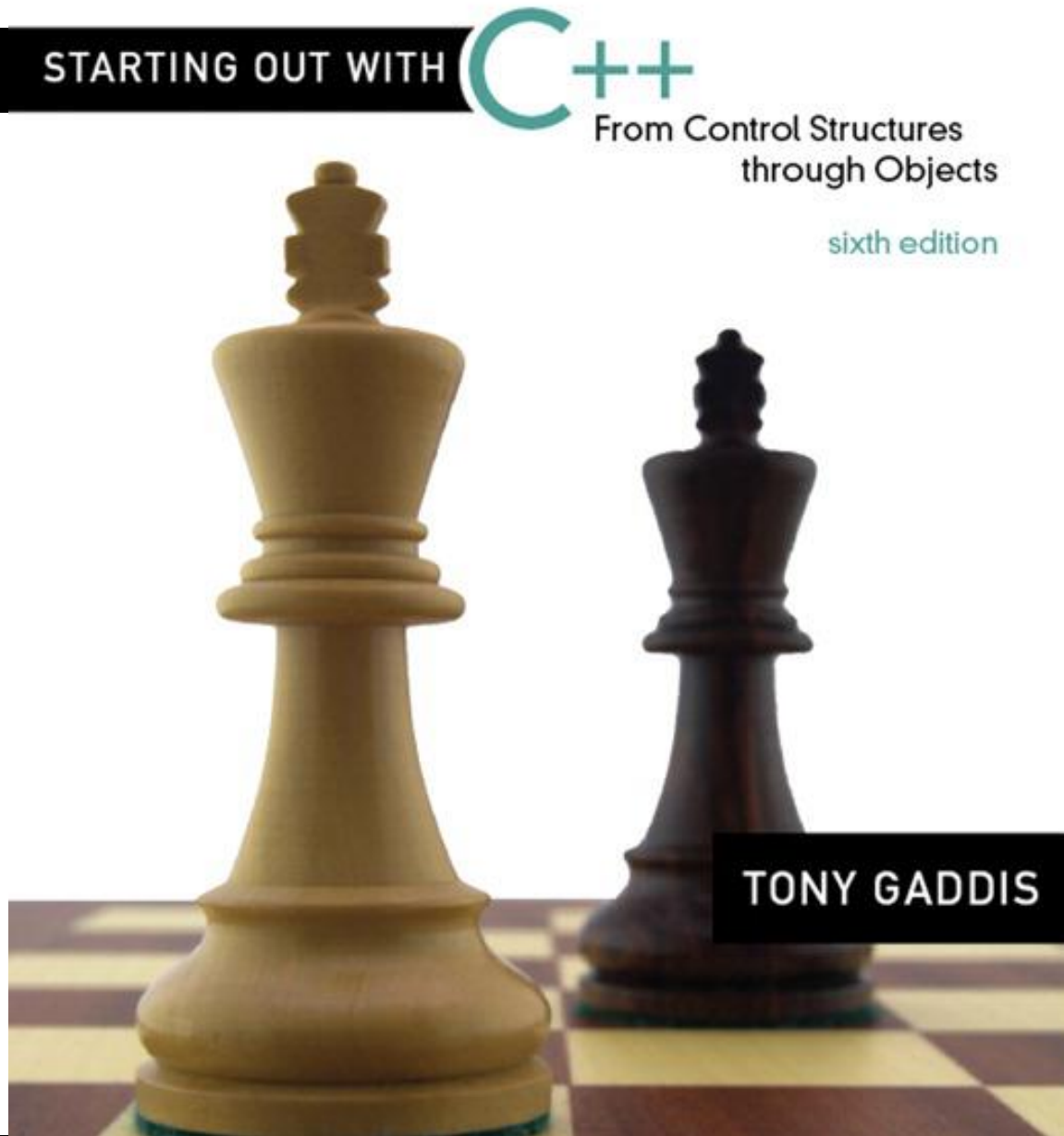
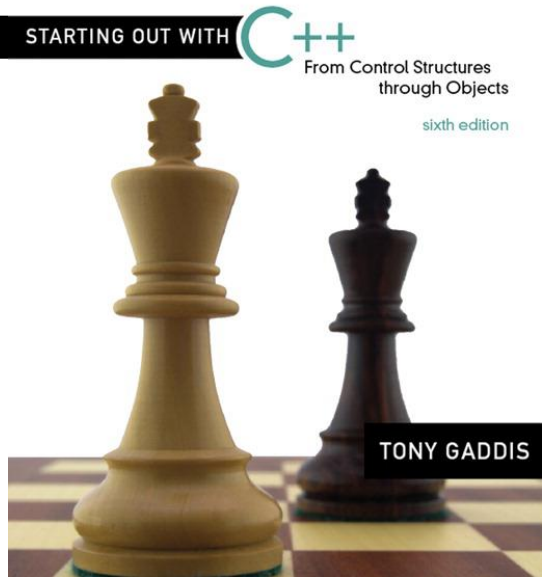
# Chapter 5:

## Looping






# 5.1

# The Increment and Decrement Operators

# 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--;
```

**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)*

**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 / uses the value of the variable
- In postfix mode (`val++, val--`) the operator returns / uses the value of the variable, *then* increments or decrements

# Prefix vs. Postfix - Examples

```
int num, val = 12;

cout << val++;          // Displays 12, then
                        // sets val to 13.

cout << ++val;          // Sets val to 14,
                        // then displays it.

num = --val;            // Sets val to 13, then
                        // stores it in num.

num = val--;            // Stores 13 in num,
                        // then sets val to 12.
```

# Notes on Increment, Decrement

- Can be used in expressions:

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

**num1=2, num2=5**

**result=6**

**num1=3, num2=4**

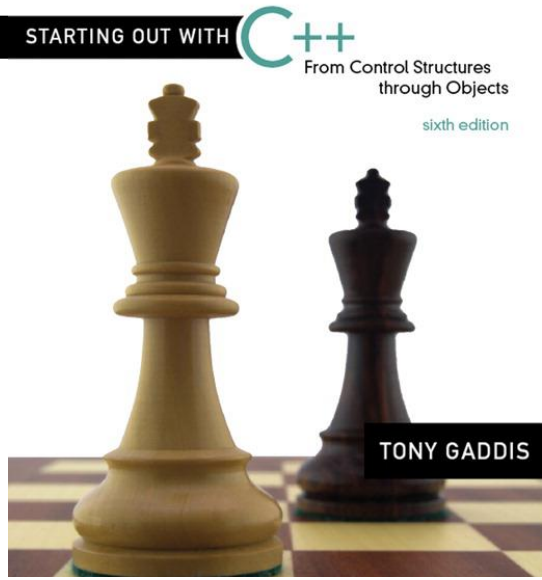
- Can only be applied to a variable, not to a number or an expression. Cannot have:

```
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;
```

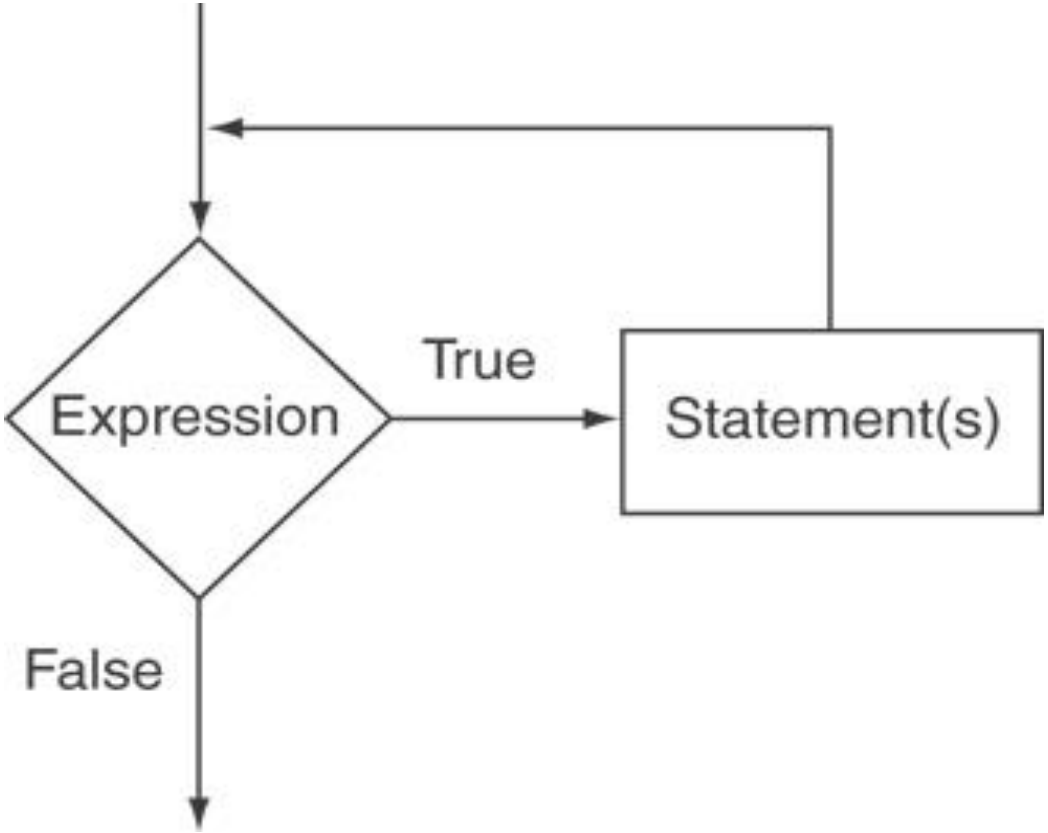
- *`statement;`* can also be a block of statements enclosed in `{ }`

# `while` Loop – How It Works

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

- *`expression`* is a condition to be evaluated
  - if `true`, then *`statement`* is executed, and *`expression`* is evaluated again
  - if `false`, then the loop is finished and the program statement immediately following *`statement`* is executed

# The Logic of a `while` Loop



# A program that displays “Hello” 5 times

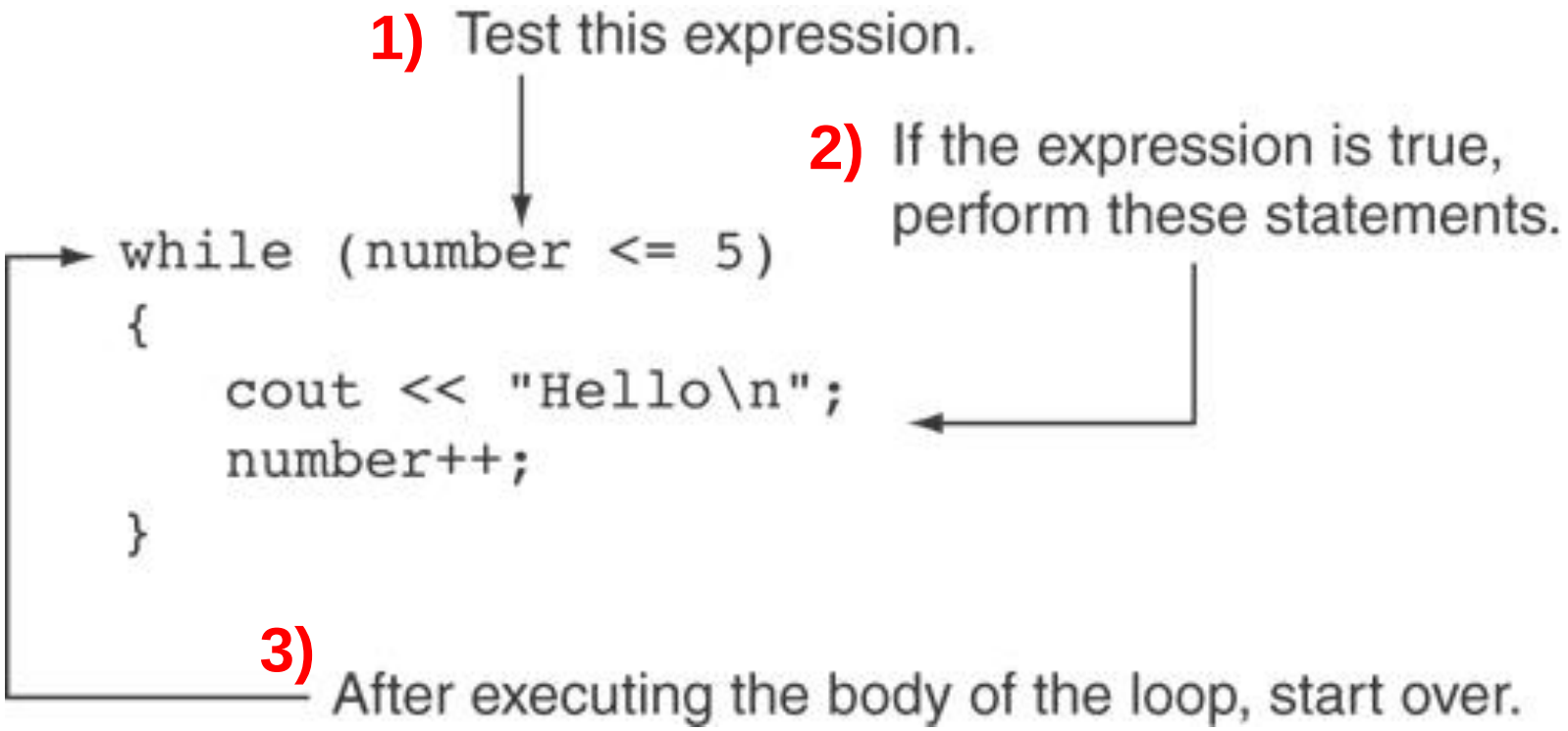
**Program 5-3**

```
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 }
```

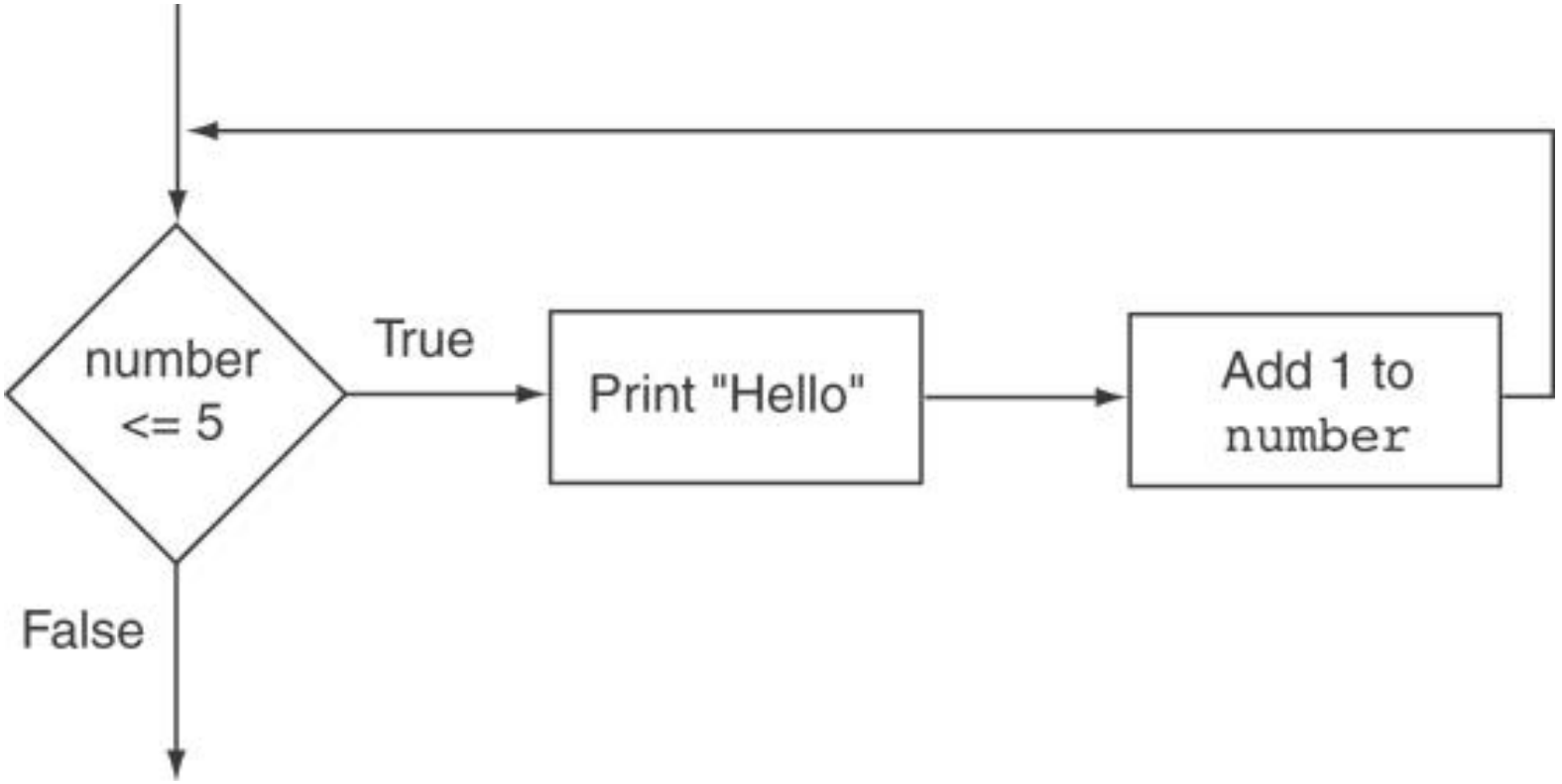
**Program Output**

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

# How the Loop in Lines 9 through 13 Works



# Flowchart of the Loop



# `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++;
}
```

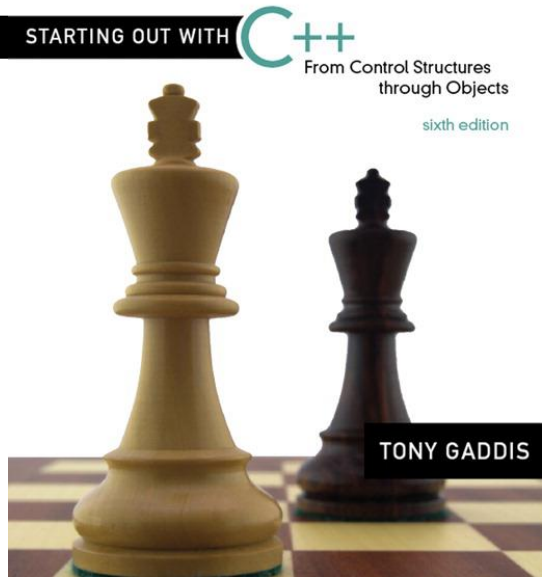
# Watch Out for Infinite Loops

- 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

# An Infinite Loop

The following program will never terminate:

```
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.
  - Garbage in, garbage out
- The while loop can be used to create input routines that reject invalid data, and repeat until valid data is entered. (Our previous programs display an error message and then terminate after detecting invalid data.)

# Using the `while` Loop for Input Validation

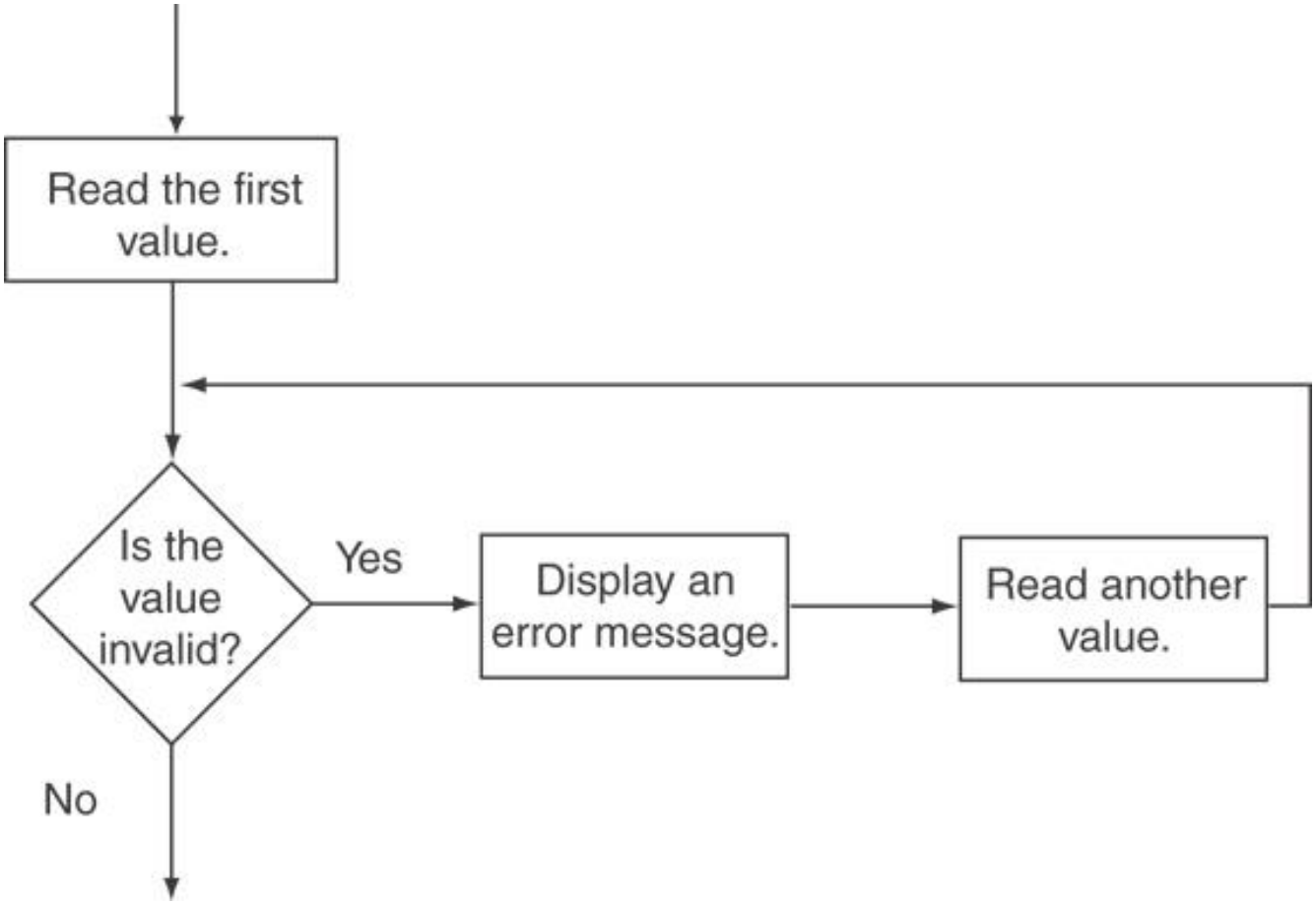
- Here's the general approach, in pseudo code:

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

# Input Validation Example

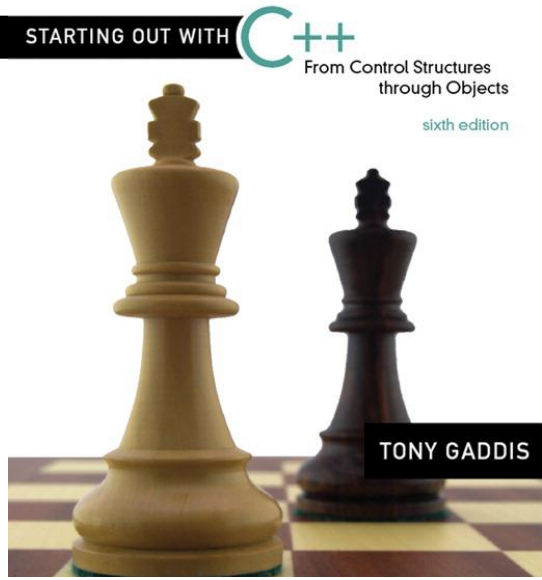
```
cout << "Enter a number less than 10: ";
cin >> number;
while (number >= 10)
{
   cout << "Invalid Entry!" << endl
        << "Enter a number less than 10: ";
   cin >> number;
}
```

# Flowchart


Read the first value.
Is the value invalid?
Yes
Display an error message.
Read another value.
No

# Input Validation Example from Program 5-5

```
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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sixth edition
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# 5.4

# Counters

# Counters

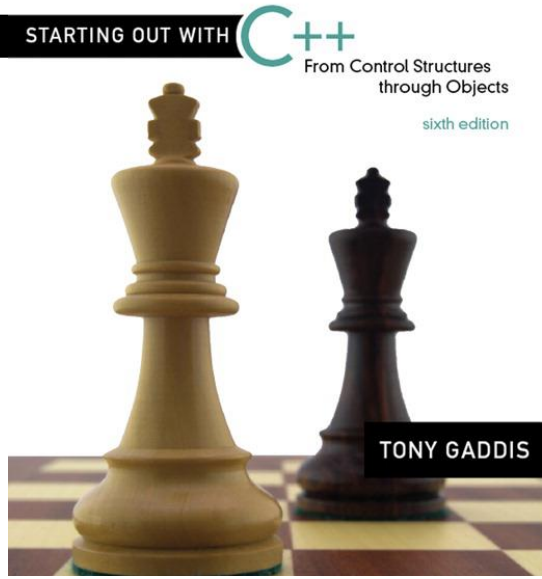
- Counter: a variable that is incremented or decremented each time a loop repeats (also known as the *loop control variable*)
- Can be used to control or keep track of the number of iterations a loop performs
- Must be initialized before entering the loop

# Counters

```
// This program shows how to use a counter to repeatedly
// display the message "Nice to meet you!" 30 times.

#include <iostream>
#include <iomanip>
using namespace std;

void main()
{
   int count=0;

   while ( count < 30 )
   {
      cout<<setw(2)<<count+1<<". Nice to meet your!\n";
      count ++;
   }
}
```

C:\windows\system32\cmd.exe

```
 1. Nice to meet your!
 2. Nice to meet your!
 3. Nice to meet your!
 4. Nice to meet your!
 5. Nice to meet your!
 6. Nice to meet your!
 7. Nice to meet your!
 8. Nice to meet your!
 9. Nice to meet your!
10. Nice to meet your!
11. Nice to meet your!
12. Nice to meet your!
13. Nice to meet your!
14. Nice to meet your!
15. Nice to meet your!
16. Nice to meet your!
17. Nice to meet your!
18. Nice to meet your!
19. Nice to meet your!
20. Nice to meet your!
21. Nice to meet your!
22. Nice to meet your!
23. Nice to meet your!
24. Nice to meet your!
25. Nice to meet your!
26. Nice to meet your!
27. Nice to meet your!
28. Nice to meet your!
29. Nice to meet your!
30. Nice to meet your!
Press any key to continue . . .
```




# 5.5

# The `do-while` Loop

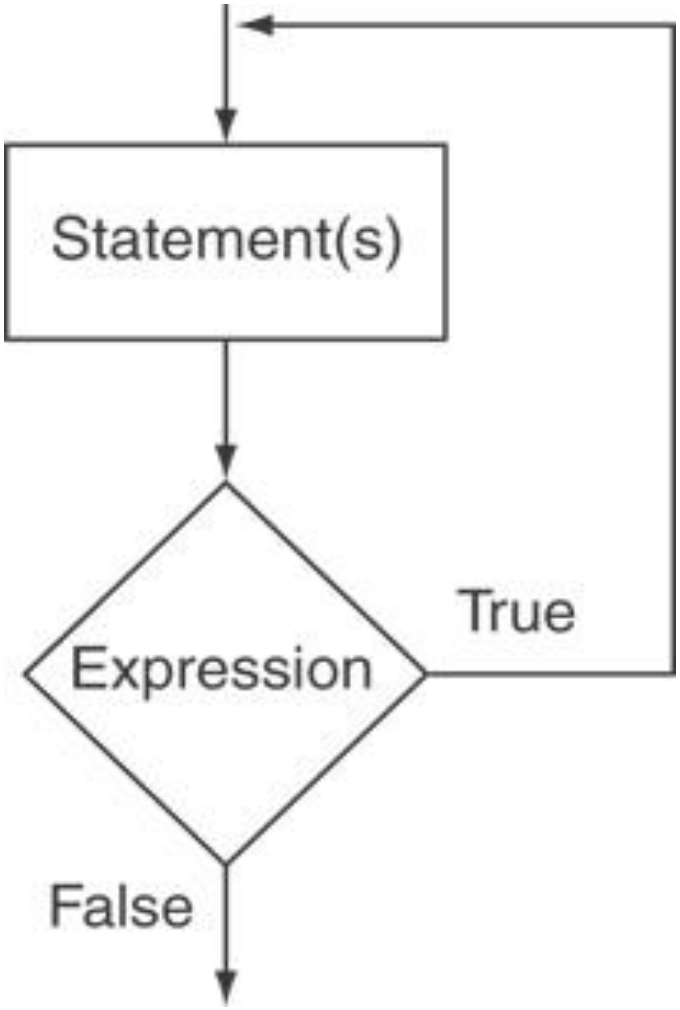
# The `do-while` Loop

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

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

- Note the `do-while` loop must be terminated with a semicolon – it is not required at the end of the `while` loop

# The Logic of a `do-while` Loop



# do-while Example

Compare the following two loops. Though the condition is false to begin with, `do-while` loop will execute once, because it is a posttest loop.

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

} while(x < 0);
```

(2)
```
int x = 1;
while (x < 0)
    cout << x << endl;
```

## Program 5-7

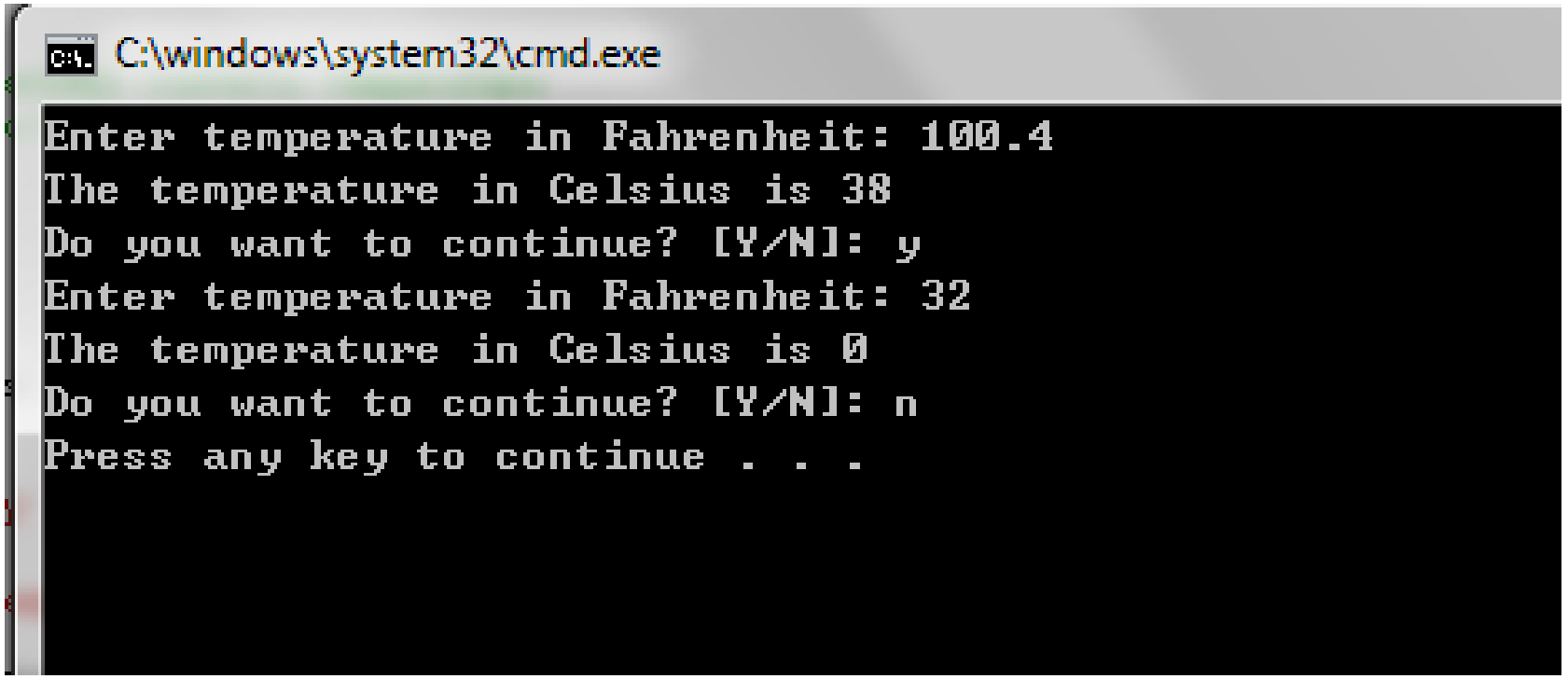
```
1  // This program averages 3 test scores. It repeats as
2  // many times as the user wishes.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8     int score1, score2, score3; // Three scores
9     double average;             // Average score
10    char again;                 // 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 }
```

**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]
```

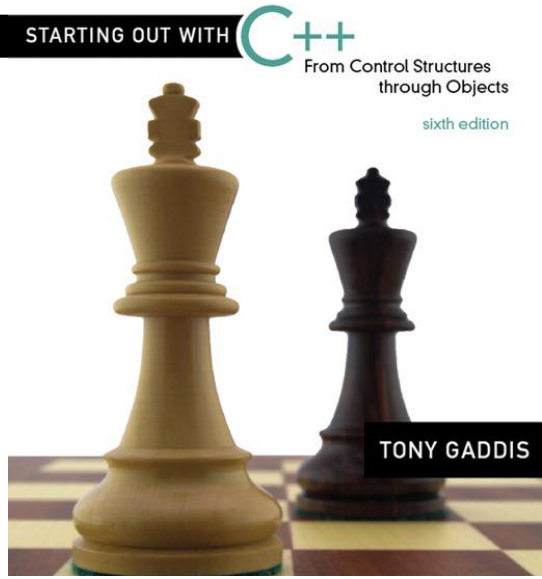
```
// This program repeatedly converts temperature
// from Fahrenheit to Celsius.
#include <iostream>
using namespace std;

int main()
{
    double fahr, cels;
    char ans;

    do
    {
       cout << "Enter temperature in Fahrenheit: ";
       cin >> fahr;
       cels = (fahr-32.0)*5.0/9.0;
       cout << "The temperature in Celsius is "
            << cels << endl;
       cout << "Do you want to continue? [Y/N]: ";
       cin >> ans;
    } while ( ans == 'Y' || ans == 'y' );
}
```

# Program output:



# `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 in the book)




# 5.6

## The `for` Loop

# The `for` Loop

- There are two categories of loops
  - Condition-controlled loops (e.g. input validation)
  - Count-controlled loops (# of iteration is known)
- The `for` loop is ideal for count-controlled loop
- General Format:

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

- No semicolon after 3rd expression or after the )

# `for` Loop - Mechanics

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

1) Perform *initialization*
2) Evaluate *test* expression (condition)
   - If `true`, execute *statement or block of statements*
   - 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

**Step 1:** Perform the initialization expression.

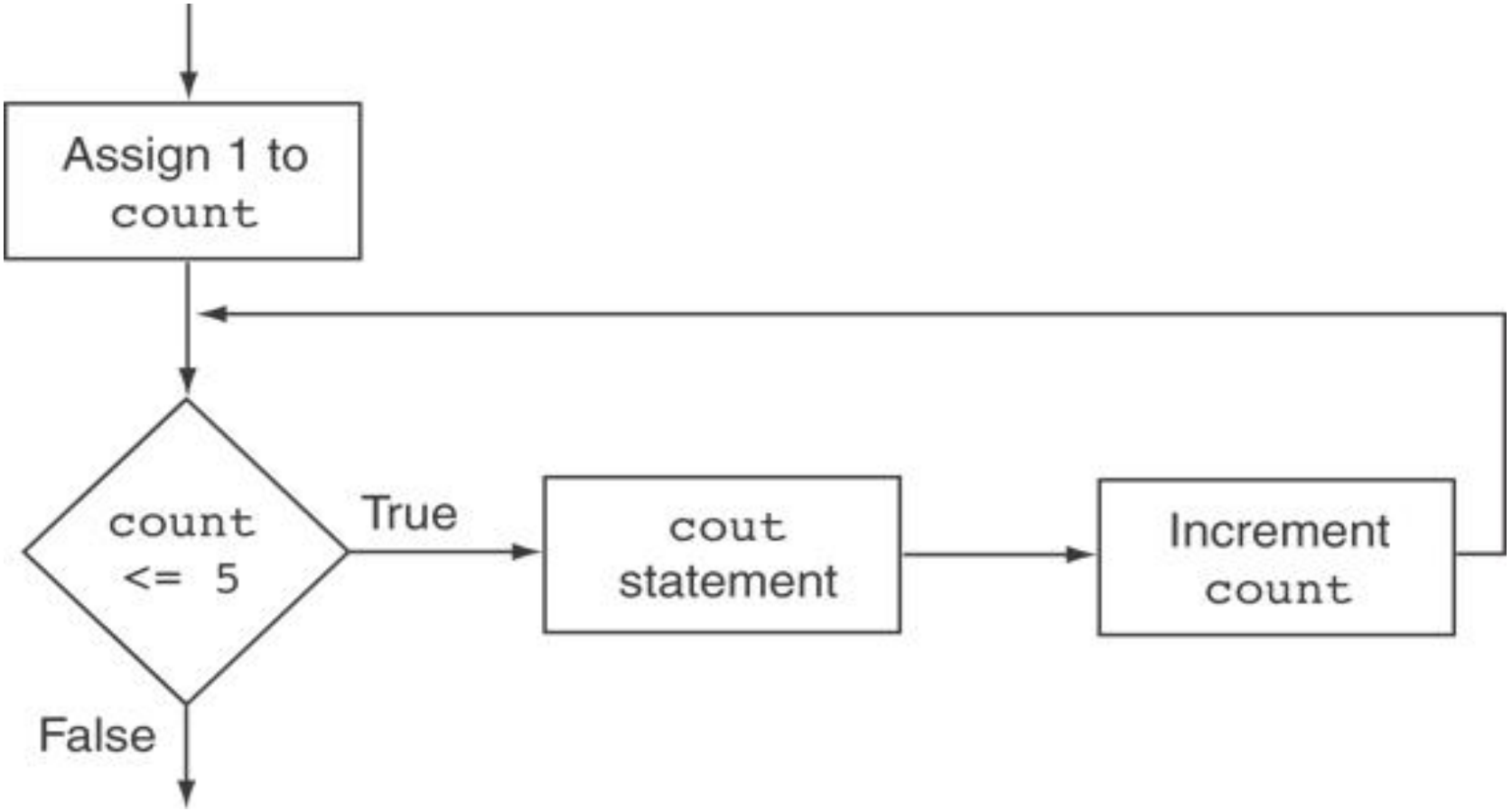
**Step 2:** Evaluate the test expression. If it is true, go to Step 3. Otherwise, terminate the loop.

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

**Step 3:** Execute the body of the loop.

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

# Flowchart for the Previous Example



## 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     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 }
```

**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 13 through 14 in Program 5-9

**Step 1:** Perform the initialization expression.

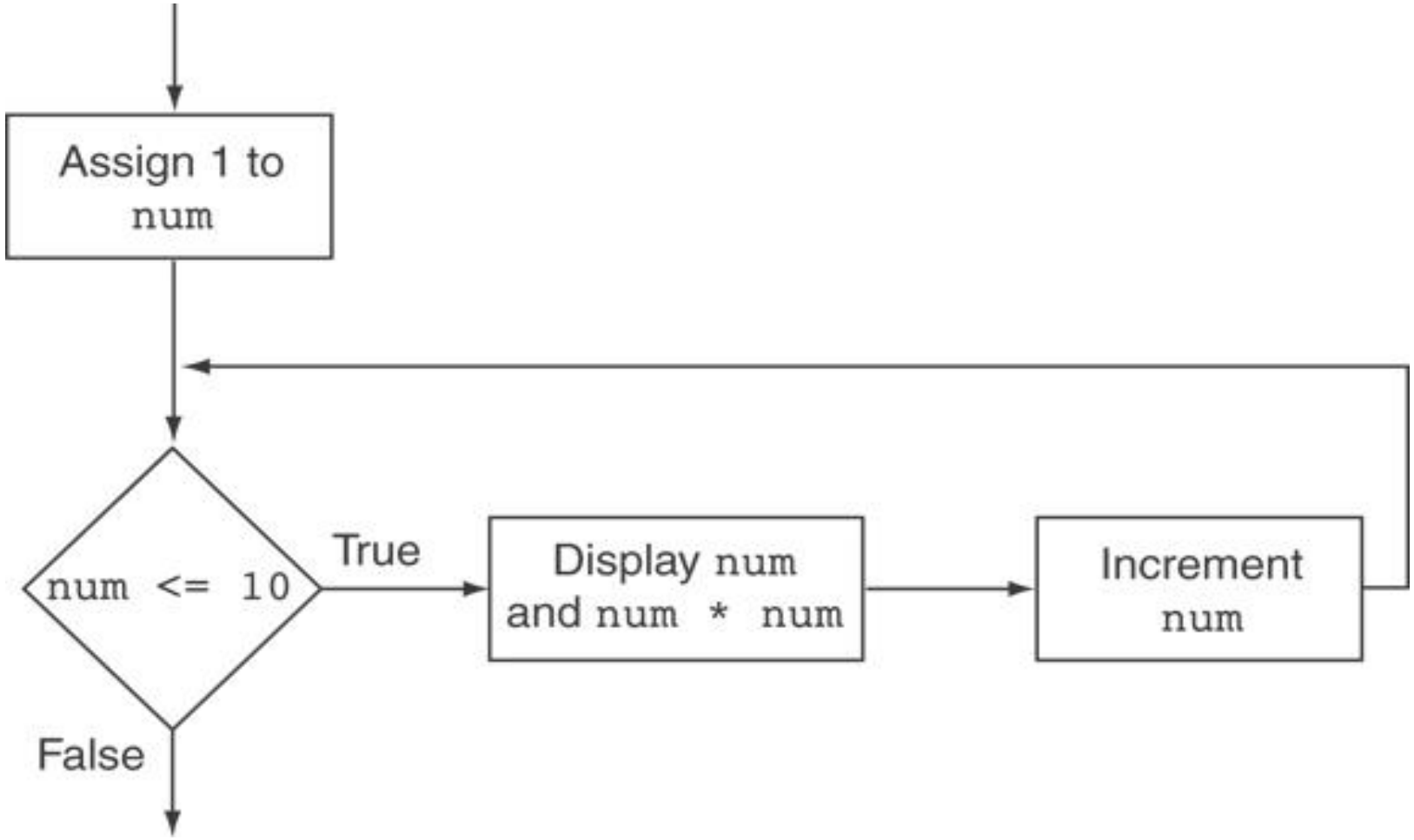
**Step 2:** Evaluate the test expression. If it is true, go to Step 3. Otherwise, terminate the loop.

```
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.

# Flowchart for Lines 13 through 14 in Program 5-9



# When to Use the `for` Loop

- Preferable to `while` or `do-while` loop when number of iteration is know
- When number of iteration is not know `while` or `do-while` loop is preferable
- `for` loop 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.
  - `while` loop: pretest
  - `do-while` loop: posttest
- 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 *`update`* expression. Separate the statements with a comma:

Update Expression

```
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:

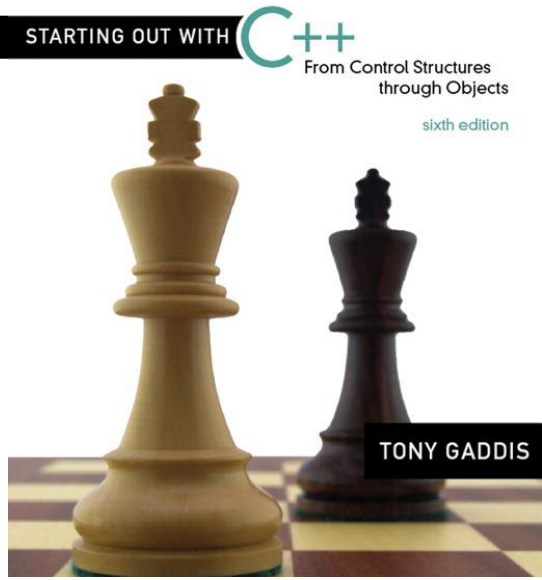
```
int sum = 0, num = 1;
for (; num <= 10; num++)
     sum += num;
```

# `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;  // sum is the accumulator
for (num=1; num<=10; num++)
{
    sum += num;
}
cout << "Sum of numbers 1 – 10 is"
     << sum << endl;
```

## Program 5-12

```
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
```

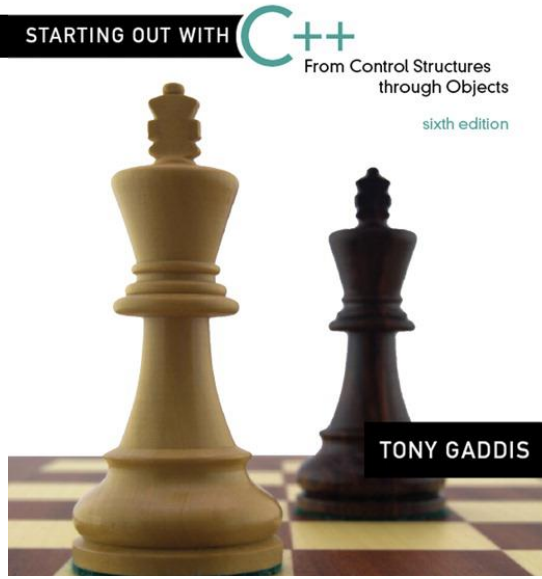
**# of iteration is specified by a variable whose value is entered during run-time**

***(Program Continues)***

```
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
```




# 5.8

# Sentinels

# Sentinels

- Sometimes the user may not know the total number of values to input in advance
- sentinel: value in a list of values that indicates end of data (also named trailer)
- Special value that cannot be confused with a valid value, *e.g.*, `-999` for a test score

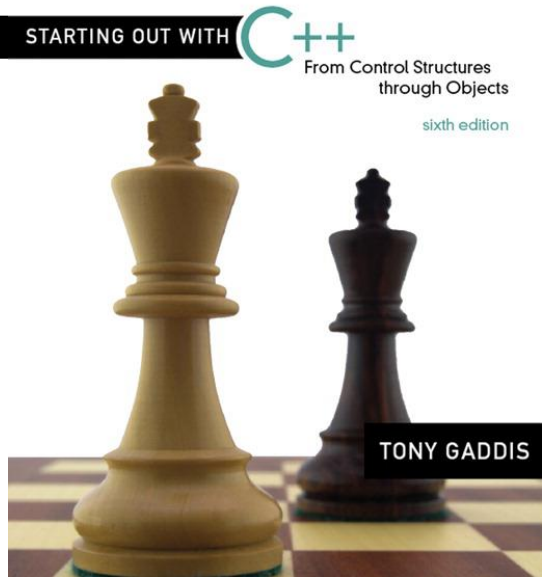
## Program 5-13

```
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 }
```

*(Program Continues)*

**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
```

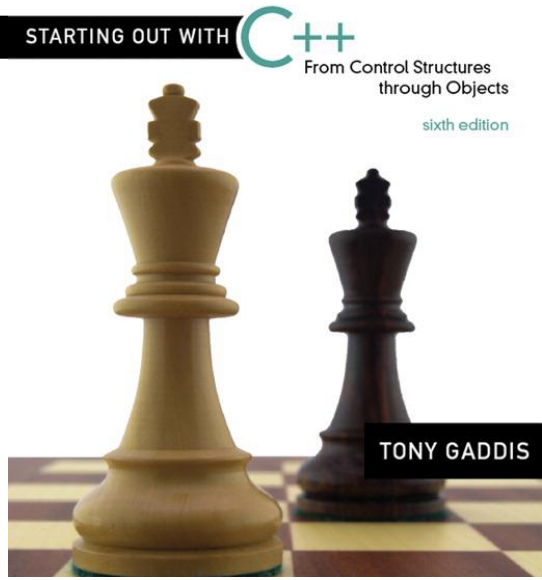



# 5.10

## Deciding Which Loop to Use

# Deciding Which Loop to Use

- Though most repetitive algorithms can be written with any of the three loops, each is best for certain situations
- `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




# 5.11

## Nested Loops

# Nested Loops

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

```
for (i=1; i<=3; i++)        //outer
{
  …
  for (j=1; j<=5; j++)      //inner
  {
     cout << "Hello!" << endl;
  }
  …
}
```

# Lines from Program 5-16

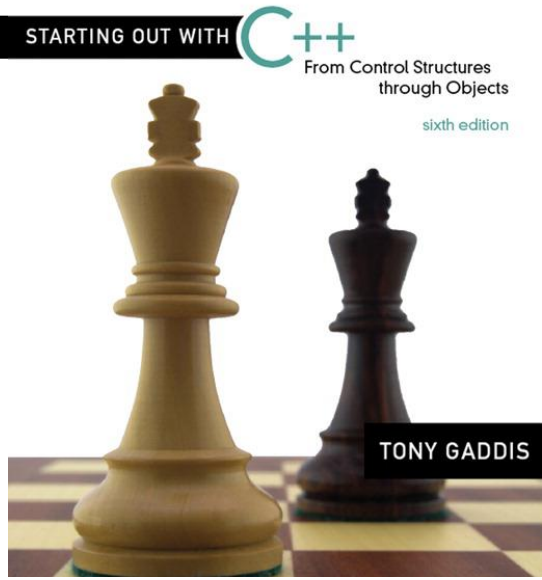
**# of iteration for inner and outer loops are determined during run-time**

```
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      }
```

Program 5-16

# 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.




# 5.12

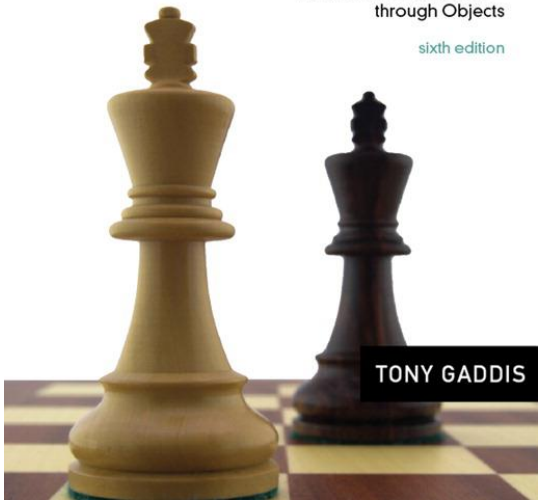
## Breaking Out of a Loop

# Breaking Out of a Loop

- Can use `break` to terminate execution of a loop (`while`, `do-while` or `for` loop) before the loop condition become false
- 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

# Breaking Out of a Loop

```
int count=0;
double score, total_score=0, avg_score;
while ( true )
{
    cout << "Enter a test score, -1 to stop: ";
    cin  >> score;

    if (score == -1)
        break;

    total_score += score;
    count++;
}
avg_score = total_score / count;
cout << "Average score = " << avg_score << endl;
```



# 5.13

## The `continue` Statement

# The `continue` Statement

- Can use `continue` to go to end of loop and prepare for next repetition (i.e. skip the rest of current iteration)
  - `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

# The `continue` Statement

```
double number, sqrt_number;

// Loop 100 times
for ( int count=0; count<100; count++ )
{
    cout << "Enter a positive number: ";
    cin  >> number;

    if ( number < 0 )    // If negative, skip the rest
        continue;        // of current iteration

    sqrt_number = sqrt(number);
    cout << "square root of " << number
         << " = " << sqrt_number << endl;
}
```