Chapter 5: Repetition

Objectives

In this chapter, you will learn about:

- Basic loop structures
- **`while`** loops
- Interactive **`while`** loops
- **`for`** loops
- Loop programming techniques

Objectives (continued)

- Nested loops
- **`do while`** loops
- Common programming errors

Basic Loop Structures

- Repetition structure has four required elements:
  - Repetition statement
  - Condition to be evaluated
  - Initial value for the condition
  - Loop termination
- Repetition statements include:
  - **`while`**
  - **`for`**
  - **`do while`**

Basic Loop Structures (continued)

- The condition can be tested
  - At the beginning: **Pretest** or **entrance-controlled** loop
  - At the end: **Posttest** or **exit-controlled** loop
- Something in the loop body must cause the condition to change, to avoid an **infinite loop**, which never terminates

Pretest and Posttest Loops

- Pretest loop: Condition is tested first; if false, statements in the loop body are never executed
- **`while`** and **`for`** loops are pretest loops

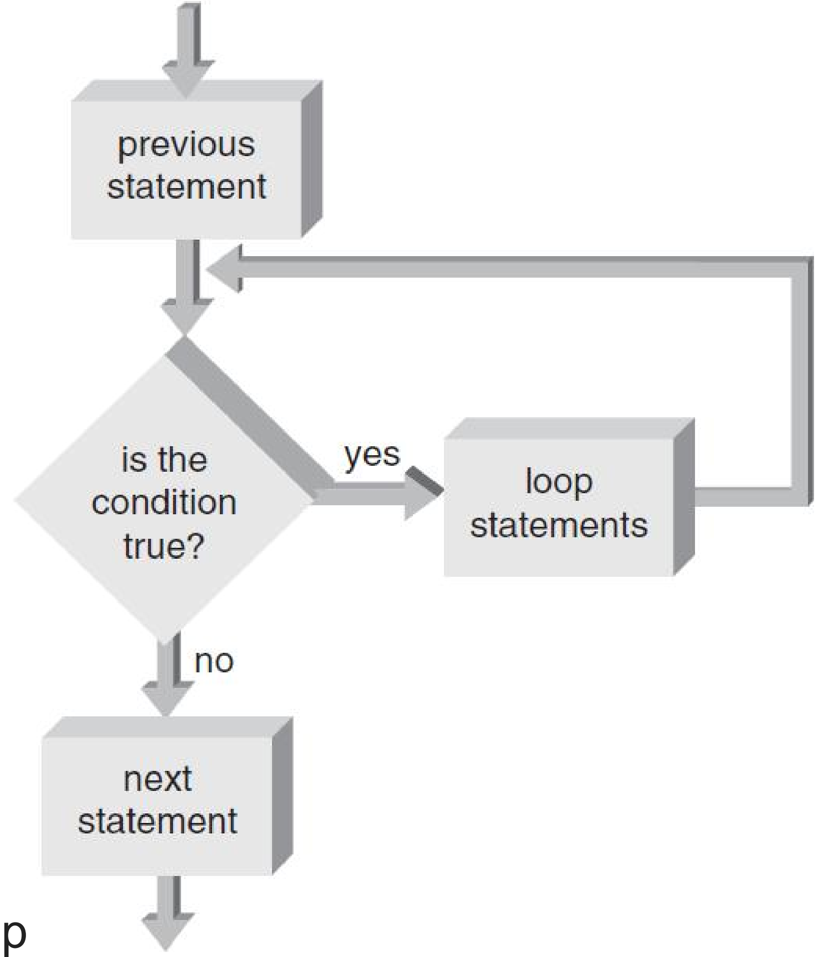


Figure 5.1 A pretest loop

Pretest and Posttest Loops (continued)

- Posttest loop: Condition is tested after the loop body statements are executed; loop body always executes at least once
- **`do while`** is a posttest loop

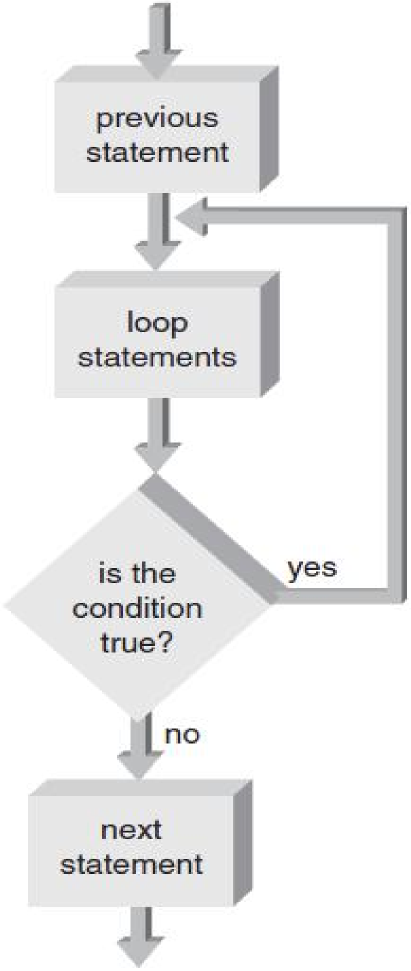


Figure 5.2 A posttest loop

Fixed-Count Versus Variable-Condition Loops

- **Fixed-count loop:** Loop is processed for a fixed number of repetitions
- **Variable-condition loop:** Number of repetitions depends on the value of a variable

`while` Loops

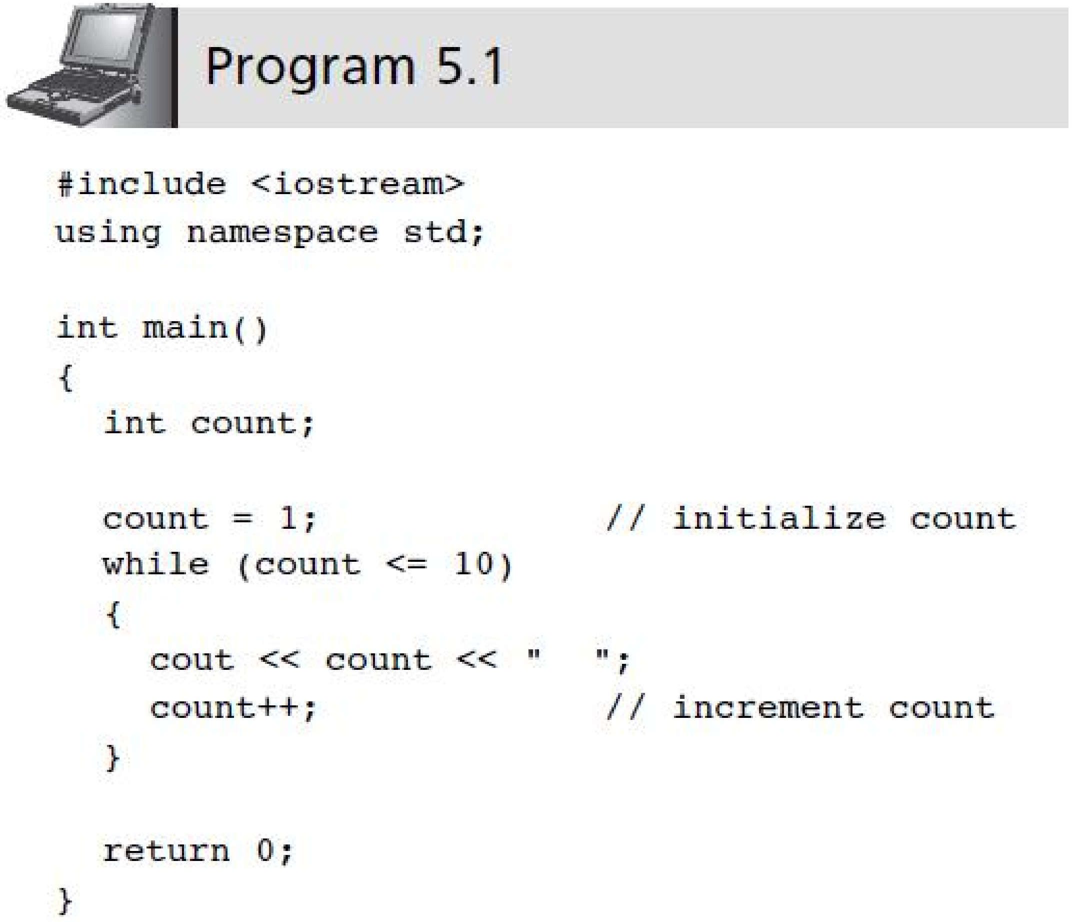
- **`while` statement** is used to create a `while` loop
  - Syntax:

    while (expression)

    statement;

- Statements following the expressions are executed as long as the expression condition remains true (evaluates to a non-zero value)

while Loops (continued)



Program 5.1

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

int main()
{
  int count;

  count = 1;              // initialize count
  while (count <= 10)
  {
    cout << count << "   ";
    count++;              // increment count
  }

  return 0;
}
```

Interactive `while` Loops

- Combining interactive data entry with the **`while`** statement provides for repetitive entry and accumulation of totals

Interactive `while` Loops (cont’d)

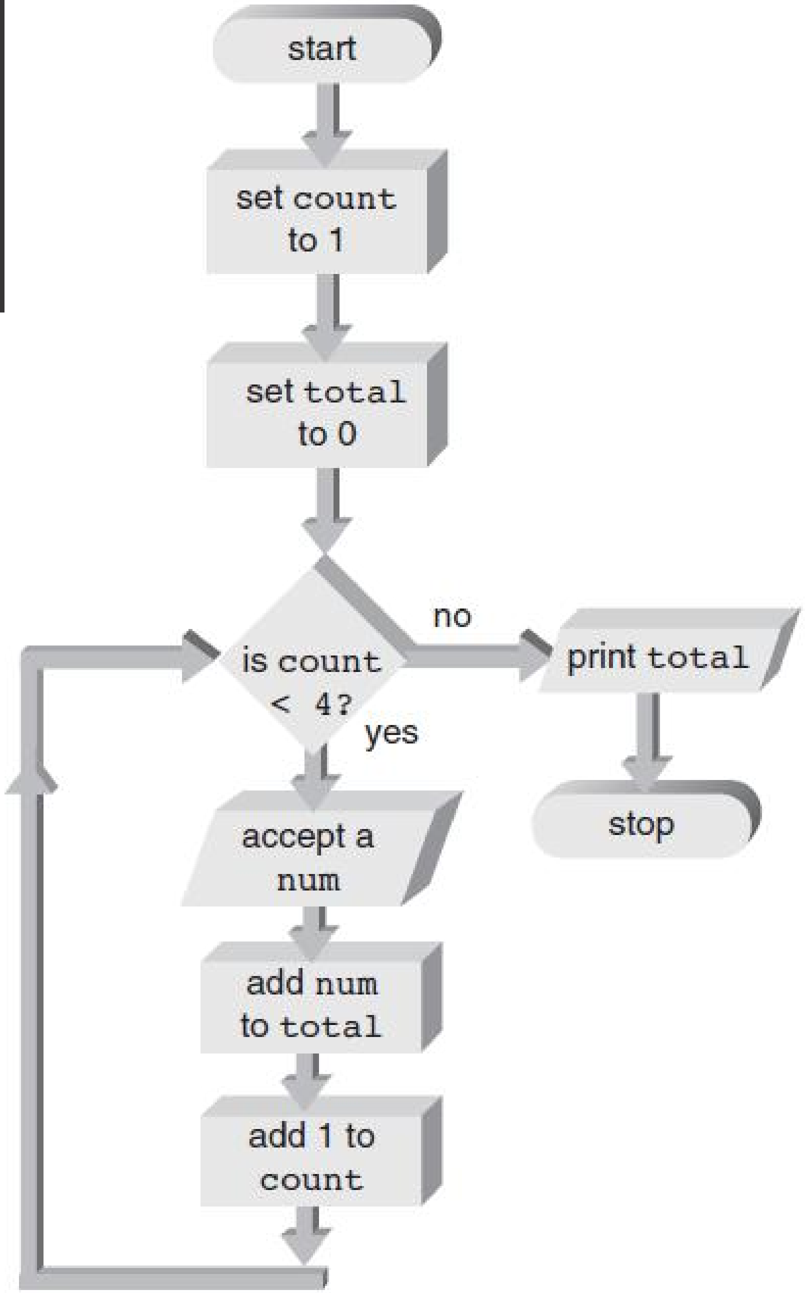


Figure 5.7 Accumulation flow of control

Sentinels

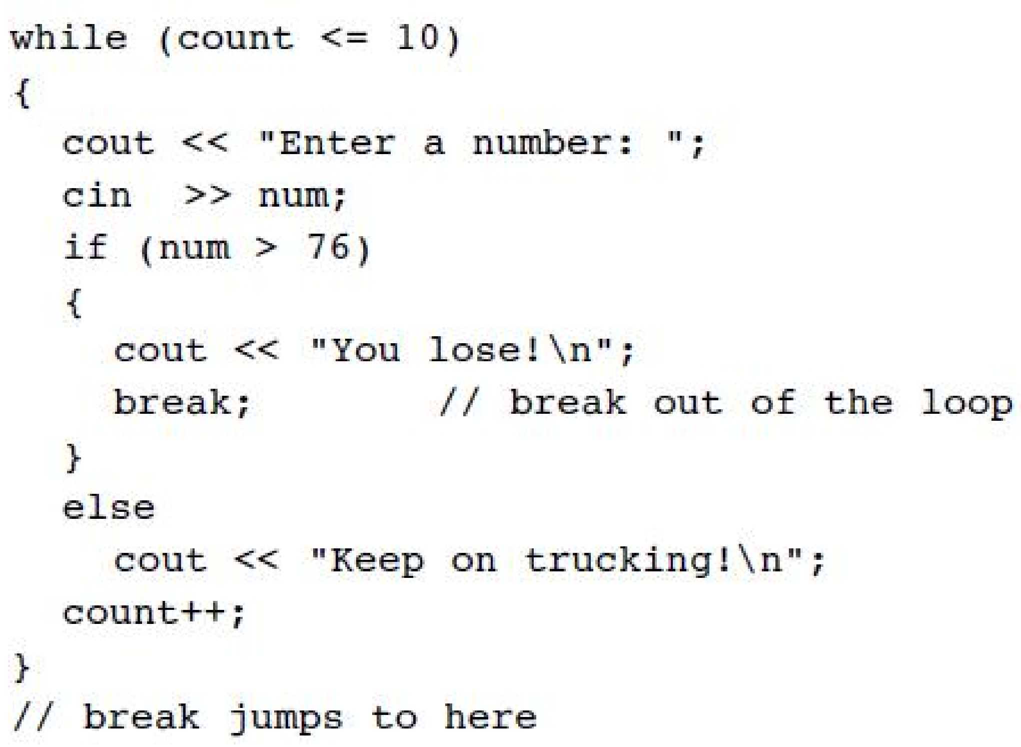
- **Sentinel:** A data value used to signal either the start or end of a data series
  - Use a sentinel when you don’t know how many values need to be entered

`break` and `continue` Statements

- **`break`** statement
  - Forces an immediate break, or exit, from **`switch`**, **`while`**, **`for`**, and **`do-while`** statements
  - Violates pure structured programming, but is useful for breaking out of loops when an unusual condition is detected

break and continue Statements (cont’d)

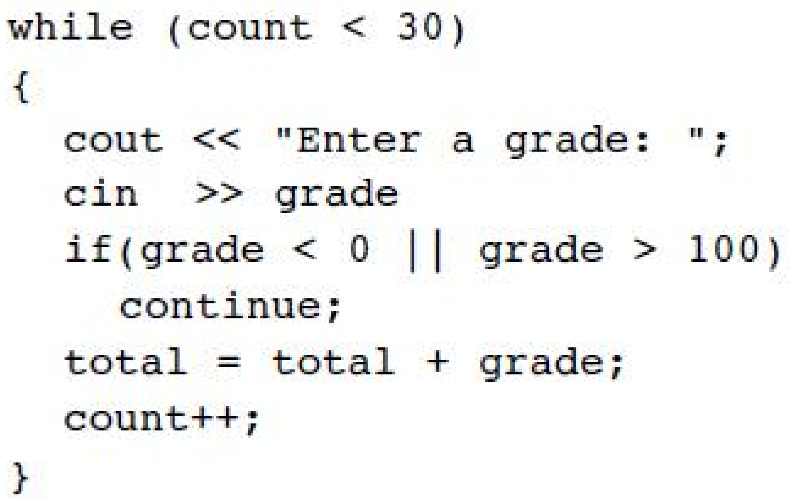
- Example of a `break` statement:



```
while (count <= 10)
{
  cout << "Enter a number: ";
  cin  >> num;
  if (num > 76)
  {
    cout << "You lose!\n";
    break;        // break out of the loop
  }
  else
    cout << "Keep on trucking!\n";
  count++;
}
// break jumps to here
```

break and continue Statements (cont’d)

- A continue statement where invalid grades are ignored, and only valid grades are added to the total:



```
while (count < 30)
{
  cout << "Enter a grade: ";
  cin  >> grade
  if(grade < 0 || grade > 100)
    continue;
  total = total + grade;
  count++;
}
```

`break` and `continue` Statements (cont'd)

- **`continue`** statement
  - Applies to **`while`**, **`do-while`**, and **`for`** statements; causes the next iteration of the loop to begin immediately
  - Useful for skipping over data that should not be processed in this iteration, while staying within the loop

The Null Statement

- **Null statement**
  - Semicolon with nothing preceding it
    - ;
  - Do-nothing statement required for syntax purposes only

`for` Loops

- `for` statement: A loop with a fixed count condition that handles alteration of the condition
  - Syntax:

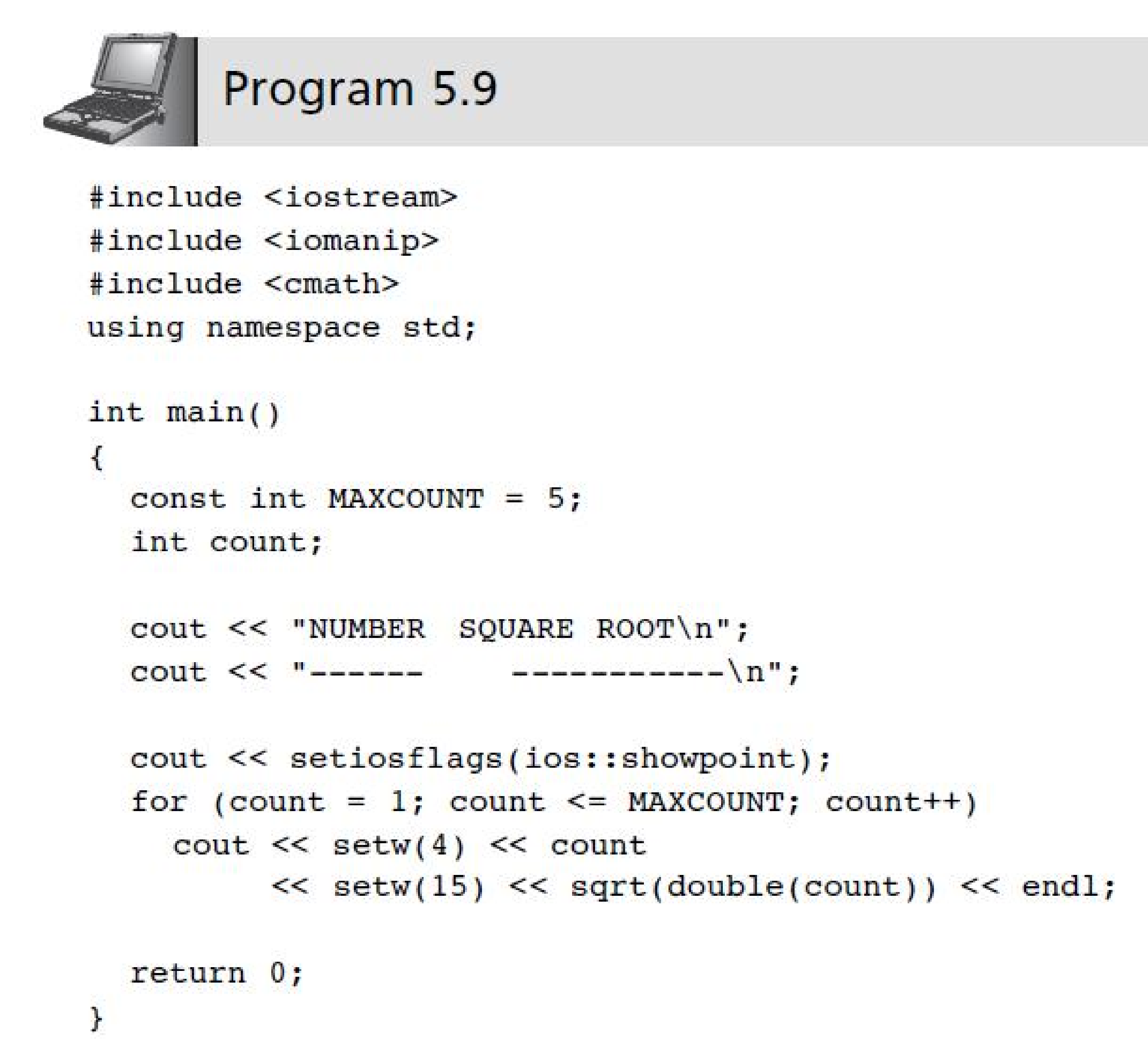
    for (initializing list; expression; altering list)

    statement;
- **Initializing list:** Sets the starting value of a counter
- **Expression:** Contains the maximum or minimum value the counter can have; determines when the loop is finished

`for` Loops (continued)

- **Altering list:** Provides the increment value that is added or subtracted from the counter in each iteration of the loop
- If initializing list is missing, the counter initial value must be provided prior to entering the `for` loop
- If altering list is missing, the counter must be altered in the loop body
- Omitting the expression will result in an infinite loop

for Loops (continued)

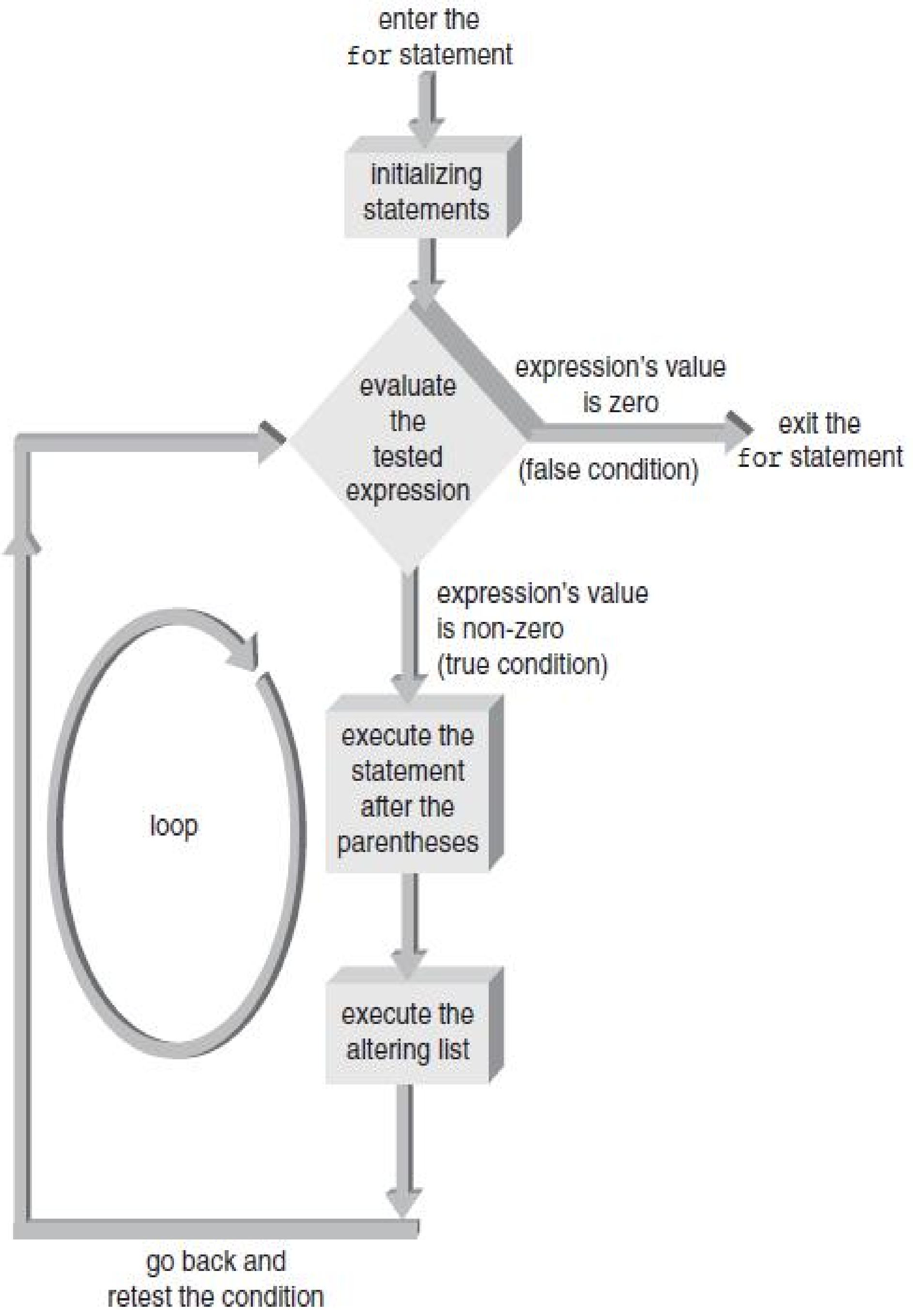


Program 5.9

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

int main()
{
  const int MAXCOUNT = 5;
  int count;

  cout << "NUMBER  SQUARE ROOT\n";
  cout << "------    -----------\n";

  cout << setiosflags(ios::showpoint);
  for (count = 1; count <= MAXCOUNT; count++)
    cout << setw(4) << count
         << setw(15) << sqrt(double(count)) << endl;

  return 0;
}
```

`for` Loops (cont'd)

Figure 5.10 `for` loop flowchart.

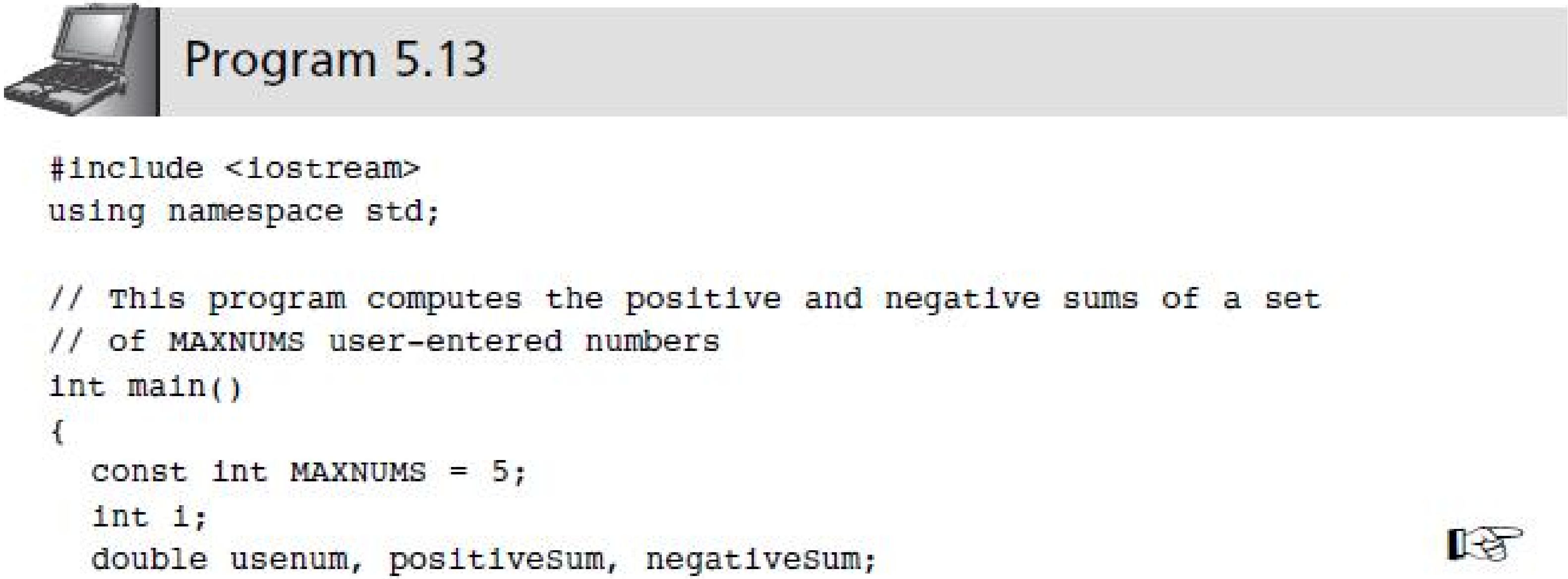


enter the for statement
initializing statements
evaluate the tested expression
expression's value is zero
(false condition)
exit the for statement
expression's value is non-zero (true condition)
execute the statement after the parentheses
execute the altering list
loop
go back and retest the condition

A Closer Look: Loop Programming Techniques

- These techniques are suitable for pretest loops (**`for`** and **`while`**):
  - **Interactive input within a loop**
    - Includes a **`cin`** statement within a **`while`** or **`for`** loop
  - **Selection within a loop**
    - Using a **`for`** or **`while`** loop to cycle through a set of values to select those values that meet some criteria

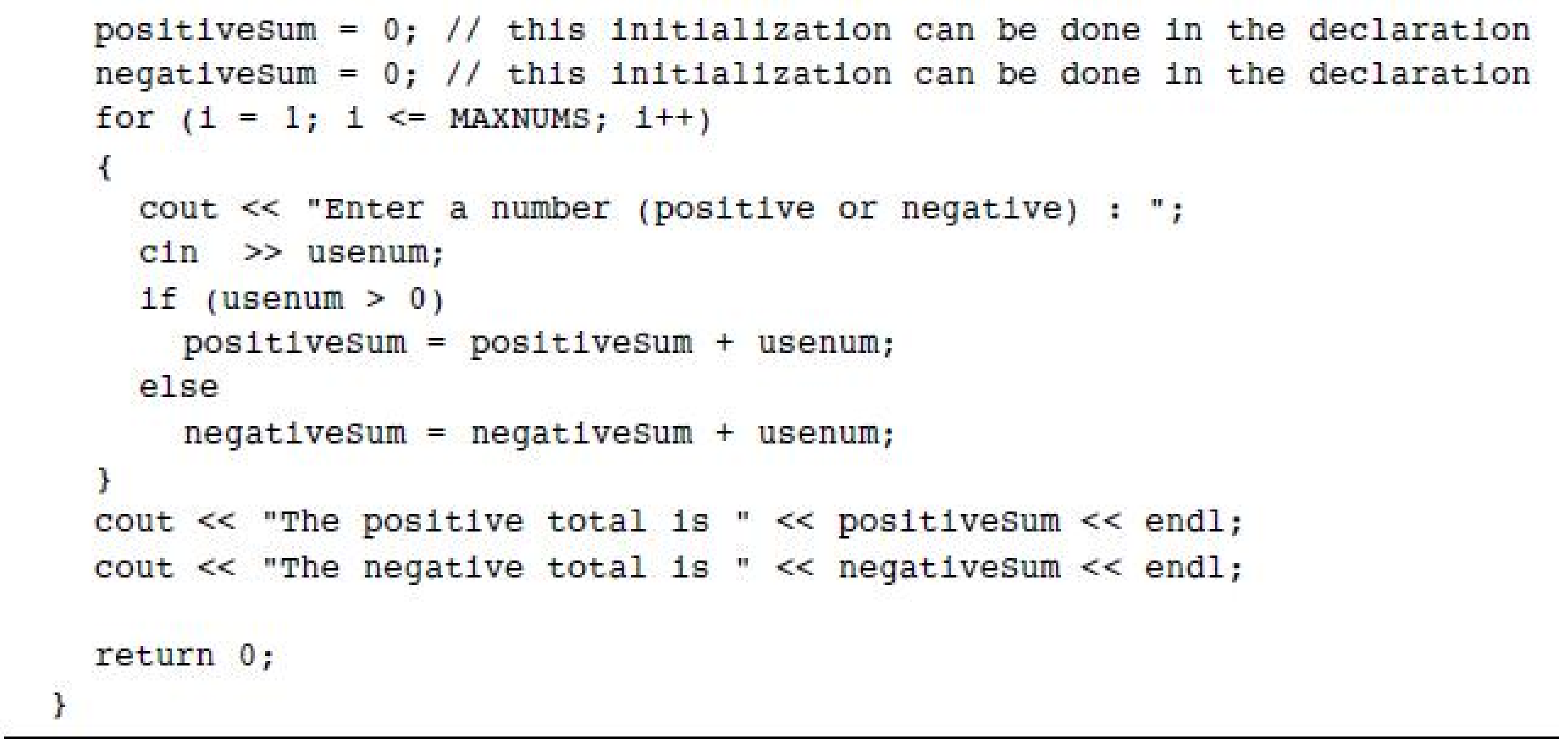
A Closer Look: Loop Programming Techniques (continued)



Program 5.13

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

// This program computes the positive and negative sums of a set
// of MAXNUMS user-entered numbers
int main()
{
  const int MAXNUMS = 5;
  int i;
  double usenum, positiveSum, negativeSum;
```

A Closer Look: Loop Programming Techniques (continued)

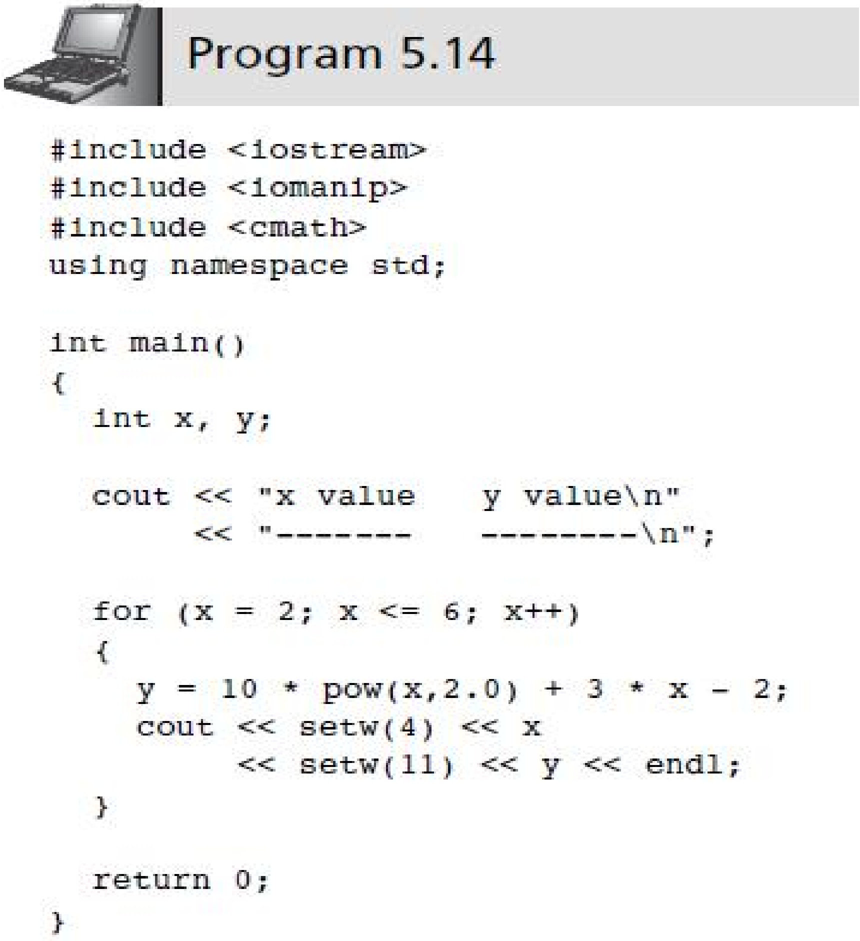


```
    positiveSum = 0; // this initialization can be done in the declaration
    negativeSum = 0; // this initialization can be done in the declaration
    for (i = 1; i <= MAXNUMS; i++)
    {
      cout << "Enter a number (positive or negative) : ";
      cin  >> usenum;
      if (usenum > 0)
        positiveSum = positiveSum + usenum;
      else
        negativeSum = negativeSum + usenum;
    }
    cout << "The positive total is " << positiveSum << endl;
    cout << "The negative total is " << negativeSum << endl;

    return 0;
  }
```

A Closer Look: Loop Programming Techniques (continued)

- **Evaluating functions of one variable**
  - Used for functions that must be evaluated over a range of values
  - Noninteger increment values can be used

A Closer Look: Loop Programming Techniques (continued)



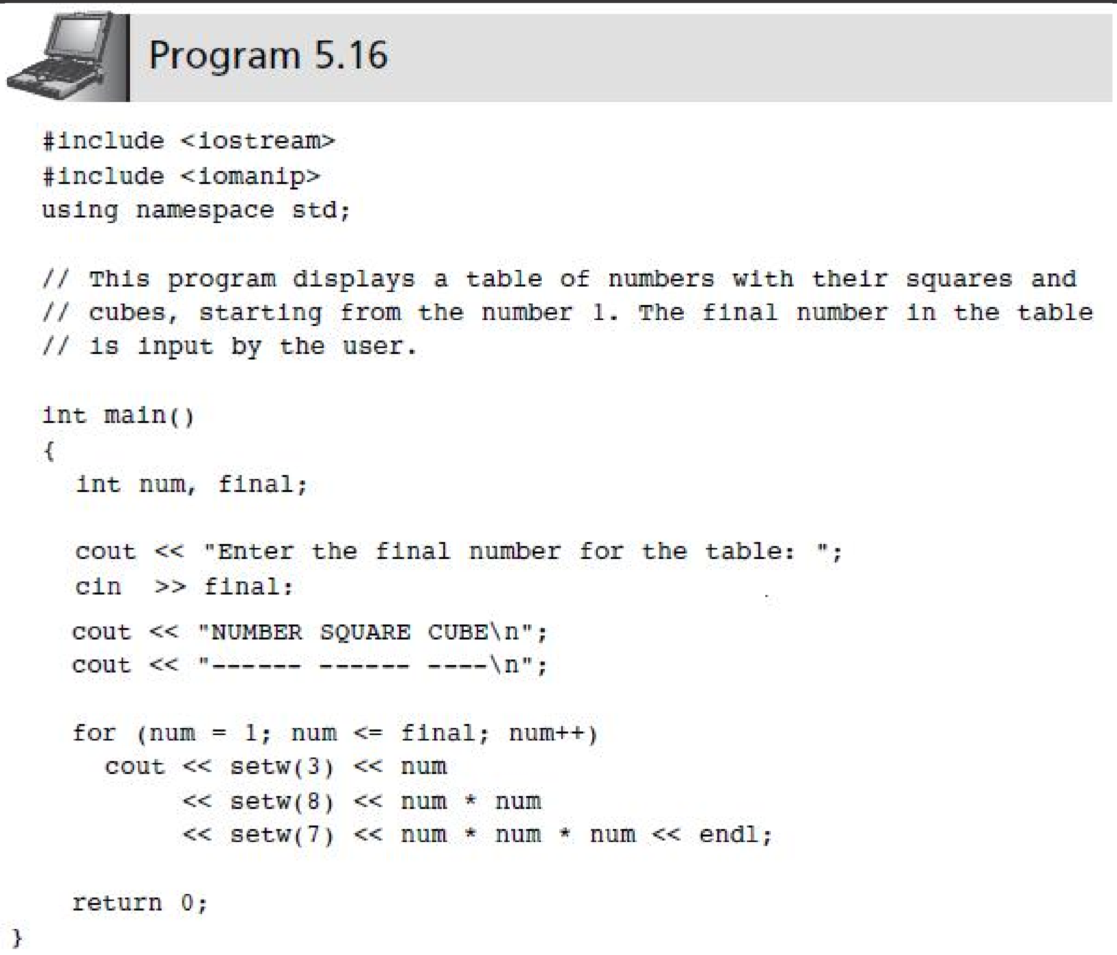
Program 5.14

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

int main()
{
  int x, y;

  cout << "x value    y value\n"
       << "-------    --------\n";

  for (x = 2; x <= 6; x++)
  {
    y = 10 * pow(x,2.0) + 3 * x - 2;
    cout << setw(4) << x
         << setw(11) << y << endl;
  }

  return 0;
}
```

A Closer Look: Loop Programming Techniques (continued)

- **Interactive loop control**
  - – Variable is used to control the loop repetitions
  - – Provides more flexibility at run-time
- **Random numbers and simulation**
  - – Pseudorandom generator used for simulators
  - – C++ functions: `rand()`; `srand()`

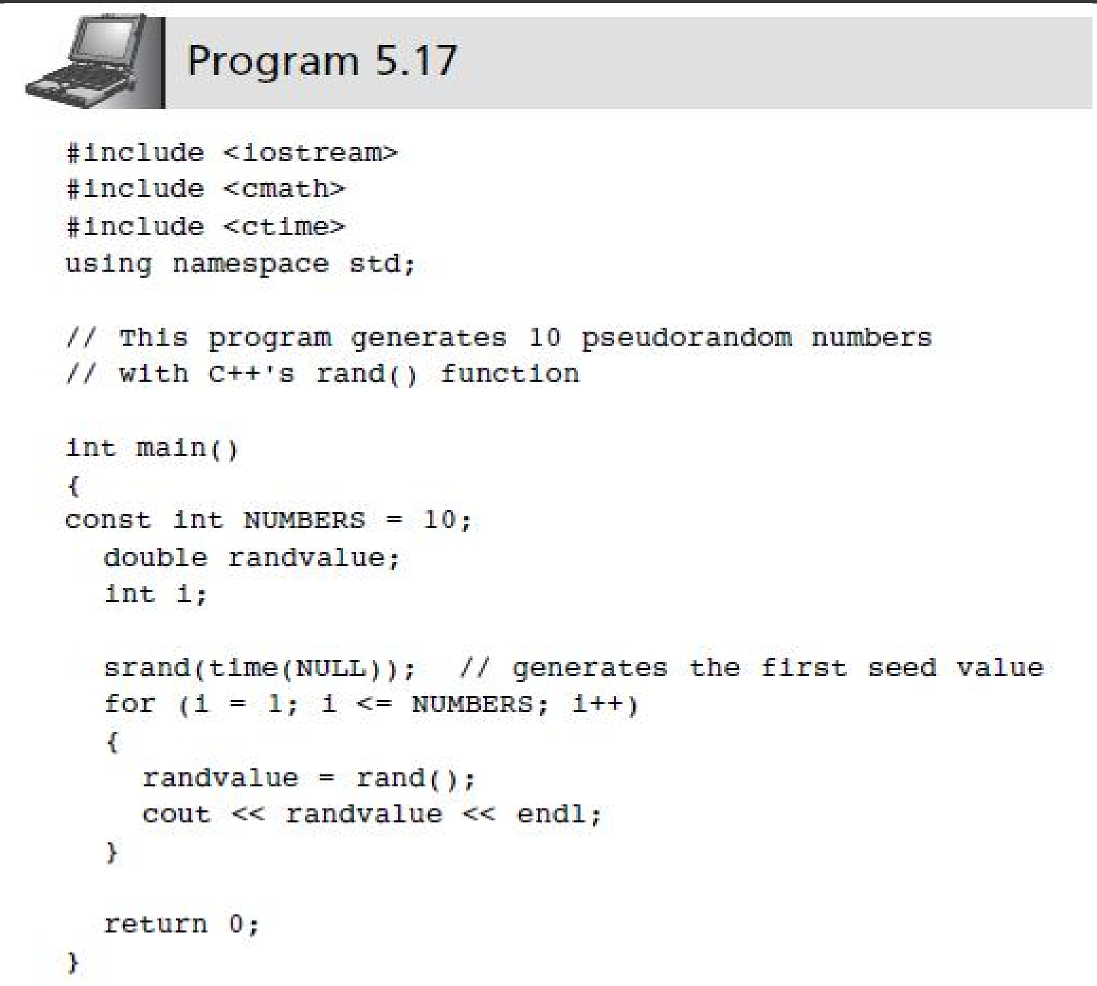
A Closer Look: Loop Programming Techniques (continued)



Program 5.16

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

// This program displays a table of numbers with their squares and
// cubes, starting from the number 1. The final number in the table
// is input by the user.

int main()
{
  int num, final;

  cout << "Enter the final number for the table: ";
  cin  >> final;
  cout << "NUMBER SQUARE CUBE\n";
  cout << "------ ------ ----\n";

  for (num = 1; num <= final; num++)
    cout << setw(3) << num
         << setw(8) << num * num
         << setw(7) << num * num * num << endl;

  return 0;
}
```

A Closer Look: Loop Programming Techniques (continued)



Program 5.17

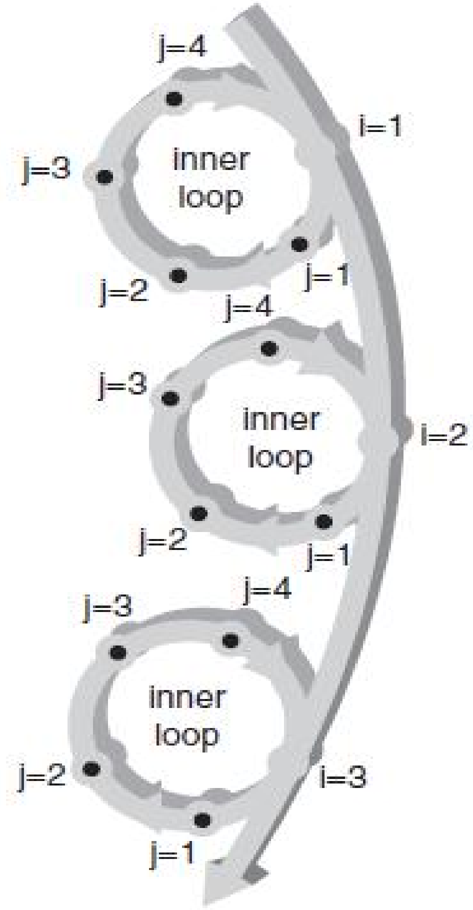
```
#include <iostream>
#include <cmath>
#include <ctime>
using namespace std;

// This program generates 10 pseudorandom numbers
// with C++'s rand() function

int main()
{
const int NUMBERS = 10;
  double randvalue;
  int i;

  srand(time(NULL));  // generates the first seed value
  for (i = 1; i <= NUMBERS; i++)
  {
    randvalue = rand();
    cout << randvalue << endl;
  }

  return 0;
}
```

Nested Loops

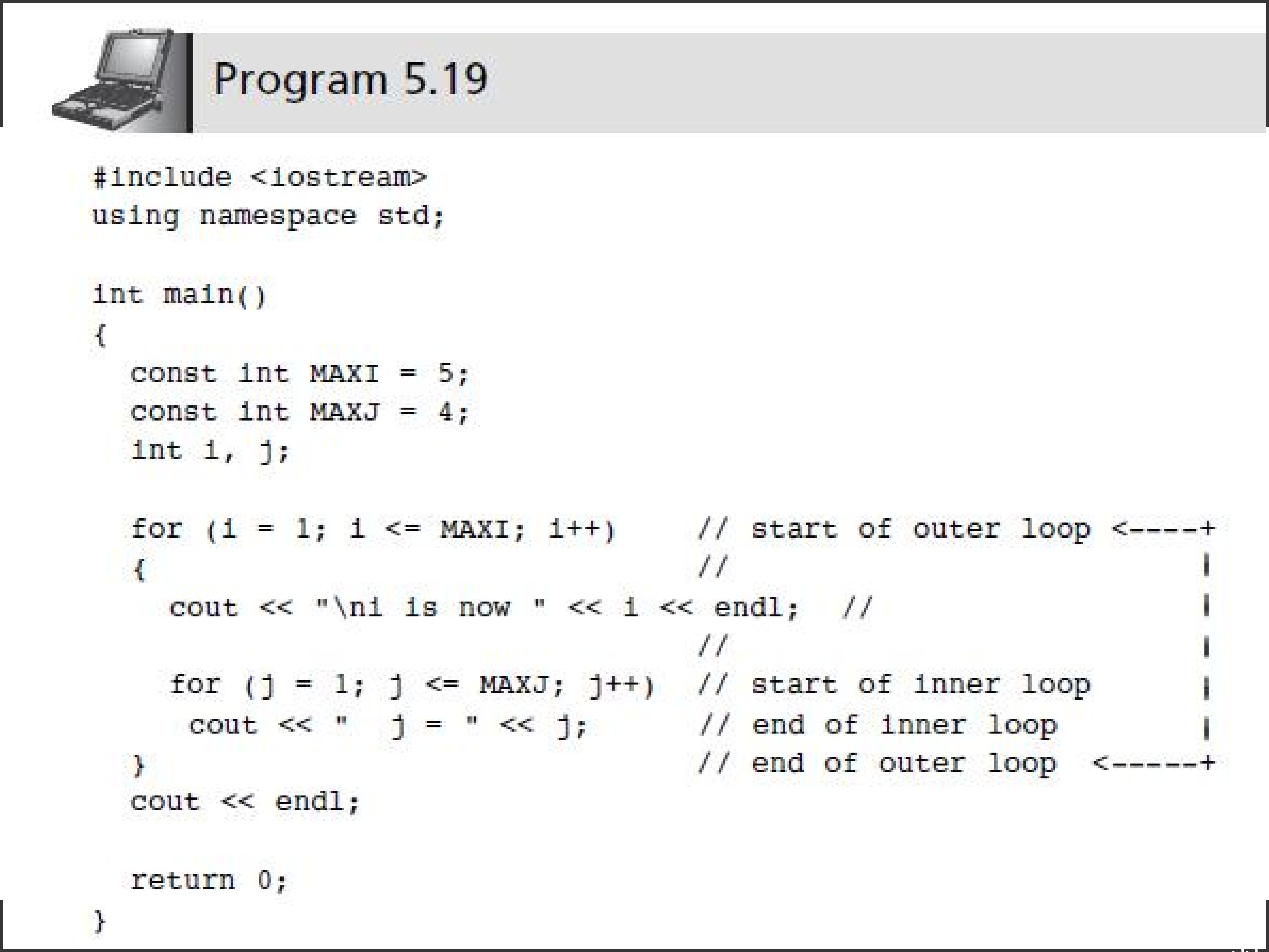
- **Nested loop:** A loop contained within another loop
  - All statements of the inner loop must be completely contained within the outer loop; no overlap allowed
  - Different variables must be used to control each loop
  - For each single iteration of the outer loop, the inner loop runs through all of its iterations

Nested Loops (continued)

Figure 5.12 For each `i, j` loops.



Nested Loops (continued)



Program 5.19

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

int main()
{
  const int MAXI = 5;
  const int MAXJ = 4;
  int i, j;

  for (i = 1; i <= MAXI; i++)     // start of outer loop <----+
  {                               //                          |
    cout << "\ni is now " << i << endl;  //                   |
                                  //                          |
    for (j = 1; j <= MAXJ; j++)   // start of inner loop      |
     cout << "  j = " << j;       // end of inner loop        |
  }                               // end of outer loop  <-----+
  cout << endl;

  return 0;
}
```

`do while` Loops

- **`do while`** loop is a posttest loop
  - Loop continues while the condition is true
  - Condition is tested at the end of the loop
  - Syntax:

    do

    statement;

    while (expression);
- All statements are executed at least once in a posttest loop

do while Loops

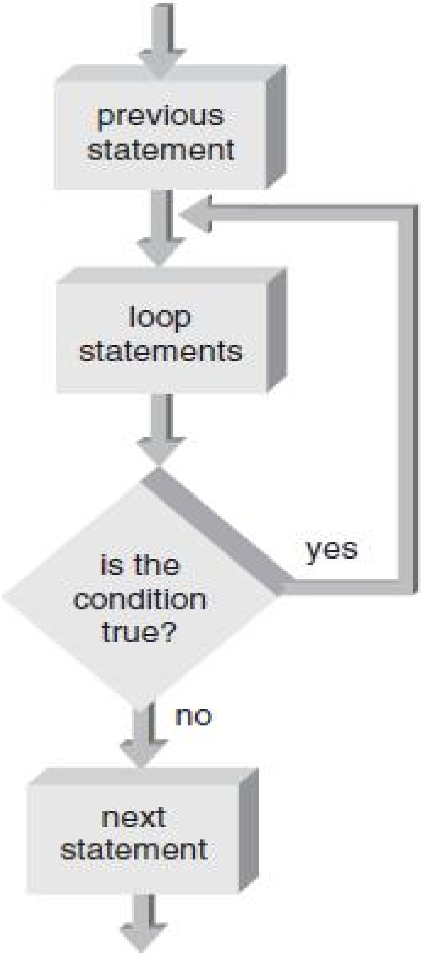
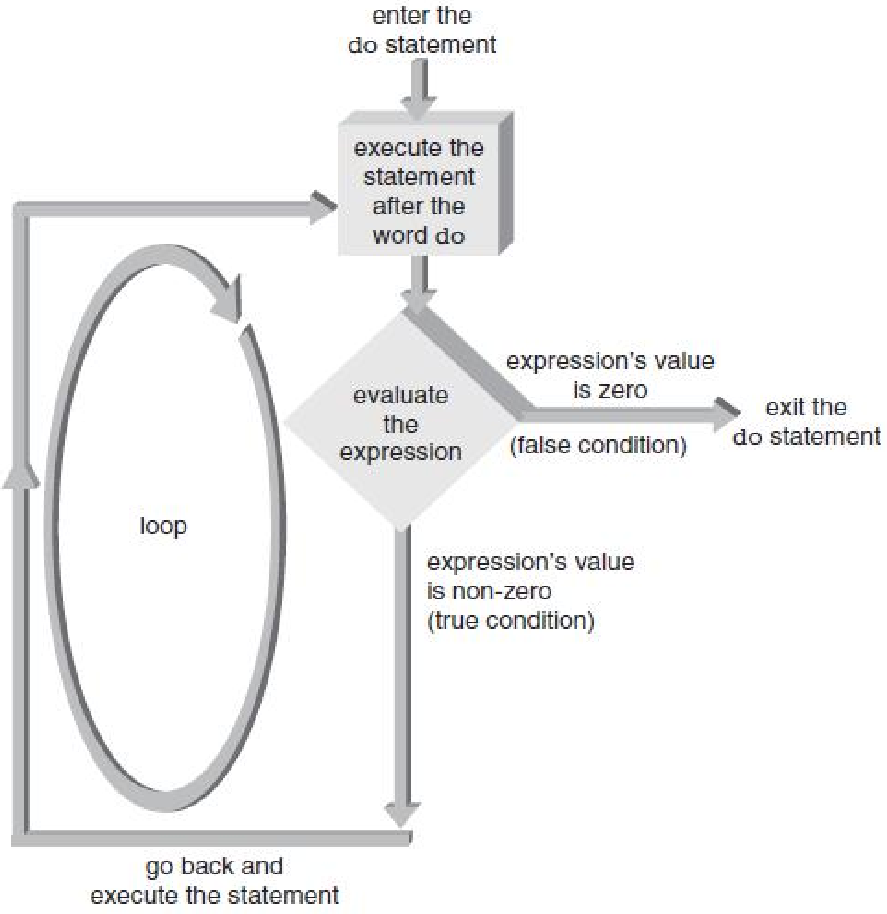


Figure 5.13 The **`do while`** loop structure.

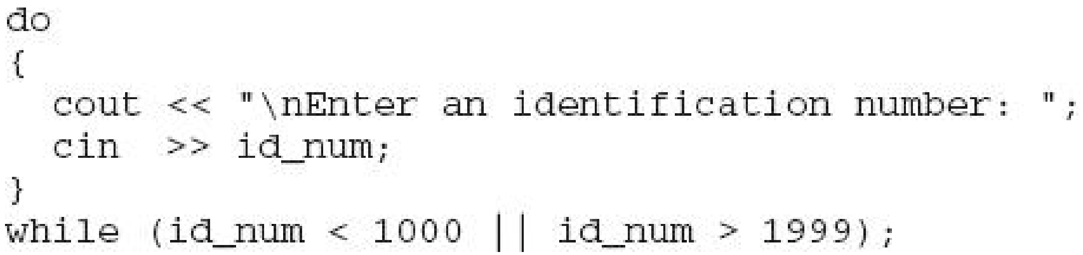
do while Loops

Figure 5.14 The **do** statement's flow of control.


enter the do statement
execute the statement after the word do
evaluate the expression
expression's value is zero
(false condition)
exit the do statement
loop
expression's value is non-zero (true condition)
go back and execute the statement

Validity Checks

- Useful in filtering user-entered input and providing data validation checks



```
do
{
  cout << "\nEnter an identification number: ";
  cin  >> id_num;
}
while (id_num < 1000 || id_num > 1999);
```

- Can enhance with **`if-else`** statement

Common Programming Errors

- Making the “off by one” error: loop executes one too many or one too few times
- Using the assignment operator (**=**) instead of the equality comparison operator (**==**) in the condition expression
- Testing for equality with floating-point or double-precision operands; use an epsilon value instead

Common Programming Errors (continued)

- Placing a semicolon at the end of the **`for`** clause, which produces a null loop body
- Using commas instead of semicolons to separate items in the **`for`** statement
- Changing the value of the control variable
- Omitting the final semicolon in a **`do`** statement

Summary

- Loop: A section of repeating code, whose repetitions are controlled by testing a condition
- Three types of loops:
  - **`while`**
  - **`for`**
  - **`do while`**
- Pretest loop: Condition is tested at beginning of loop; loop body may not ever execute; ex., **`while`**, **`for`** loops

Summary (continued)

- Posttest loop: Condition is tested at end of loop; loop body executes at least once; ex., **`do while`**
- Fixed-count loop: Number of repetitions is set in the loop condition
- Variable-condition loop: Number of repetitions is controlled by the value of a variable