is evaluated
  - if `true`, then *`statement`* is executed, and *`expression`* is evaluated again
  - if `false`, then the loop is finished and program statements following *`statement`* execute

The Logic of a `while` Loop



The `while` loop in Program 5-3

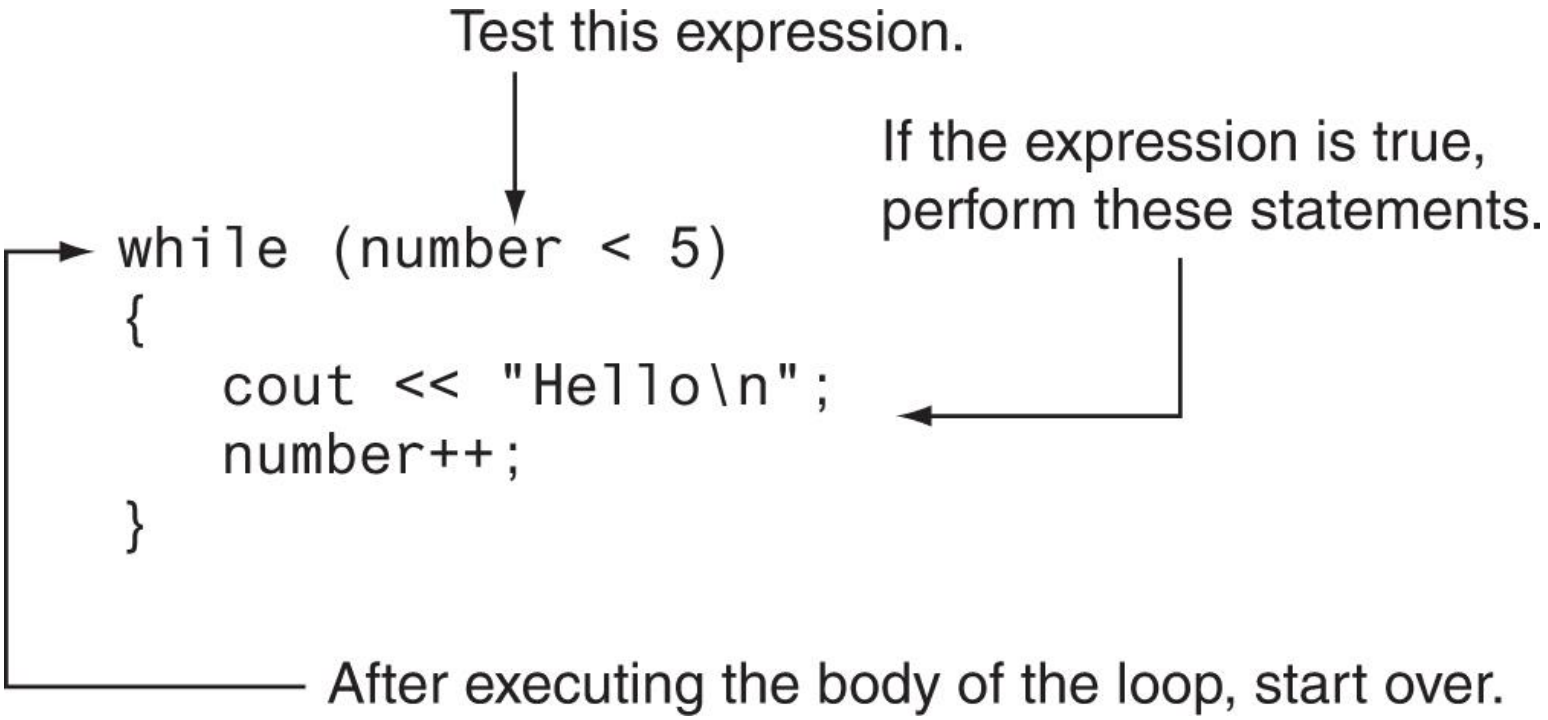
Program 5-3

```
1  // This program demonstrates a simple while loop.
2  #include <iostream>
3  using namespace std;
4
5  int main()
6  {
7     int number = 1;
8
9     while (number <= 5)
10    {
11       cout << "Hello\n";
12       number++;
13    }
14    cout << "That's all!\n";
15    return 0;
16 }
```

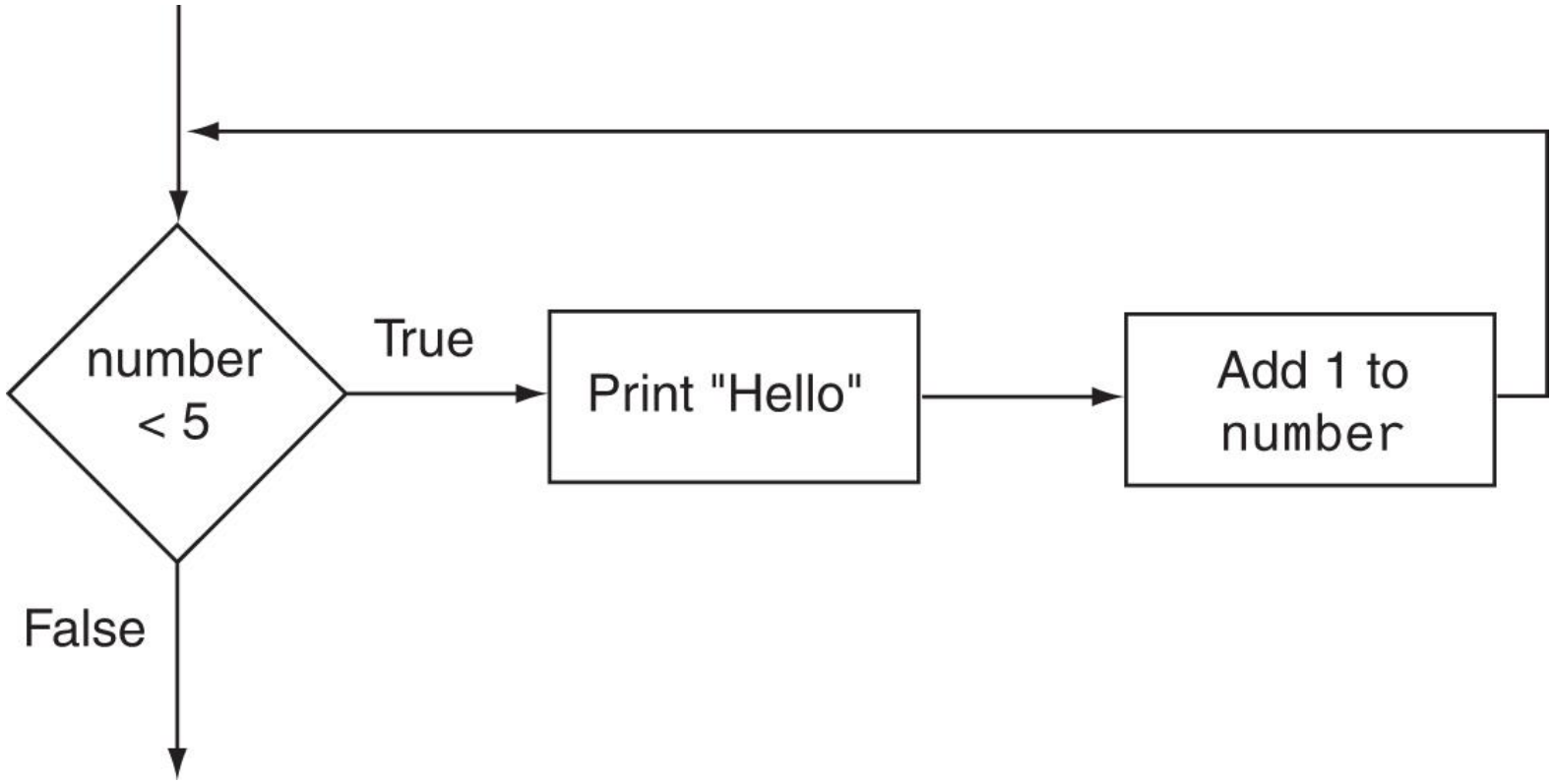
Program Output

```
Hello
Hello
Hello
Hello
Hello
That's all!
```

How the `while` Loop in Program 5-3 Lines 9 through 13 Works



Flowchart of the `while` Loop in Program 5-3



The `while` Loop is a Pretest Loop

`expression` is evaluated *before* the loop executes. The following loop will never execute:

```
int number = 6;
while (number <= 5)
{
   cout << "Hello\n";
   number++;
}
```

Watch Out for Infinite Loops

- The loop must contain code to make *`expression`* become `false`
- Otherwise, the loop will have no way of stopping
- Such a loop is called an *infinite loop*, because it will repeat an infinite number of times

Example of an Infinite Loop

```
int number = 1;
while (number <= 5)
{
    cout << "Hello\n";
}
```

5.3

Using the `while` Loop for Input Validation

Using the `while` Loop for Input Validation

- Input validation is the process of inspecting data that is given to the program as input and determining whether it is valid.

- The while loop can be used to create input routines that reject invalid data, and repeat until valid data is entered.

Using the `while` Loop for Input Validation

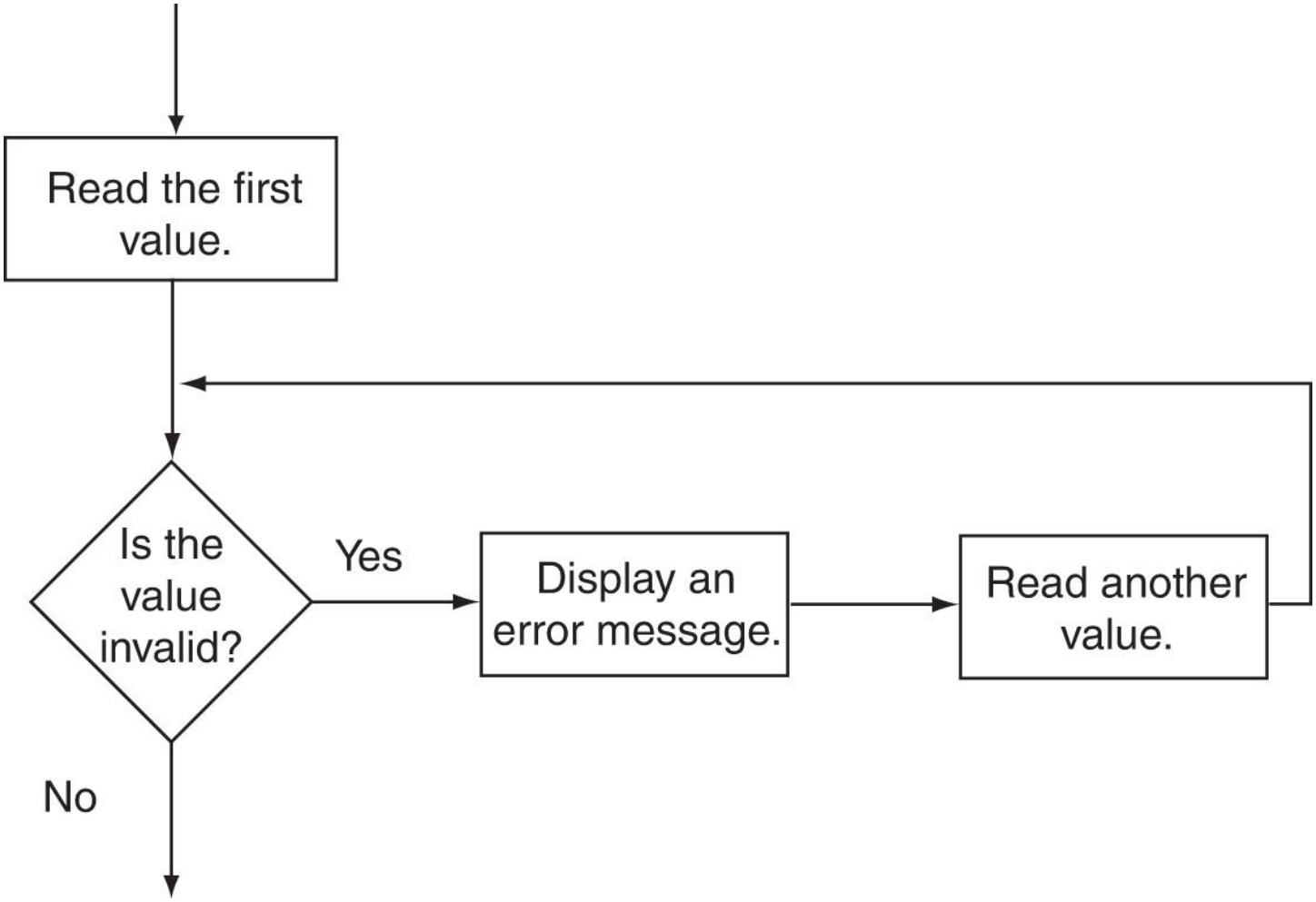
- Here's the general approach, in pseudocode:

Read an item of input.
While the input is invalid
    Display an error message.
    Read the input again.
End While

Input Validation Example

```
cout << "Enter a number less than 10: ";
cin >> number;
while (number >= 10)
{
   cout << "Invalid Entry!"
        << "Enter a number less than 10: ";
   cin >> number;
}
```

Flowchart for Input Validation



Input Validation in Program 5-5

```
20    // Get the number of players per team.
21    cout << "How many players do you wish per team? ";
22    cin >> teamPlayers;
23
24    // Validate the input.
25    while (teamPlayers < MIN_PLAYERS || teamPlayers > MAX_PLAYERS)
26    {
27       // Explain the error.
28       cout << "You should have at least " << MIN_PLAYERS
29            << " but no more than " << MAX_PLAYERS << " per team.\n";
30
31       // Get the input again.
32       cout << "How many players do you wish per team? ";
33       cin >> teamPlayers;
34    }
35
36    // Get the number of players available.
37    cout << "How many players are available? ";
38    cin >> players;
39
40    // Validate the input.
41    while (players <= 0)
42    {
43       // Get the input again.
44       cout << "Please enter 0 or greater: ";
45       cin >> players;
46    }
```

5.4

Counters

Counters

- Counter: a variable that is incremented or decremented each time a loop repeats
- Can be used to control execution of the loop (also known as the *loop control variable*)
- Must be initialized before entering loop

A Counter Variable Controls the Loop in Program 5-6

Program 5-6

```
1  // This program displays a list of numbers and
2  // their squares.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8     const int MIN_NUMBER = 1,    // Starting number to square
9               MAX_NUMBER = 10;   // Maximum number to square
10
11    int num = MIN_NUMBER;        // Counter
12
13    cout << "Number Number Squared\n";
14    cout << "-------------------------\n";
```

Continued…

A Counter Variable Controls the Loop in Program 5-6

```
15     while (num <= MAX_NUMBER)
16     {
17        cout << num << "\t\t" << (num * num) << endl;
18        num++; //Increment the counter.
19     }
20     return 0;
21  }
```

Program Output

```
Number Number Squared
---------------------
1            1
2            4
3            9
4            16
5            25
6            36
7            49
8            64
9            81
10           100
```

5.5

The `do-while` Loop

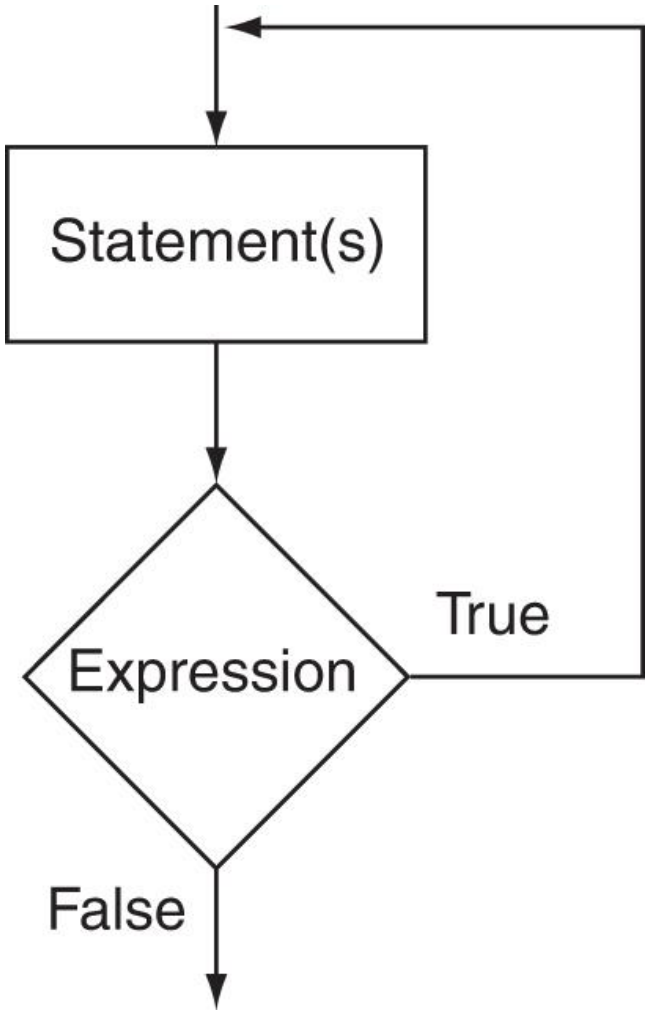
The `do-while` Loop

- `do-while`: a posttest loop – execute the loop, then test the `expression`
- General Format:

```
do
   statement;  // or block in { }
while (expression);
```

- Note that a semicolon is required after `(expression)`

The Logic of a `do-while` Loop



An Example `do-while` Loop

```
int x = 1;
do
{
    cout << x << endl;
} while(x < 0);
```

Although the test expression is false, this loop will execute one time because `do-while` is a posttest loop.

A `do-while` Loop in Program 5-7

Program 5-7

```
1  // This program averages 3 test scores. It repeats as
2  // many times as the user wishes.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8     int score1, score2, score3; // Three scores
9     double average;             // Average score
10    char again;                 // To hold Y or N input
11
12    do
13    {
14       // Get three scores.
15       cout << "Enter 3 scores and I will average them: ";
16       cin >> score1 >> score2 >> score3;
17
18       // Calculate and display the average.
19       average = (score1 + score2 + score3) / 3.0;
20       cout << "The average is " << average << ".\n";
21
22       // Does the user want to average another set?
23       cout << "Do you want to average another set? (Y/N) ";
24       cin >> again;
25    } while (again == 'Y' || again == 'y');
26    return 0;
27 }
```

Continued…

A `do-while` Loop in Program 5-7

Program Output with Example Input Shown in Bold

```
Enter 3 scores and I will average them: 80 90 70 [Enter]
The average is 80.
Do you want to average another set? (Y/N) y [Enter]
Enter 3 scores and I will average them: 60 75 88 [Enter]
The average is 74.3333.
Do you want to average another set? (Y/N) n [Enter]
```

`do-while` Loop Notes

- Loop always executes at least once
- Execution continues as long as *`expression`* is `true`, stops repetition when *`expression`* becomes `false`
- Useful in menu-driven programs to bring user back to menu to make another choice (*see* Program 5-8 *on pages* 245-246)

5.6

The `for` Loop

The `for` Loop

- Useful for counter-controlled loop
- General Format:

```
for(initialization; test; update)
   statement; // or block in { }
```

- No semicolon after the `update` expression or after the)

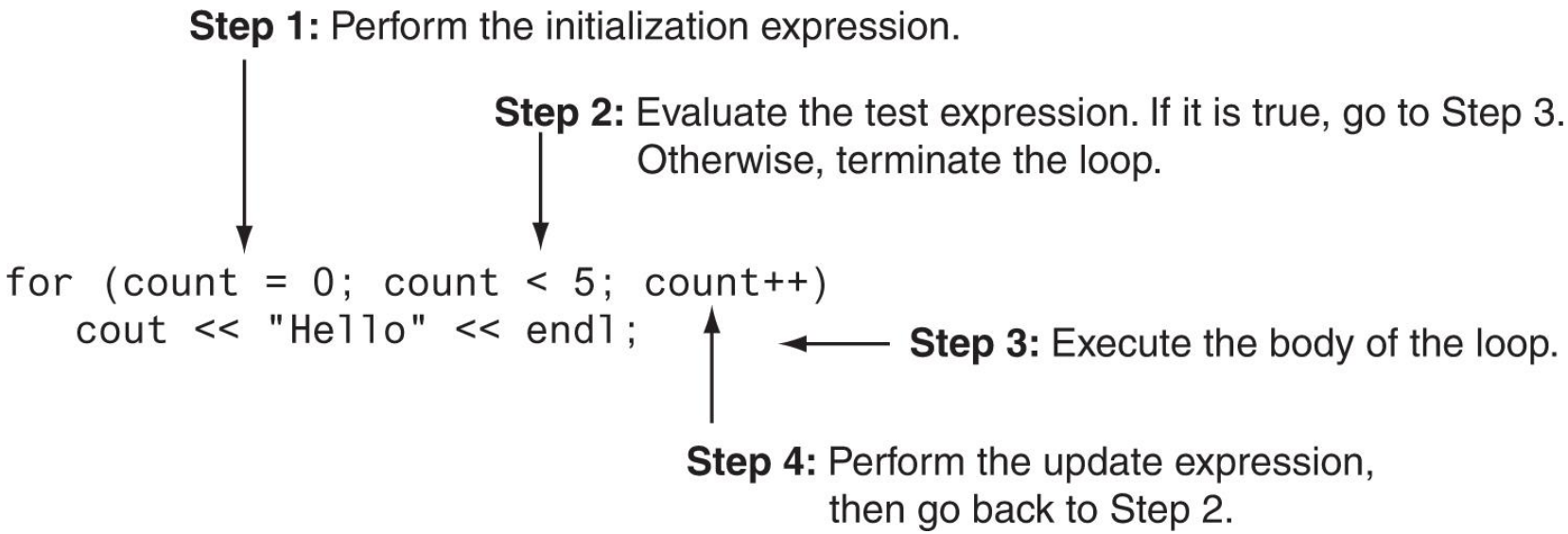
`for` Loop - Mechanics

```
for(initialization; test; update)
        statement; // or block in { }
```

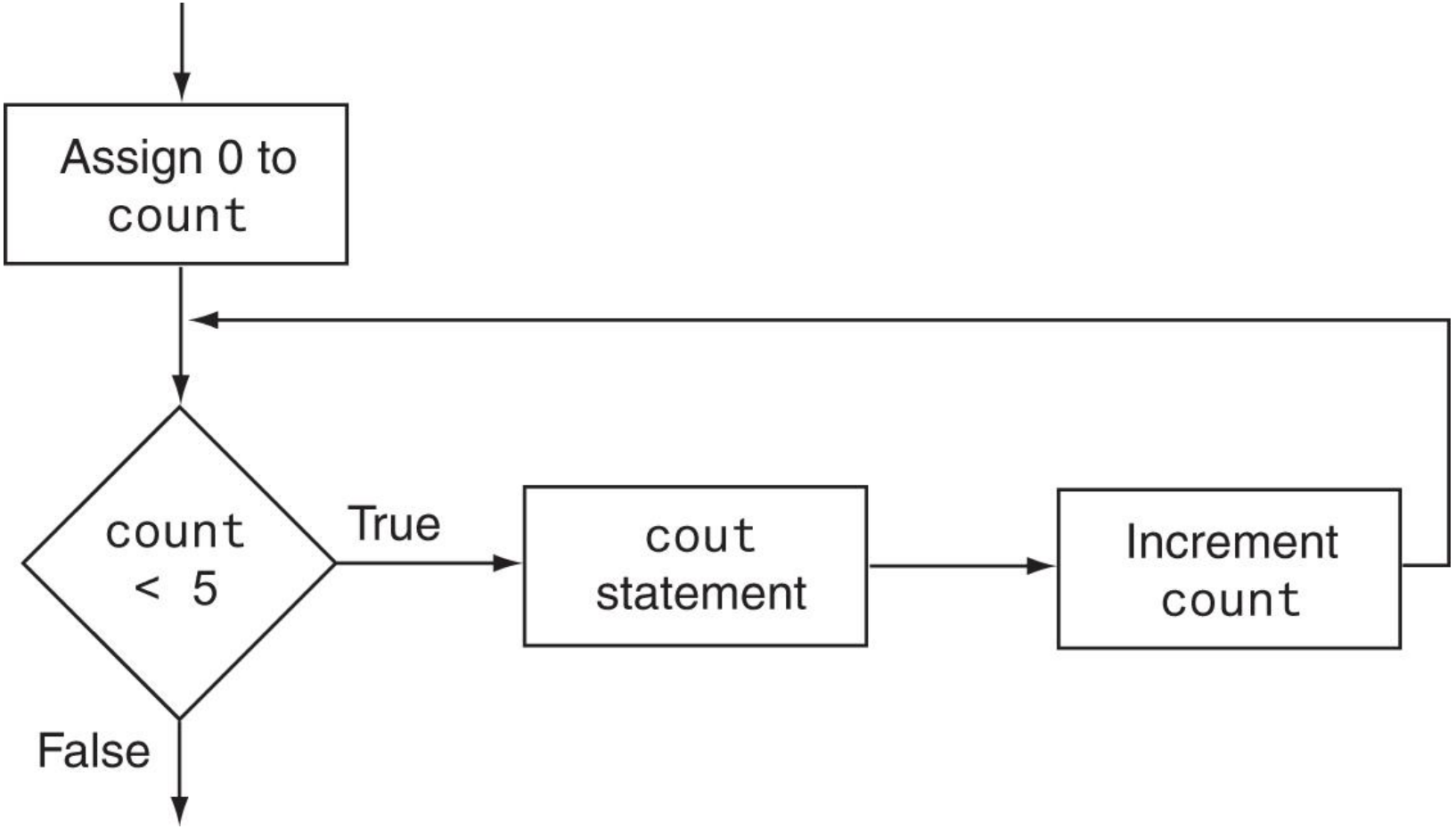
1) Perform *initialization*
2) Evaluate *test* expression
   - If `true`, execute *statement*
   - If `false`, terminate loop execution
3) Execute *update*, then re-evaluate *test* expression

`for` Loop - Example

A Closer Look at the Previous Example



Flowchart for the Previous Example



A `for` Loop in Program 5-9

Program 5-9

```
1  // This program displays the numbers 1 through 10 and
2  // their squares.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8     const int MIN_NUMBER = 1,    // Starting value
9               MAX_NUMBER = 10;   // Ending value
10    int num;
11
12    cout << "Number Number Squared\n";
13    cout << "-------------------------\n";
14
15    for (num = MIN_NUMBER; num <= MAX_NUMBER; num++)
16       cout << num << "\t\t" << (num * num) << endl;
17
18    return 0;
19 }
```

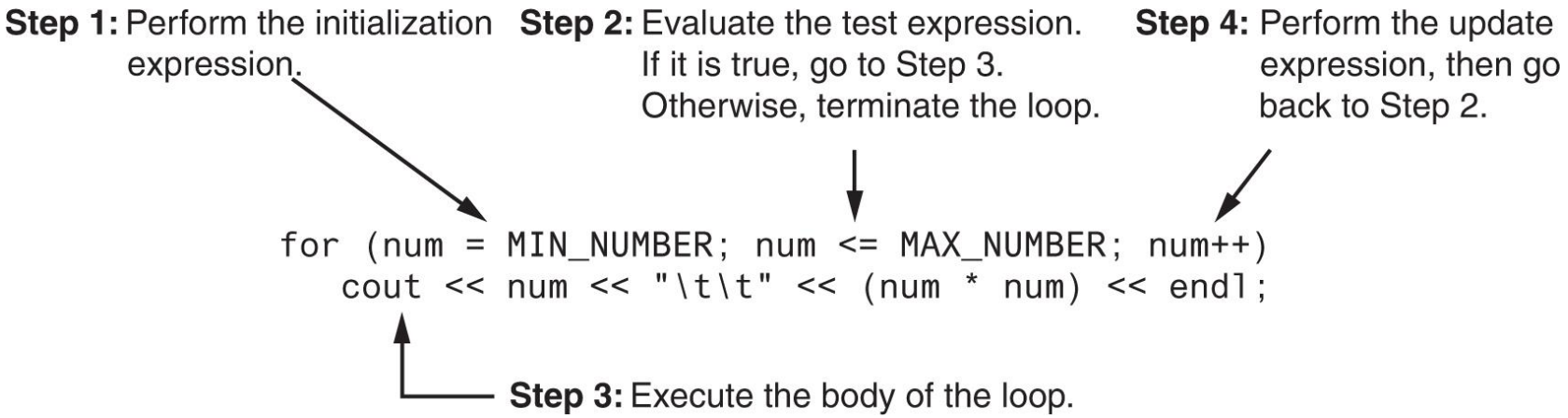
Continued…

A `for` Loop in Program 5-9

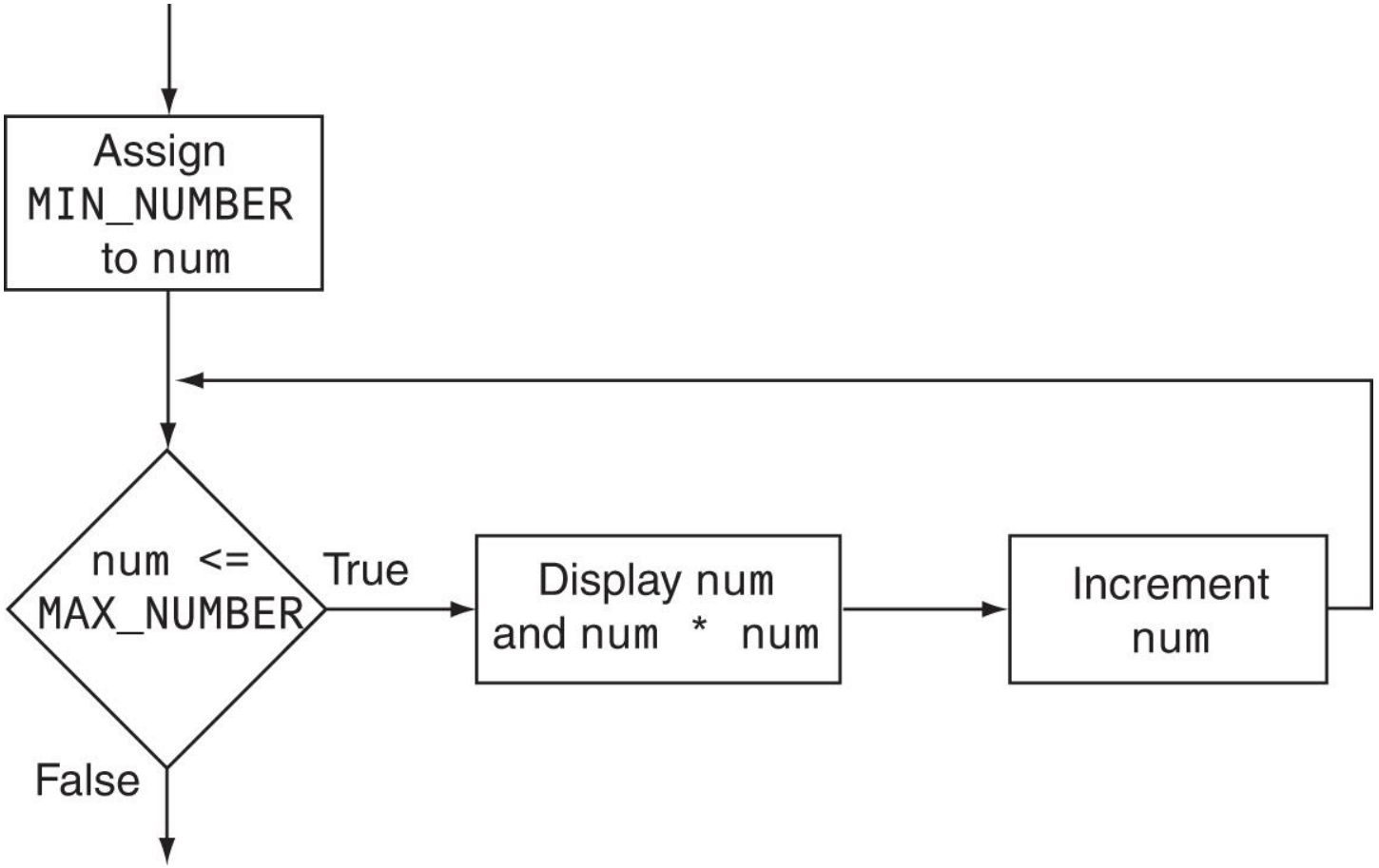
Program Output

```
Number Number Squared
---------------------
1              1
2              4
3              9
4              16
5              25
6              36
7              49
8              64
9              81
10             100
```

A Closer Look at Lines 15 through 16 in Program 5-9



Flowchart for Lines 15 through 16 in Program 5-9



When to Use the `for` Loop

- In any situation that clearly requires
  - an initialization
  - a false condition to stop the loop
  - an update to occur at the end of each iteration

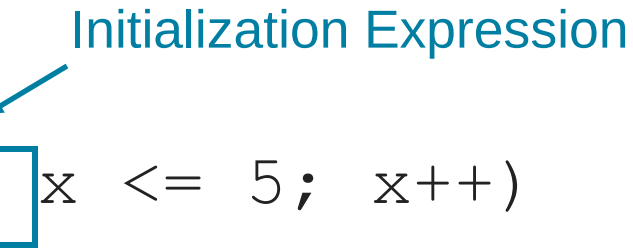
The `for` Loop is a Pretest Loop

- The for loop tests its test expression before each iteration, so it is a pretest loop.
- The following loop will never iterate:

```
for (count = 11; count <= 10;
count++)
   cout << "Hello" << endl;
```

`for` Loop - Modifications

- You can have multiple statements in the *`initialization`* expression. Separate the statements with a comma:

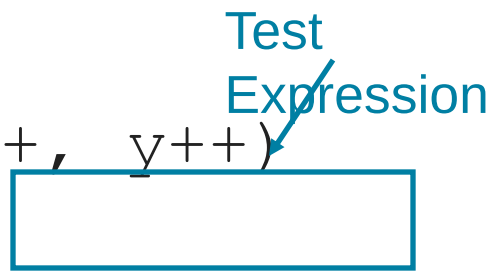



```
int x, y;
for (x=1, y=1; x <= 5; x++)
{
   cout << x << " plus " << y
        << " equals " << (x+y)
        << endl;
}
```

`for` Loop - Modifications

- You can also have multiple statements in the *`test`* expression. Separate the statements with a comma:

```
int x, y;
for (x=1, y=1; x <= 5; x++, y++)
{
   cout << x << " plus " << y
        << " equals " << (x+y)
        << endl;
}
```



`for` Loop - Modifications

- You can omit the *`initialization`* expression if it has already been done:

```
int sum = 0, num = 1;
for (; num <= 10; num++)
     sum += num;
```

`for` Loop - Modifications

- You can declare variables in the *`initialization`* expression:

```
int sum = 0;
for (int num = 0; num <= 10; num++)
     sum += num;
```

The scope of the variable `num` is the `for` loop.

5.7

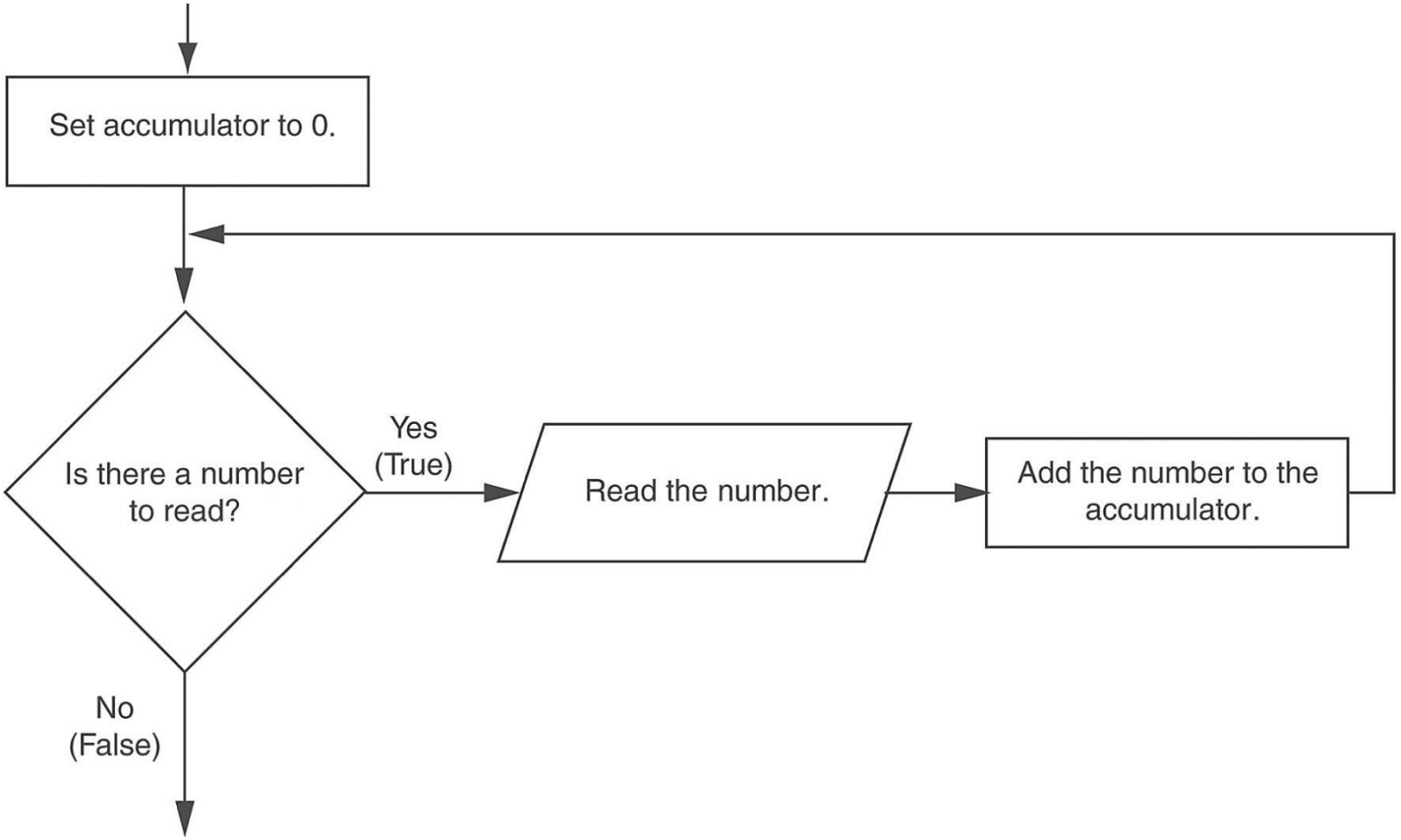
Keeping a Running Total

Keeping a Running Total

- running total: accumulated sum of numbers from each repetition of loop
- accumulator: variable that holds running total

```
 int sum=0, num=1; // sum is the
while (num <= 10) // accumulator
{   sum += num;
    num++;
}
cout << "Sum of numbers 1 - 10 is"
     << sum << endl;
```

Logic for Keeping a Running Total



A Running Total in Program 5-12

Program 5-12

```
1  // This program takes daily sales amounts over a period of time
2  // and calculates their total.
3  #include <iostream>
4  #include <iomanip>
5  using namespace std;
6
7  int main()
8  {
9       int days;            // Number of days
10      double total = 0.0; // Accumulator, initialized with 0
11
12      // Get the number of days.
13      cout << "For how many days do you have sales amounts? ";
```

Continued…

A Running Total in Program 5-12

```
14      cin >> days;
15
16      // Get the sales for each day and accumulate a total.
17      for (int count = 1; count <= days; count++)
18      {
19          double sales;
20          cout << "Enter the sales for day " << count << ": ";
21          cin >> sales;
22          total += sales;  // Accumulate the running total.
23      }
24
25      // Display the total sales.
26      cout << fixed << showpoint << setprecision(2);
27      cout << "The total sales are $" << total << endl;
28      return 0;
29  }
```

Program Output with Example Input Shown in Bold

```
For how many days do you have sales amounts? 5 Enter
Enter the sales for day 1: 489.32 Enter
Enter the sales for day 2: 421.65 Enter
Enter the sales for day 3: 497.89 Enter
Enter the sales for day 4: 532.37 Enter
Enter the sales for day 5: 506.92 Enter
The total sales are $2448.15
```

5.8

Sentinels

Sentinels

- sentinel: value in a list of values that indicates end of data
- Special value that cannot be confused with a valid value, *e.g.*, `-999` for a test score
- Used to terminate input when user may not know how many values will be entered

A Sentinel in Program 5-13

Program 5-13

```
1  // This program calculates the total number of points a
2  // soccer team has earned over a series of games. The user
3  // enters a series of point values, then -1 when finished.
4  #include <iostream>
5  using namespace std;
6
7  int main()
8  {
9     int game = 1,    // Game counter
10        points,      // To hold a number of points
11        total = 0;   // Accumulator
12
13    cout << "Enter the number of points your team has earned\n";
14    cout << "so far in the season, then enter -1 when finished.\n\n";
15    cout << "Enter the points for game " << game << ": ";
16    cin >> points;
17
18    while (points != -1)
19    {
20       total += points;
21       game++;
22       cout << "Enter the points for game " << game << ": ";
23       cin >> points;
24    }
25    cout << "\nThe total points are " << total << endl;
26    return 0;
27 }
```

Continued…

A Sentinel in Program 5-13

Program Output with Example Input Shown in Bold

```
Enter the number of points your team has earned
so far in the season, then enter -1 when finished.

Enter the points for game 1: 7 [Enter]
Enter the points for game 2: 9 [Enter]
Enter the points for game 3: 4 [Enter]
Enter the points for game 4: 6 [Enter]
Enter the points for game 5: 8 [Enter]
Enter the points for game 6: -1 [Enter]

The total points are 34
```

5.9

Deciding Which Loop to Use

Deciding Which Loop to Use

- The `while` loop is a conditional pretest loop
  - Iterates as long as a certain condition exits
  - Validating input
  - Reading lists of data terminated by a sentinel
- The `do-while` loop is a conditional posttest loop
  - Always iterates at least once
  - Repeating a menu
- The `for` loop is a pretest loop
  - Built-in expressions for initializing, testing, and updating
  - Situations where the exact number of iterations is known

5.10

Nested Loops

Nested Loops

- A nested loop is a loop inside the body of another loop
- Inner (inside), outer (outside) loops:

```
for (row=1; row<=3; row++)  //outer
   for (col=1; col<=3; col++)//inner
     cout << row * col << endl;
```

Nested `for` Loop in Program 5-14

```
26    // Determine each student's average score.
27    for (int student = 1; student <= numStudents; student++)
28    {
29       total = 0;       // Initialize the accumulator.
30       for (int test = 1; test <= numTests; test++)
31       {
32          double score;
33          cout << "Enter score " << test << " for ";
34          cout << "student " << student << ": ";
35          cin >> score;
36          total += score;
37       }
38       average = total / numTests;
39       cout << "The average score for student " << student;
40       cout << " is " << average << ".\n\n";
41    }
```

Inner Loop

Outer Loop

Nested Loops - Notes

- Inner loop goes through all repetitions for each repetition of outer loop
- Inner loop repetitions complete sooner than outer loop
- Total number of repetitions for inner loop is product of number of repetitions of the two loops.

5.11

Using Files for Data Storage

Using Files for Data Storage

- Can use files instead of keyboard, monitor screen for program input, output
- Allows data to be retained between program runs
- Steps:
  - *Open* the file
  - *Use* the file (read from, write to, or both)
  - *Close* the file

Files: What is Needed

- Use `fstream` header file for file access
- File stream types:
  - `ifstream` for input from a file
  - `ofstream` for output to a file
  - `fstream` for input from or output to a file
- Define file stream objects:

```
ifstream infile;
ofstream outfile;
```

Opening Files

- Create a link between file name (outside the program) and file stream object (inside the program)
- Use the `open` member function:

```
infile.open("inventory.dat");
outfile.open("report.txt");
```

- Filename may include drive, path info.
- Output file will be created if necessary; existing file will be erased first
- Input file must exist for `open` to work

Testing for File Open Errors

- Can test a file stream object to detect if an open operation failed:

```
infile.open("test.txt");
if (!infile)
{
    cout << "File open failure!";
}
```

- Can also use the `fail` member function

Using Files

- Can use output file object and << to send data to a file:

```
outfile << "Inventory report";
```

- Can use input file object and >> to copy data from file to variables:

```
infile >> partNum;
infile >> qtyInStock >> qtyOnOrder;
```

Using Loops to Process Files

- The stream extraction operator >> returns `true` when a value was successfully read, `false` otherwise

- Can be tested in a `while` loop to continue execution as long as values are read from the file:

```
while (inputFile >> number) ...
```

Closing Files

- Use the `close` member function:

```
infile.close();
outfile.close();
```

- Don’t wait for operating system to close files at program end:
  - may be limit on number of open files
  - may be buffered output data waiting to send to file

Letting the User Specify a Filename

- In many cases, you will want the user to specify the name of a file for the program to open.
- In C++ 11, you can pass a `string` object as an argument to a file stream object's `open` member function.

Letting the User Specify a Filename in Program 5-24

Program 5-24

```
1  // This program lets the user enter a filename.
2  #include <iostream>
3  #include <string>
4  #include <fstream>
5  using namespace std;
6
7  int main()
8  {
9       ifstream inputFile;
10      string filename;
11      int number;
12
13      // Get the filename from the user.
14      cout << "Enter the filename: ";
15      cin >> filename;
16
17      // Open the file.
18      inputFile.open(filename);
19
20      // If the file successfully opened, process it.
21      if (inputFile)
```

Continued…

Letting the User Specify a Filename in Program 5-24

```
22      {
23          // Read the numbers from the file and
24          // display them.
25          while (inputFile >> number)
26          {
27              cout << number << endl;
28          }
29
30          // Close the file.
31          inputFile.close();
32      }
33      else
34      {
35          // Display an error message.
36          cout << "Error opening the file.\n";
37      }
38      return 0;
39  }
```

Program Output with Example Input Shown in Bold

```
Enter the filename: ListOfNumbers.txt [Enter]
100
200
300
400
500
600
700
```

Using the `c_str` Member Function in Older Versions of C++

- Prior to C++ 11, the `open` member function requires that you pass the name of the file as a null-terminated string, which is also known as a *C-string*.
- *String literals are stored* in memory as null-terminated C-strings, but *string objects* are **not**.

Using the `c_str` Member Function in Older Versions of C++

- `string` objects have a member function named `c_str`
  - It returns the contents of the object formatted as a null-terminated C-string.
  - Here is the general format of how you call the `c_str` function:

```
stringObject.c_str()
```

    - Line 18 in Program 5-24 could be rewritten in the following manner:

```
inputFile.open(filename.c_str());
```

5.12

Breaking and Continuing a Loop

Breaking Out of a Loop

- Can use `break` to terminate execution of a loop
- Use sparingly if at all – makes code harder to understand and debug
- When used in an inner loop, terminates that loop only and goes back to outer loop

The `continue` Statement

- Can use `continue` to go to end of loop and prepare for next repetition
  - `while`, `do-while` loops: go to test, repeat loop if test passes
  - `for` loop: perform update step, then test, then repeat loop if test passes
- Use sparingly – like `break`, can make program logic hard to follow