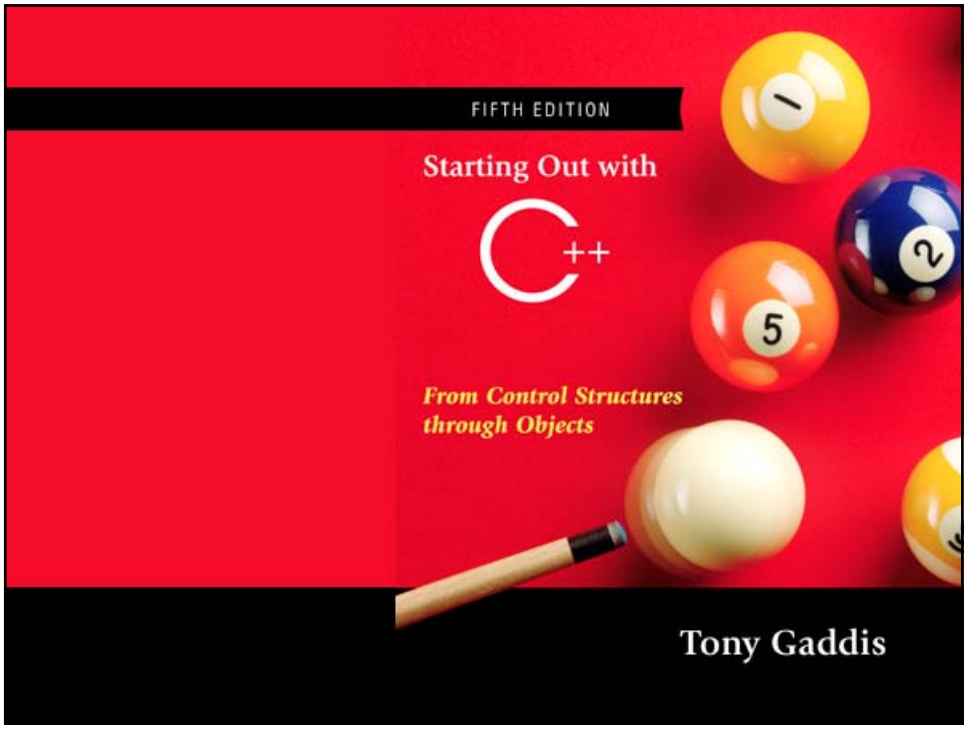

Chapter 5

Looping

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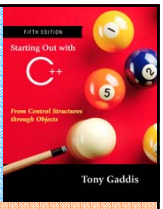

5.1 The Increment and Decrement Operators

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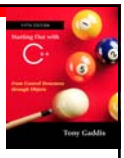
The Increment and Decrement Operators



- ++ 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++;`

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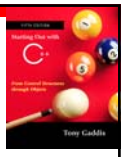
The Increment and Decrement Operators



- `--` 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--;`

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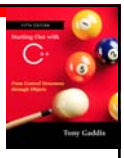

Program 5-1

```
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
```

(Program Continues)

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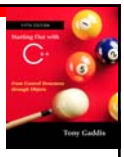

Program 5-1 *(continued)*

```
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
```

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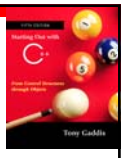

Prefix vs. Postfix

- `++` 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

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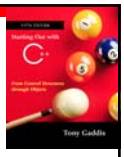
Prefix vs. Postfix - Examples



```
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
```

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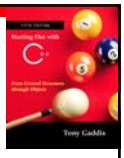
Notes on Increment, Decrement



- 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

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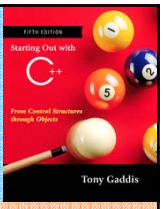

5.2 Introduction to Loops: The `while` Loop

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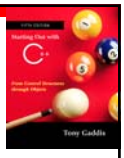
Introduction to Loops: The `while` Loop



- 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 `{ }`

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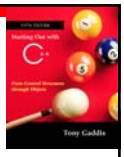
while Loop – How It Works



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

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

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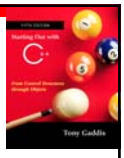
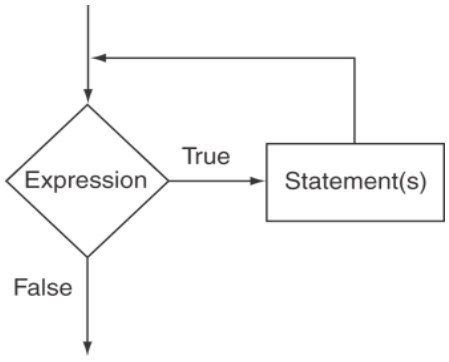
The Logic of a while Loop





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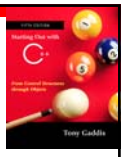

Program 5-3

```
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!
```

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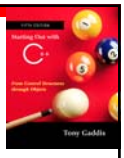
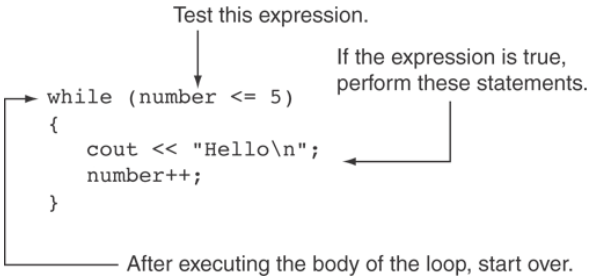
How the Loop in Lines 9 through 13 Works





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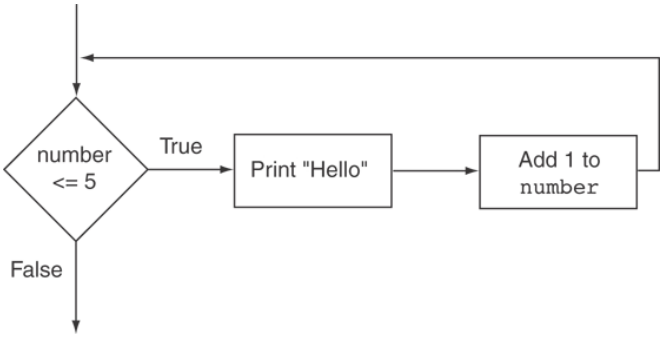
Flowchart of the Loop



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`while` 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++;
}
```

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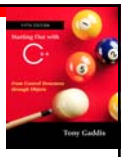
Watch Out for Infinite Loops



- 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

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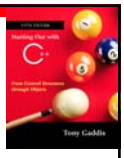
An Infinite Loop



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

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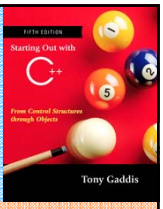

5.3 Using the `while` Loop for Input Validation

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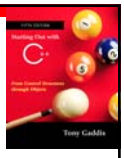
Using the `while` Loop for Input Validation



- 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.

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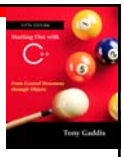
Using the `while` Loop for Input Validation



- 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

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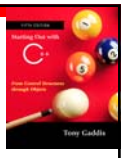
Input Validation Example



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

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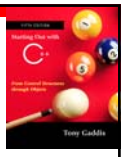
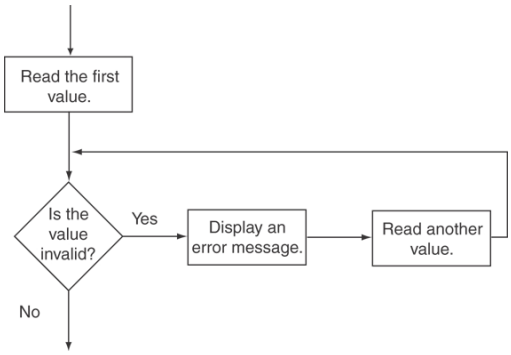
Flowchart





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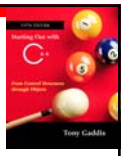
Input Validation Example from Program 5-4



```
29      // Get the number of players available.
30      cout << "How many players are available? ";
31      cin >> players;
32
33      // Validate the input.
34      while (players <= 0)
35      {
36         cout << "Please enter a positive number: ";
37         cin >> players;
38      }
```

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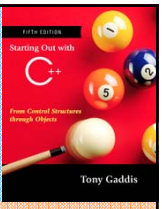

5.4 Counters

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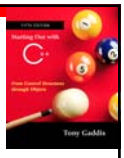
Counters



- 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

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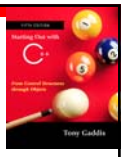

Program 5-5

```
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     int num = 1; //Initialize the counter.
9
10    cout << "Number Number Squared\n";
11    cout << "-------------------------\n";
12    while (num <= 10)
13    {
14       cout << num << "\t\t" << (num * num) << endl;
15       num++; //Increment the counter.
16    }
17    return 0;
18 }
```

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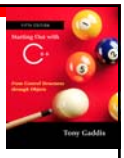

Program Output

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

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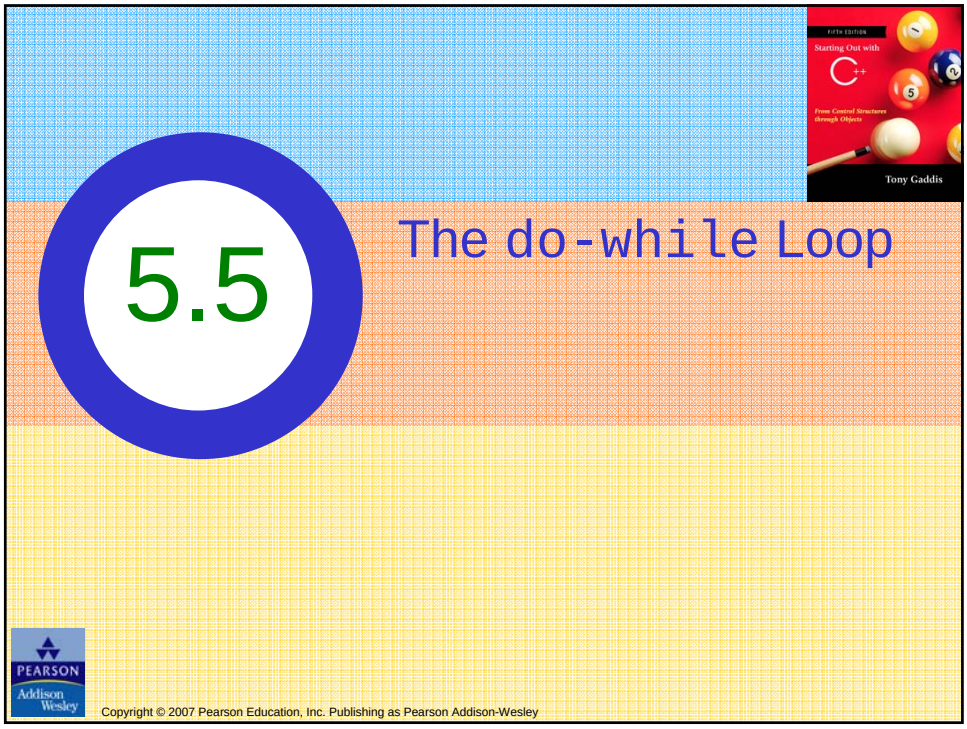

The do-while Loop

- `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)`

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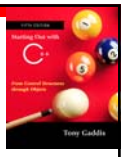
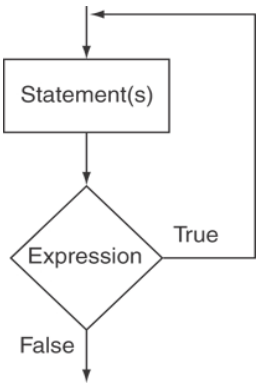
The Logic of a do-while Loop





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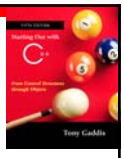
do-while Example



```
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.

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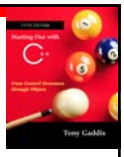

Program 5-6

```
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 }
```

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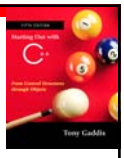

Program Output with Example Input Shown in Bold

```
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]
```

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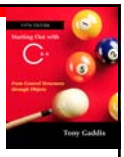
`do-while` Loop Notes



- 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 5-7 in the book)

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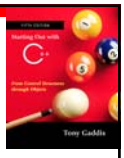
The `for` Loop



- Useful for counter-controlled loop
- General Format:

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

- No semicolon after 3rd expression or after the)

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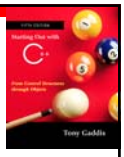
for Loop - Mechanics



```
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

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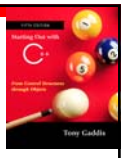
for Loop - Example



```
int count;

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

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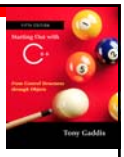
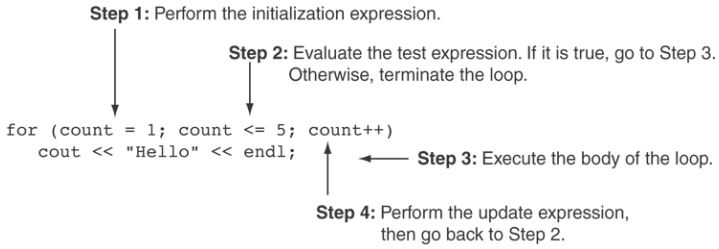
A Closer Look at the Previous Example





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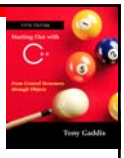
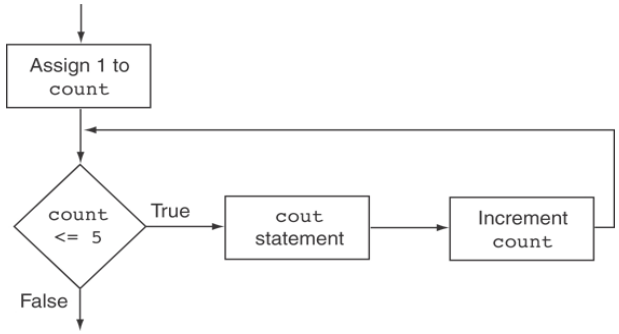
Flowchart for the Previous Example





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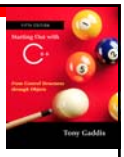

Program 5-8

```
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     int num;
9
10    cout << "Number     Number Squared\n";
11    cout << "-------------------------\n";
12
13    for (num = 1; num <= 10; num++)
14       cout << num << "\t\t" << (num * num) << endl;
15    return 0;
16 }
```

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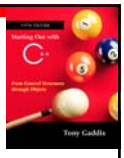

Program Output

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

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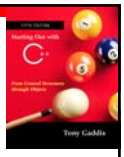
A Closer Look at Lines 13 through 14 in Program 5-8



Step 1: Perform the initialization expression.

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

```
for (num = 1; num <= 10; num++)
   cout << num << "\t\t" << (num * num) << endl;
```

Step 3: Execute the body of the loop.

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

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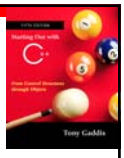
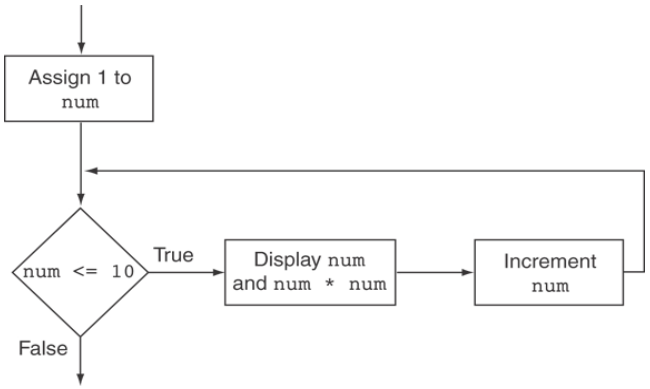
Flowchart for Lines 13 through 14 in Program 5-8





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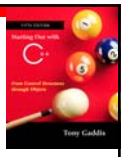
When to Use the `for` Loop



- 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

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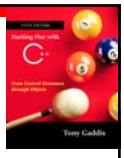
The `for` Loop is a Pretest Loop



- 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;
```

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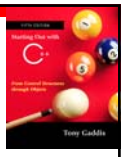
for Loop - Modifications



- 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;
}
```

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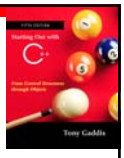
for Loop - Modifications



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

Test Expression

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

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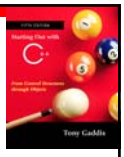
`for` Loop - Modifications



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

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

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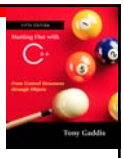
`for` Loop - Modifications



- 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.

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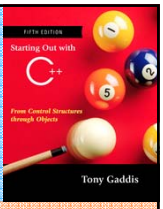

5.7 Keeping a Running Total

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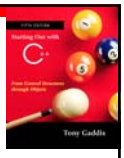
Keeping a Running Total



- 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;
```

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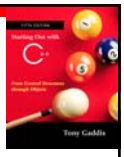

Program 5-10

```
1  // This program takes daily sales figures 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 figures? ";
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
```

(Program Continues)

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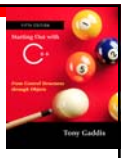

Program 5-10 *(continued)*

```
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 figures? 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
```

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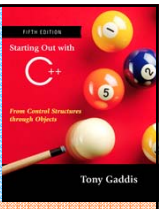

5.8 Sentinels

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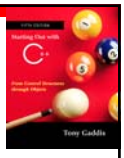

Sentinels

- 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

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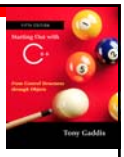

Program 5-11

```
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 }
```

(Program Continues)

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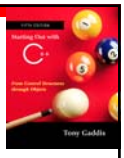

Program Output with Example Input Shown in Bold

```
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
```

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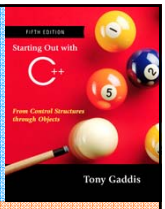

5.9 Using a Loop to Read Data from a File

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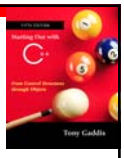
Using a Loop to Read Data from a File



- 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) ...
```

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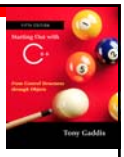

Program 5-13

```
1  // This program displays all of the numbers in a file.
2  #include <iostream>
3  #include <fstream>
4  using namespace std;
5
6  int main()
7  {
8     ifstream inputFile;  // File stream object
9     int number;          // To hold a value from the file
10
11    inputFile.open("numbers.txt");     // Open the file.
12    if (!inputFile)                    // Test for errors.
13       cout << "Error opening file.\n";
14    else
15    {
16       while (inputFile >> number)     // Read a number
17       {
18          cout << number << endl;      // Display the number.
19       }
20       inputFile.close();              // Close the file.
21    }
22    return 0;
23 }
```

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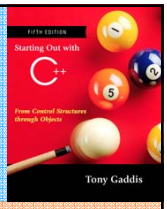

5.10 Deciding Which Loop to Use

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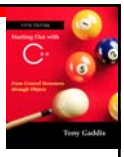
Deciding Which Loop to Use



- `while`: pretest loop; loop body may not be executed at all
- `do-while`: posttest loop; loop body will always be executed at least once
- `for`: pretest loop with initialization and update expression; useful with counters, or if precise number of repetitions is needed

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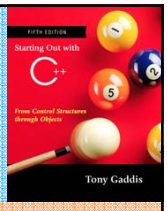

5.11 Nested Loops

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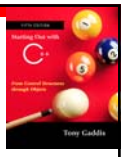
Nested Loops



- 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;
```

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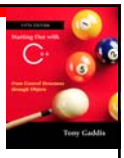
Lines from Program 5-14



```
22    // Determine each student's average score.
23    for (int student = 1; student <= numStudents; student++)
24    {
25       total = 0;      // Initialize the accumulator.
26       for (int test = 1; test <= numTests; test++)
27       {
28          int score;
29          cout << "Enter score " << test << " for ";
30          cout << "student " << student << ": ";
31          cin >> score;
32          total += score;
33       }
34       average = total / numTests;
35       cout << "The average score for student " << student;
36       cout << " is " << average << ".\n\n";
37    }
```

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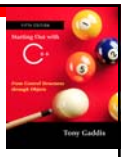
Nested Loops - Notes



- 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.

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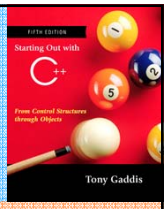

5.12 Breaking Out of a Loop

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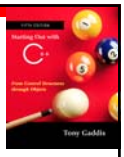
Breaking Out of a Loop



- 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

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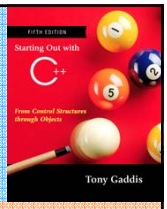

5.13 The `continue` Statement

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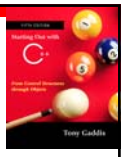
The `continue` Statement



- 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

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