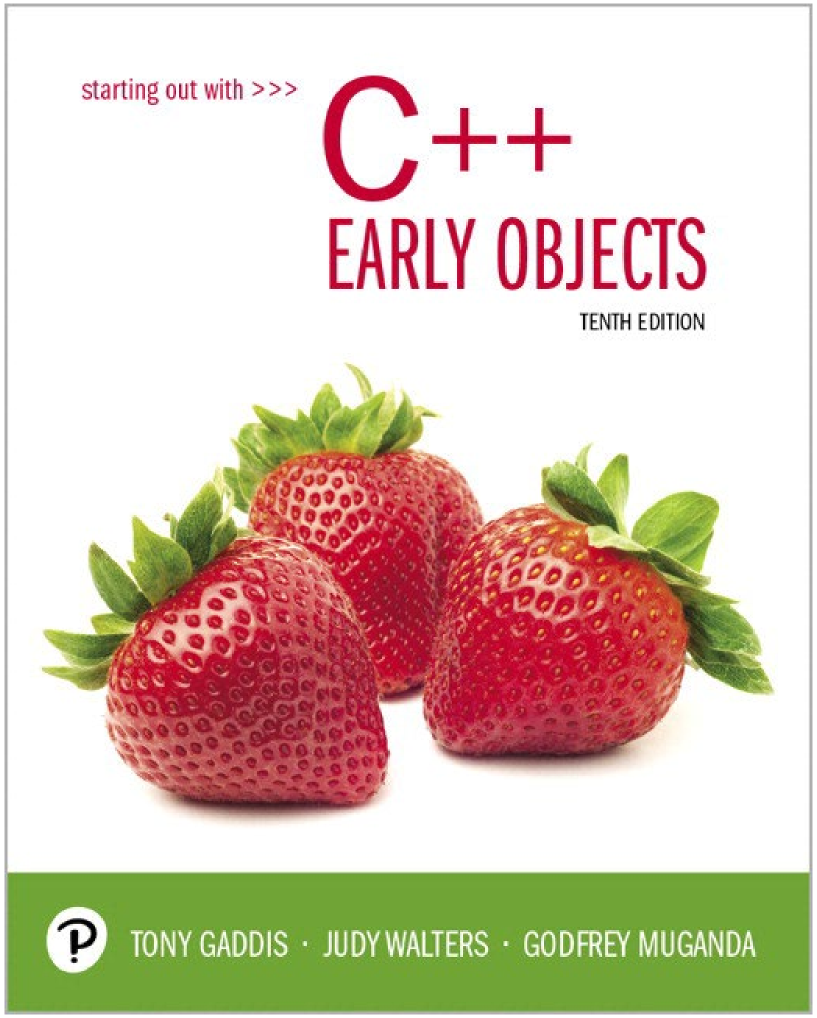
Starting Out with C++ Early Objects

Tenth Edition



Chapter 5

Looping

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5.1 Introduction to Loops: The `while` Loop

- Loop: a part of a program that may execute > 1 time (*i.e.*, it repeats)
- `while` loop format:

```
while (condition)
{   statement(s);
}
```

- The `{ }` can be omitted if there is only one statement in the body of the loop

How the `while` Loop Works

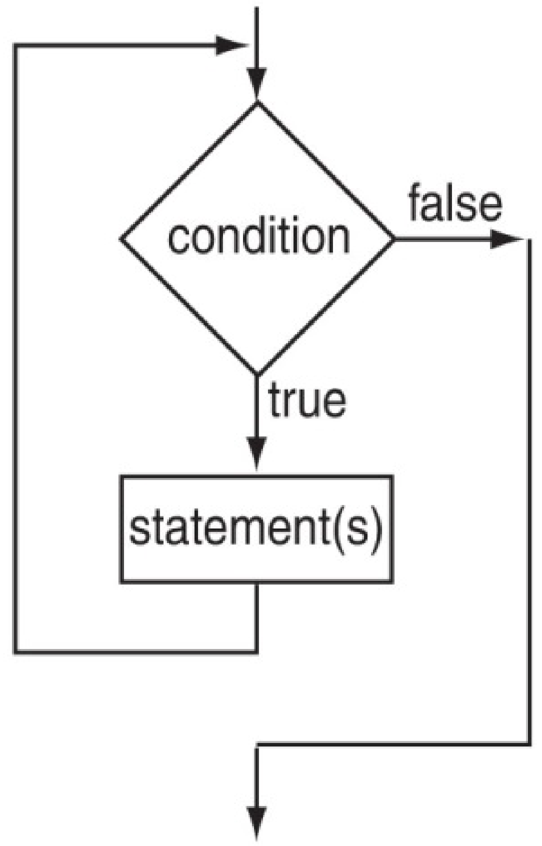
```
while (condition)
{   statement(s);
}
```

`condition` is evaluated

- if it is true, the *`statement(s)`* are executed, and then *`condition`* is evaluated again
- if it is false, the loop is exited

An iteration is an execution of the loop body

`while` Loop Flow of Control



`while` Loop Example

```
int val = 5;
while (val >= 0)
{    cout << val << "  ";
     val = val - 1;
}
```

- produces output:

```
 5  4  3  2  1  0
```

- **`val`** is called a loop control variable

`while` Loop Is a Pretest Loop

- **`while`** is a pretest loop (the ***`condition`*** is evaluated <u>before</u> the loop executes)
- If the condition is initially false, the statement(s) in the body of the loop are never executed
- If the condition is initially true, the statement(s) in the body will continue to be executed until the condition becomes false

Exiting the Loop

- The loop must contain code to allow the ***condition*** to eventually become **`false`** so the loop can be exited
- Otherwise, you have an infinite loop (*i.e.*, a loop that does not stop)
- Example infinite loop:

```
x = 5;
while (x > 0)      // infinite loop because
   cout << x;      // x is always > 0
```

Common Loop Errors

- Don’t put ; immediately after ***(condition)***
- Don’t forget the { } :

```
int numEntries = 1;
while (numEntries <=3)
    cout << "Still working … ";
    numEntries++; // not in the loop body
```

- Don’t use = when you mean to use ==

```
while (numEntries = 3)   // always true
{
    cout << "Still working … ";
    numEntries++;
}
```

`while` Loop Programming Style

- Loop body statements should be indented
- Align { and } with the loop header and place them on lines by themselves

Note: The conventions above make the source code more understandable by someone who is reading it. They have no effect on how the source code compiles or how the program executes.

5.2 Using the `while` Loop for Input Validation

Loops are an appropriate structure for validating user input data

1. Prompt for and read in the data.
2. Use a **`while`** loop to test if data is valid.
3. Enter the loop only if data is <u>not</u> valid.
4. In the loop body, display an error message and prompt the user to re-enter the data.
5. The loop will not be exited until the user enters valid data.

Input Validation Loop Example

```
cout << "Enter a number (1-100) and"
     << " I will guess it. ";
cin  >> number;

while ((number < 1) || (number > 100))
{  cout << "Number must be between 1 and 100."
        << " Re-enter your number. ";
   cin  >> number;
}
// Code to use the valid number follows
```

5.3 The Increment and Decrement Operators

- Increment – increase the value in variable

  `++` adds one to a variable

  `val++;` is the same as `val = val + 1;`

- Decrement – reduce the value in variable

  `--` subtracts one from a variable

  `val--;` is the same as `val = val - 1;`

- can be used in prefix mode (before) or postfix mode (after) a variable

Prefix Mode

- `++val` and `--val` increment or decrement the variable, *then* return the new value of the variable.
- It is this returned new value of the variable that is used in any other operations within the same statement

Prefix Mode Example

```
int x = 1, y = 1;

x = ++y;            // y is incremented to 2,
                    // then 2 is assigned to x
cout << x
  << "  " << y; // Displays 2  2

x = --y;            // y is decremented to 1,
                    // then 1 is assigned to x
cout << x
  << "  " << y; // Displays 1 1
```

Postfix Mode

- **`val++`** and **`val--`** return the current value of the variable, *then* increment or decrement the variable
- It is this returned current value of the variable that is used in any other operations within the same statement

Postfix Mode Example

```
int x = 1, y = 1;

x = y++;           // y++ returns a 1
                   // The 1 is assigned to x
                   // and y is incremented to 2
cout << x
  << "  " << y; // Displays 1  2

x = y--;           // y-- returns a 2
                   // The 2 is assigned to x
                   // and y is decremented to 1
cout << x
  << "  " << y; // Displays 2 1
```

Increment & Decrement Notes

- They can be used in arithmetic expressions

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

- They must be applied to a variable, not an expression or a literal value. You cannot have

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

- They can be used in relational expressions

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

- Pre- and post-operations will cause different comparisons

5.4 Counters

- Counter: a variable that is incremented or decremented each time a loop iterates
- It can be used to control the execution of the loop (as a loop control variable)
- It must be initialized before entering loop
- It may be incremented/decremented either inside the loop or in the loop test

Letting the User Control the Loop

- A program can be written so that user input determines loop repetition
- This can be used when program processes a list of items, and the user knows the number of items
- The user is prompted before the loop is entered. The user input is used to control number of repetitions

User Controls the Loop Example

```
int num, limit;
cout << "Table of squares\n";
cout << "How high to go? ";
cin  >> limit;
cout << "\n\nnumber square\n";
num = 1;
while (num <= limit)
{   cout << setw(5) << num << setw(6)
          << num*num << endl;
    num++;
}
```

5.5 Keeping a Running Total

- running total: an accumulated sum of numbers from iterations of loop
- accumulator: a 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;
```

5.6 Sentinels

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

Sentinel Example

```
int total = 0;
cout << "Enter points earned "
     << "(or -1 to finish): ";
cin  >> points;

while (points != -1) // -1 is the sentinel
{
   total += points;
   cout << "Enter points earned: ";
   cin  >> points;
}
```

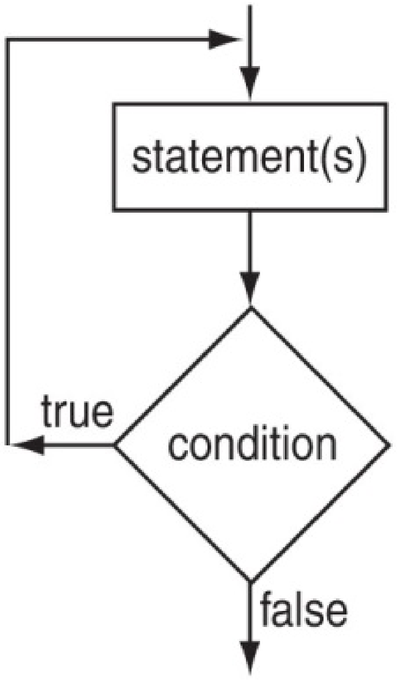
5.7 The `do-while` Loop

- **`do-while`**: a post test loop (***`condition`*** is evaluated <u>after</u> the loop executes)
- Format:

```
do
{   1 or more statements;
} while (condition);
```

Note the required ;

`do-while` Flow of Control



`do-while` Loop Notes

- The loop body always executes at least once
- Execution continues as long as the ***`condition`*** is **`true`**; the loop is exited when the ***`condition`*** becomes **`false`**
- { } are not required if the body contains a single statement
- ; after ***`(condition)`*** is required

`do-while` and Menu-Driven Programs

- do-while can be used in a menu-driven program to bring the user back to the menu to make another choice
- To simplify the processing of user input, use the **`toupper`** (‘to uppercase’) or **`tolower`** (‘to lowercase’) function. This allows you to check user input regardless of the case of the input. Note: requires **`cctype`** to be included.

Menu-Driven Program Example

```
do {
   // code to display menu
   // and perform actions
   cout << "Another choice? (Y/N) ";
} while ((choice =='Y')||(choice=='y'));
```

The condition could be written as

```
      (toupper(choice) == 'Y');
```

or as

```
      (tolower(choice) == 'y');
```

5.8 The `for` Loop

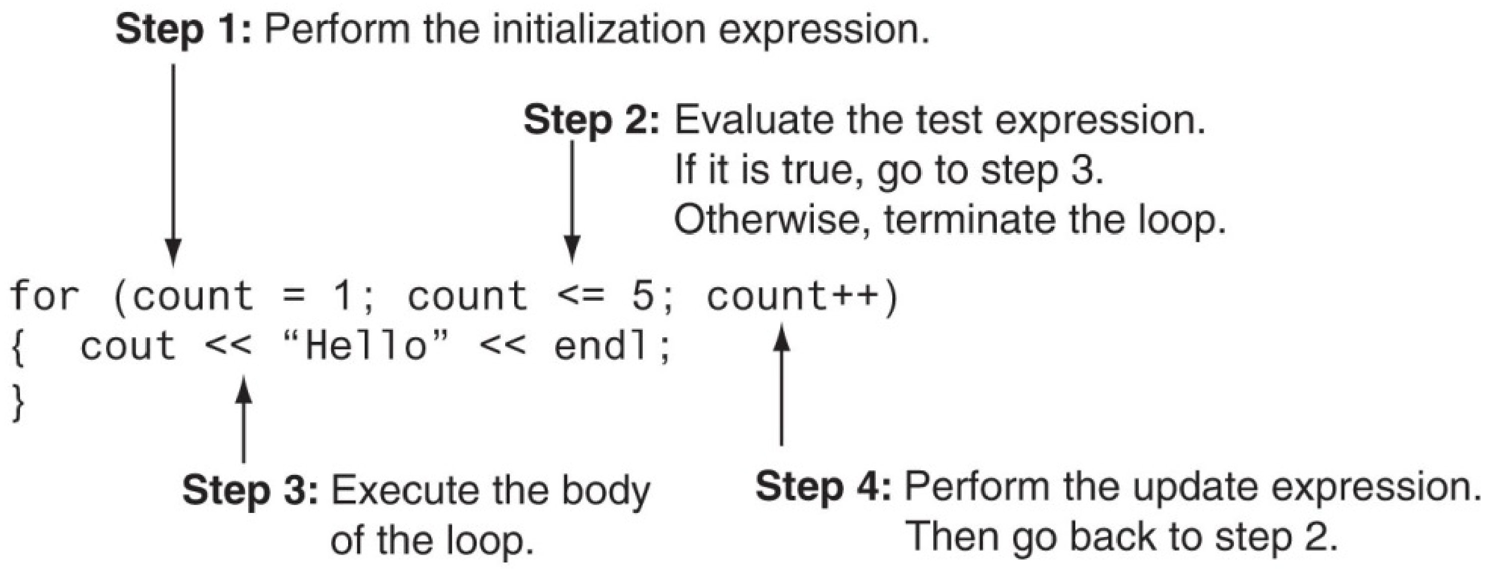
- It is a pretest loop that executes zero or more times
- It is useful for a counter-controlled loop
- Format:

Required ;

```
for( initialization; test; update )
 {    1 or more statements;
 }
```

They don't go here

for Loop Mechanics



Step 1: Perform the initialization expression.

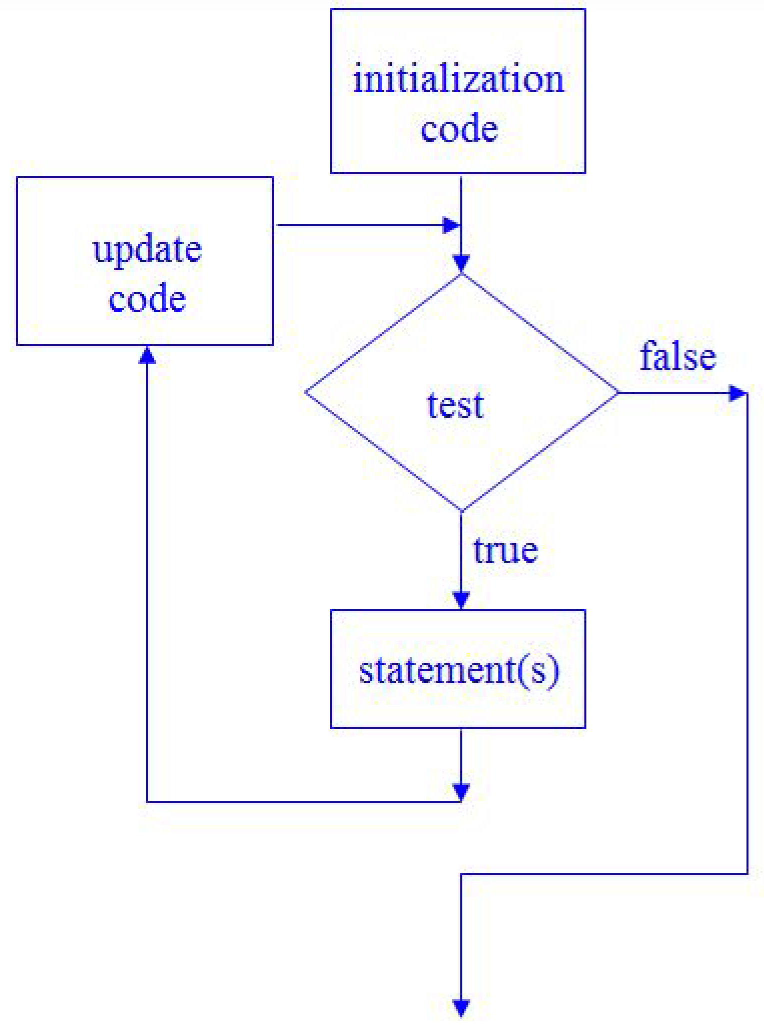
Step 2: Evaluate the test expression.
If it is true, go to step 3.
Otherwise, terminate the loop.

```
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.

`for` Loop Flow of Control



for Loop Example

```
int sum = 0, num;
for (num = 1; num <= 10; num++)
   sum += num;
cout << "Sum of numbers 1 - 10 is "
        << sum << endl;
```

`for` Loop Notes

- If ***`test`*** is false the first time it is evaluated, the body of the loop will not be executed
- The update expression can increment or decrement by any amount
- Variables used in the initialization section should not be modified in the body of the loop

`for` Loop Modifications

- You can define variables in initialization code
  - Their scope is the `for` loop
- Initialization and update code can contain more than one statement
  - Separate the statements with commas
- Example:

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

More `for` Loop Modifications (These are NOT Recommended)

- Can omit ***initialization*** if already done

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

- Can omit ***update*** if done in loop body

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

- Can omit the loop body if all of the work is done in the header

5.9 Deciding Which Loop to Use

- `while`: pretest loop (loop body may not be executed at all)
- `do-while`: post test loop (loop body will always be executed at least once)
- `for`: pretest loop (loop body may not be executed at all); has initialization and update code; is useful with counters or if precise number of iterations is known

5.10 Nested Loops

- A nested loop is a loop that is inside the body of another loop
- Example:

outer loop

inner loop

```
for (row = 1; row <= 3; row++)
{
   for (col = 1; col <= 3; col++)
   {
      cout << row * col << endl
   }
}
```

Pearson

Notes on Nested Loops

- The inner loop goes through all of its iterations for each iteration of the outer loop
- The inner loop completes its iterations faster than the outer loop
- The total number of iterations for inner loop is product of number of iterations of the two loops. In previous example, inner loop iterates 9 times in total.

5.11 Breaking Out of a Loop

- **`break`** can be used to terminate the execution of a loop iteration
- Use it sparingly if at all – it makes code harder to understand
- When used in an inner loop, **`break`** terminates that loop only and returns to the outer loop

The `continue` Statement

- You can use **`continue`** to go to the end of the loop and prepare for next iteration
  - **`while`** and **`do-while`** loops go to the test expression and repeat the loop if test is true
  - **`for`** loop goes to the update step, then test, and repeats the loop if test condition is true
- Use **`continue`** sparingly – like **`break`**, it can make program logic hard to understand

5.12 Using Files for Data Storage

- We can use a file instead of the computer screen for program output
- Files are stored on secondary storage media, such as a disk
- Files allow data to be retained between program executions
- We can later use the file instead of a keyboard for program input

File Types

- Text file – contains information encoded as text, such as letters, digits, and punctuation. It can be viewed with a text editor such as Notepad.
- Binary file – contains binary (0s and 1s) information that has not been encoded as text. It cannot be viewed with a text editor.

File Access – Ways to Use the Data in a File

- Sequential access – read the 1st piece of data, read the 2nd piece of data, …, read the last piece of data. To access the n-th piece of data, you have to retrieve the preceding (n-1) pieces first.
- Random (direct) access – retrieve any piece of data directly, without the need to retrieve preceding data items.

What is Needed to Use Files

1. Include the **`ifstream`** and / or **`ofstream`** header file(s)
2. Define a file stream object
   - **`ifstream`** for input (read data) from a file

     ```
     ifstream inFile;
     ```

   - **`ofstream`** for output (write data) to a file

     ```
     ofstream outFile;
     ```

Open the File 1 of 2

3. Open the file

- Use the **`open`** member function

```
inFile.open("inventory.dat");
outFile.open("report.txt");
```

- The filename may include drive, path info.
- The filename must include the full name, including extensions.
- The output file will be created if necessary; an existing output file will be erased first
- Input file must exist for **`open`** to work

Open the File 2 of 2

Creating a filestream object and opening a file can be accomplished in a single statement:

```
ifstream inFile("inventory.dat");

ofstream outFile("report.txt");
```

Again, input file must exist in order to be opened. Output file will be created or erased as needed.

Use the File

4. Use the file

- 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 the file to variables

```
inFile >> partNum;
inFile >> qtyInStock >> qtyOnOrder;
```

Close the File

5. Close the file

- Use the **`close`** member function

```
inFile.close();
outFile.close();
```

- Don’t wait for operating system to close files at program end
  - There may be limit on number of open files
  - There may be buffered output data waiting to be sent to a file that could be lost

Input File – the Read Position

- Read Position – the location of the next piece of data in an input file
- It is initially set to the first byte in the file
- It advances for each data item that is read. Successive reads will retrieve successive data items.

User-Specified Filenames

- A program can prompt the user to enter the names of input and/or output files. This makes the program more versatile.
- Filenames can be read into string objects. In C++ prior to C++ 11, the C-string representation of the string object can be passed to the open function:

```
cout << "Which input file? ";
cin >> inputFileName;
inFile.open(inputFileName.c_str());
```

- In C++ 11, the string object can be passed to the open() function directly.

Using the >> Operator to Test for End of File (EOF) on an Input File

- The stream extraction operator (>>) returns a true or false value indicating if a read is successful
- This can be tested to find the end of file since the read “fails” (the read expression is false) when there is no more data
- Example:

```
while (inFile >> score)
    sum += score;
```

File Open Errors

- An error will occur if an attempt to open a file for input fails:
  - File does not exist
  - Filename is misspelled
  - File exists, but is in a different place
- The file stream object is set to true if the open operation succeeded. It can be tested to see if the file can be used:

```
if (inFile)
{
  // process data from file
}
else
   cout << "Error on file open\n";
```

5.13 Creating Good Test Data

- When testing a program, the quality of the test data is more important than the quantity.
- Test data should show how different parts of the program execute
- Test data should evaluate how program handles:
  - normal data
  - data that is at the limits the valid range
  - invalid data

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