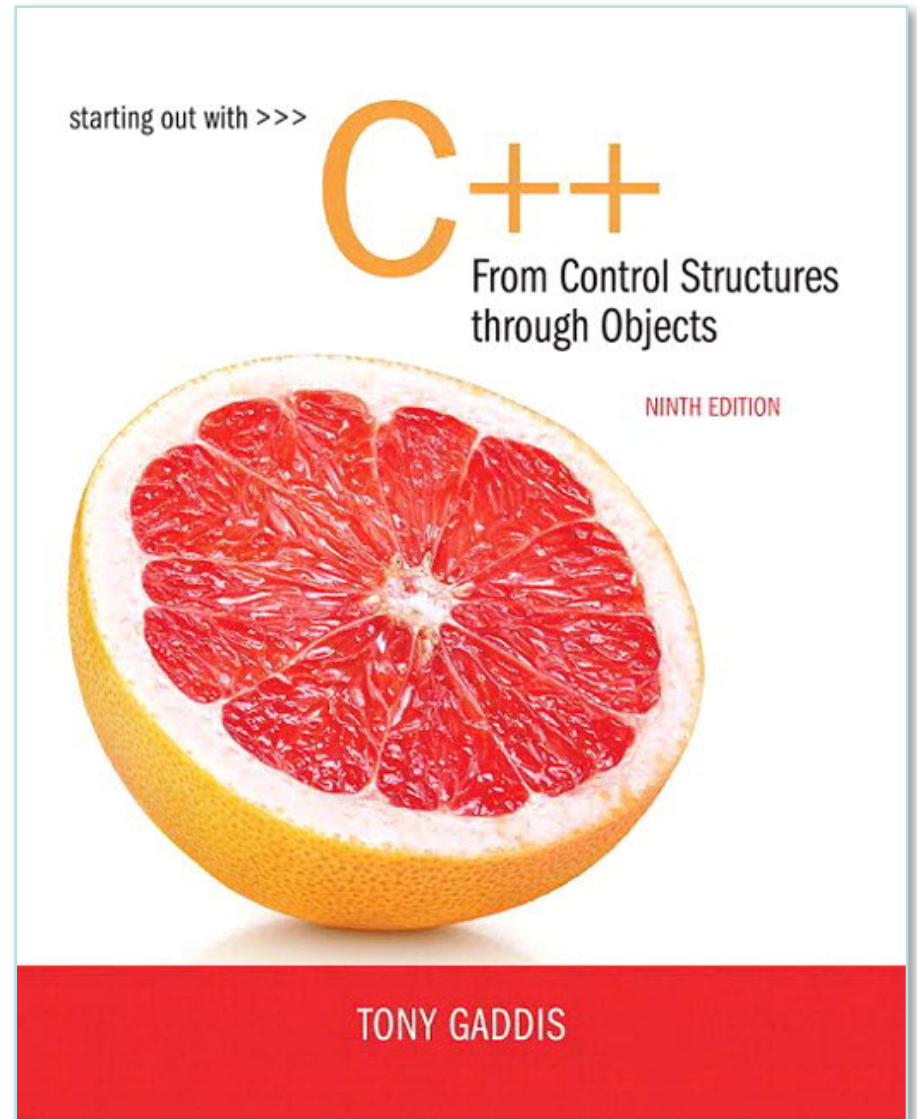


Chapter 5:

Loops and Files



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;
```

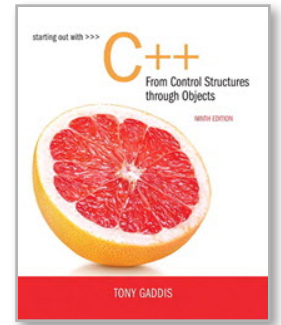
- Must be applied to something that has a location in memory. Cannot have:

```
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;
```

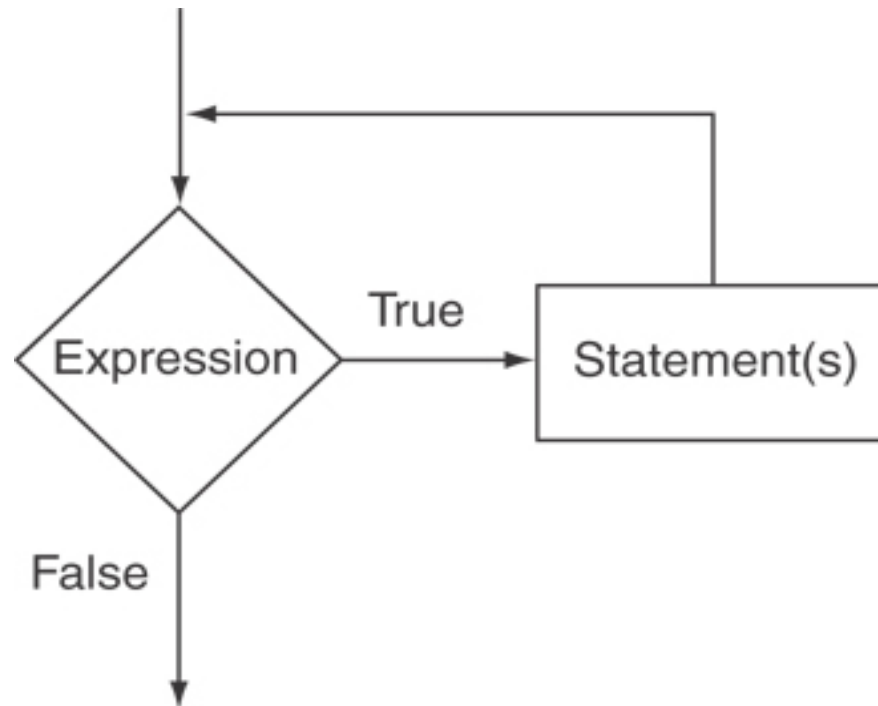
- *statement*; can also be a block of statements enclosed in { }

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

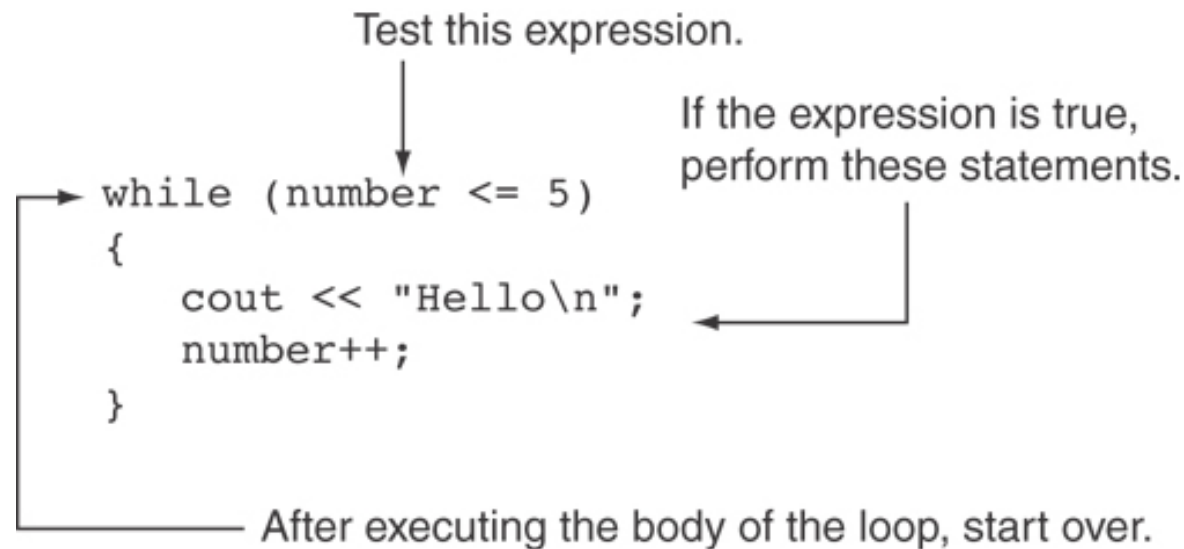
Program 5-3

```
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 }
```

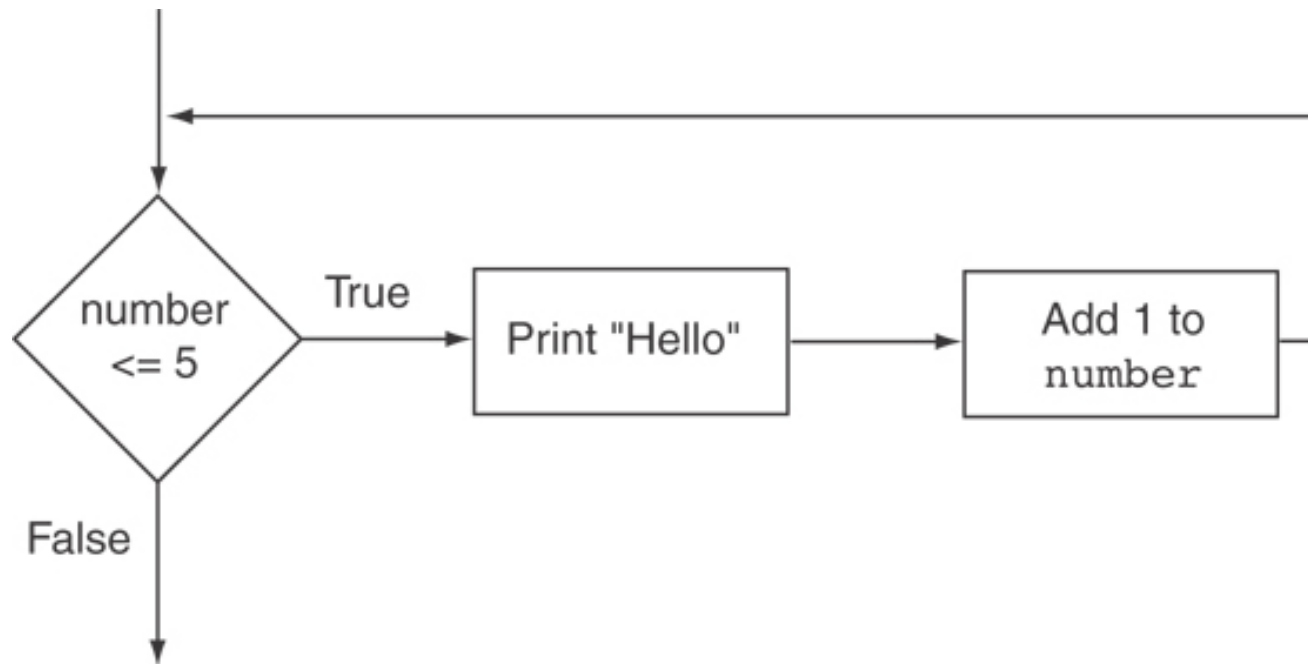
Program Output

```
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:

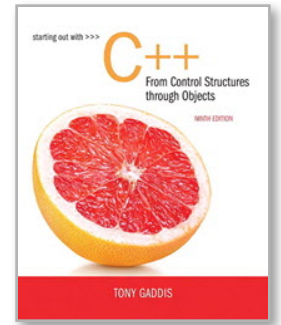
```
int number = 6;
while (number <= 5)
{
    cout << "Hello\n";
    number++;
}
```


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.*

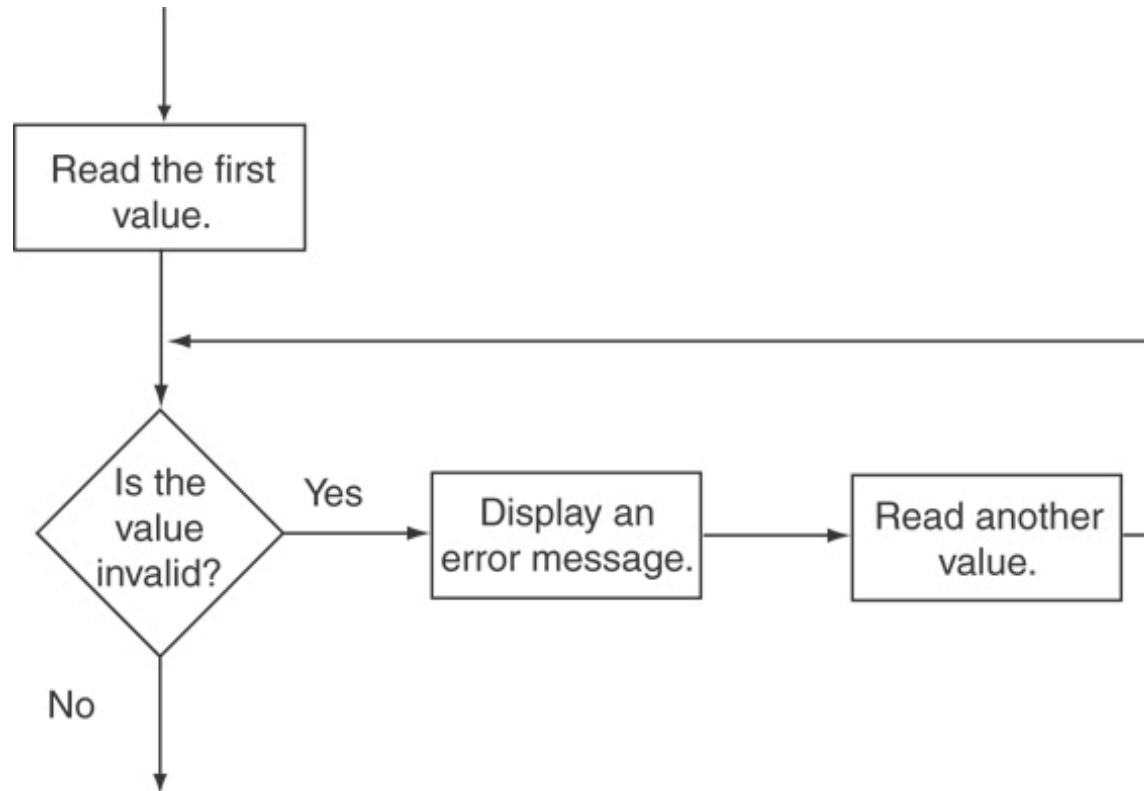
Read the input again.

End While

Input Validation Example

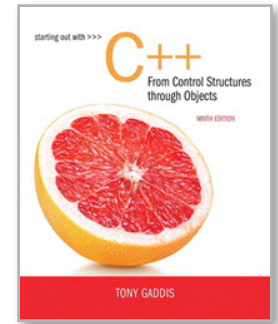
```
cout << "Enter a number less than 10: ";
cin >> number;
while (number >= 10)
{
    cout << "Invalid Entry!"
        << "Enter a number less than 10: ";
    cin >> number;
}
```

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...

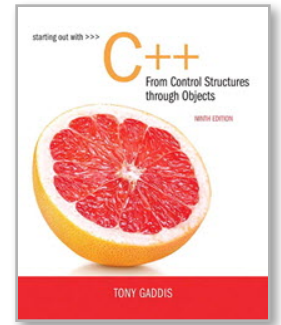
A Counter Variable Controls the Loop in Program 5-6

```
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

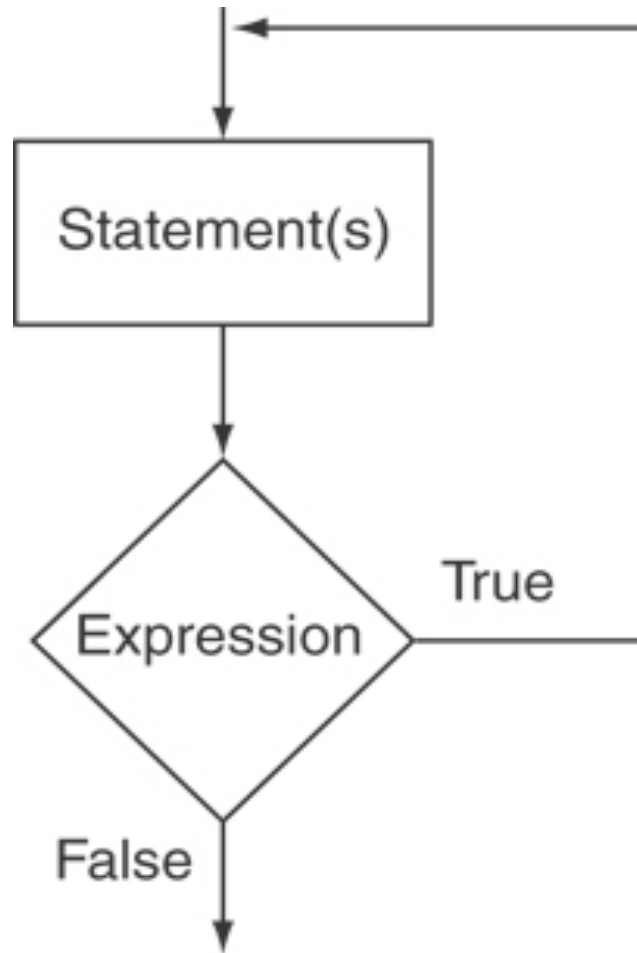
- do-while: a posttest loop – execute the loop, then test the `expression`

- 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]

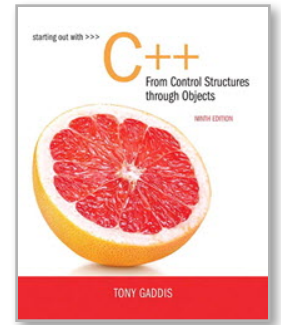
Enter 3 scores and I will average them: **60 75 88** [Enter]

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 { }
```

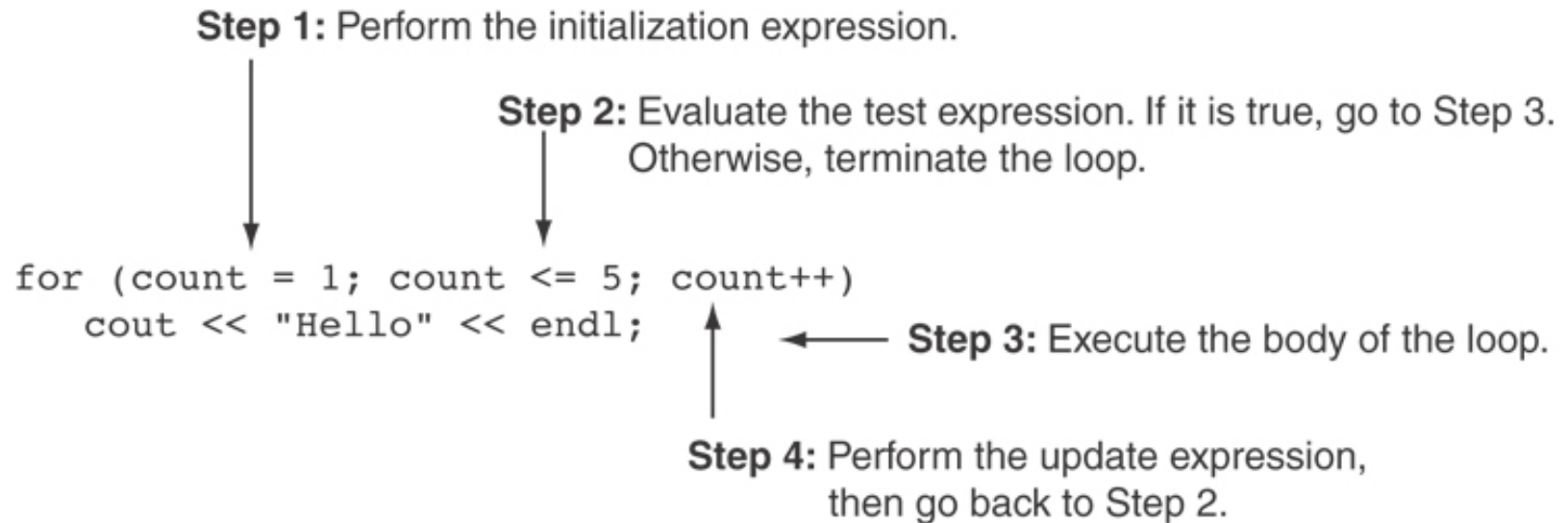
- 1) Perform *initialization*
- 2) Evaluate *test* expression
 - If true, execute *statement*
 - If false, terminate loop execution
- 3) Execute *update*, then re-evaluate *test* expression

for Loop - Example

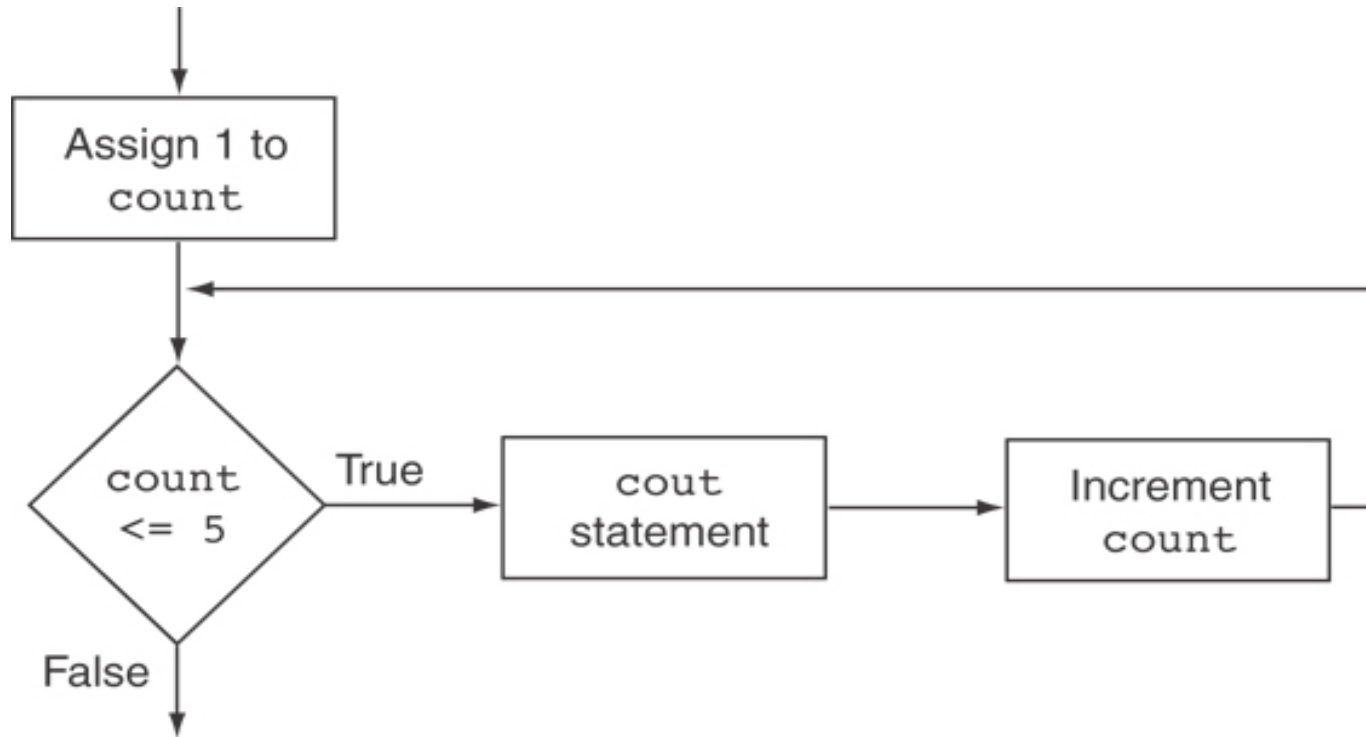
```
int count;
```

```
for (count = 1; count <= 5; count++)  
    cout << "Hello" << endl;
```

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

Step 1: Perform the initialization expression.

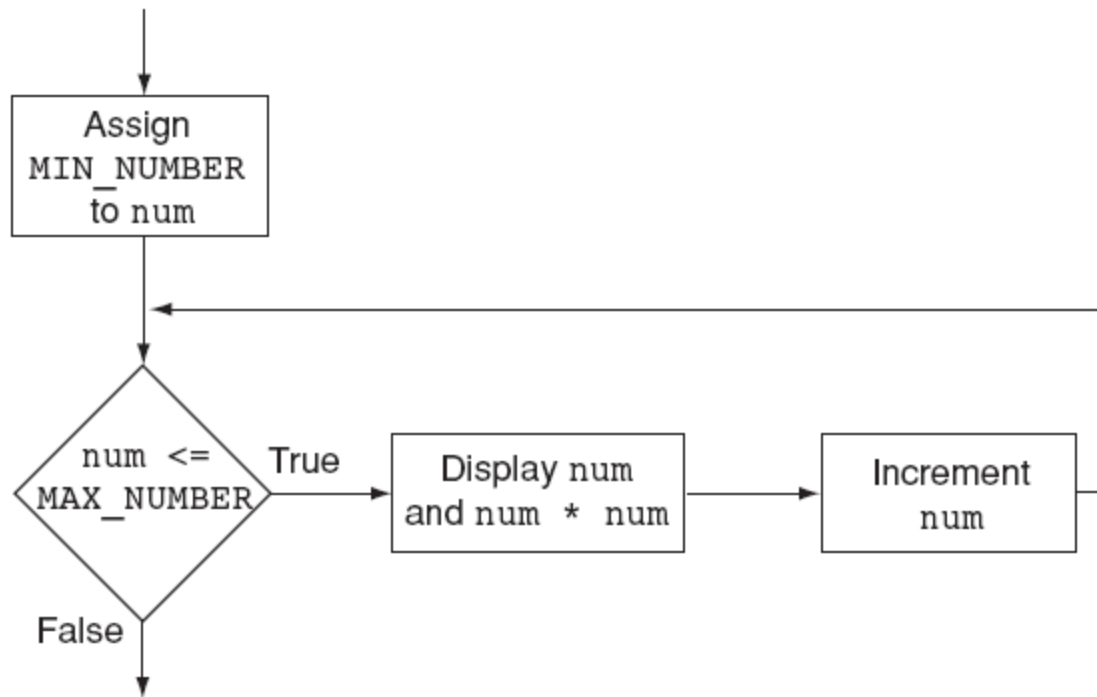
Step 2: Evaluate the test expression.
If it is true, go to Step 3.
Otherwise, terminate the loop.

Step 4: Perform the update expression, then go back to Step 2.

```
for (num = MIN_NUMBER; num <= MAX_NUMBER; num++)  
    cout << num << "\t\t" << (num * num) << endl;
```

Step 3: Execute the body of the loop.

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:

Initialization Expression

```
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;  
}
```

Test Expression



for Loop - Modifications

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

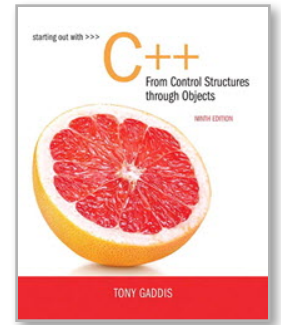
```
int sum = 0, num = 1;  
for (; num <= 10; num++)  
    sum += num;
```

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

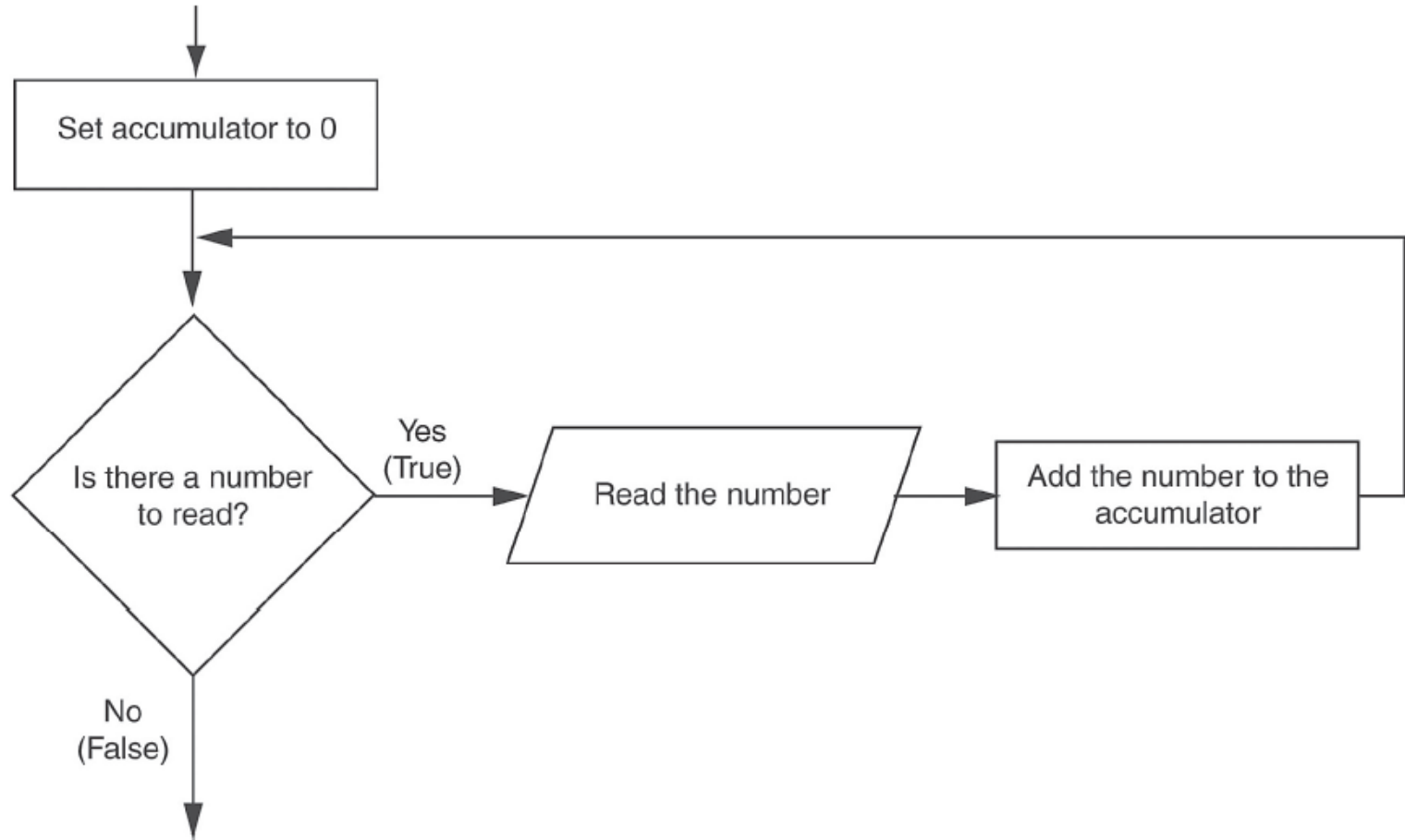
Keeping a Running Total

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 the sales for day 1: **489.32**

Enter the sales for day 2: **421.65**

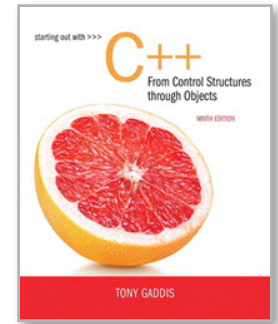
Enter the sales for day 3: **497.89**

Enter the sales for day 4: **532.37**

Enter the sales for day 5: **506.92**

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...

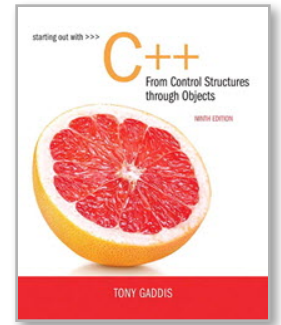
A Sentinel in Program 5-13

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

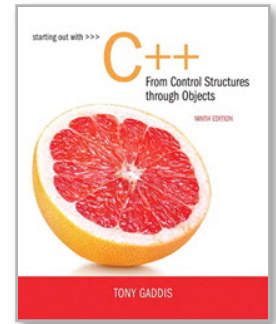


5.9

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 exists
 - 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

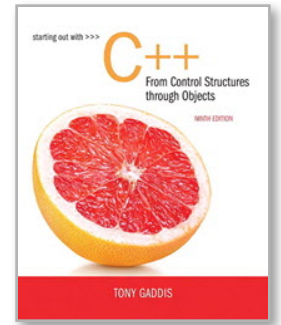
```
26 // Determine each student's average score.
27 for (int student = 1; student <= numStudents; student++)
28 {
29     total = 0; // Initialize the accumulator.
30     for (int test = 1; test <= numTests; test++)
31     {
32         double score;
33         cout << "Enter score " << test << " for ";
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**.*

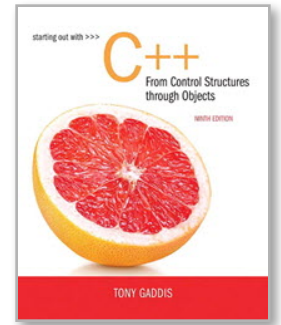
Using the `c_str` Member Function in Older Versions of C++

- `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