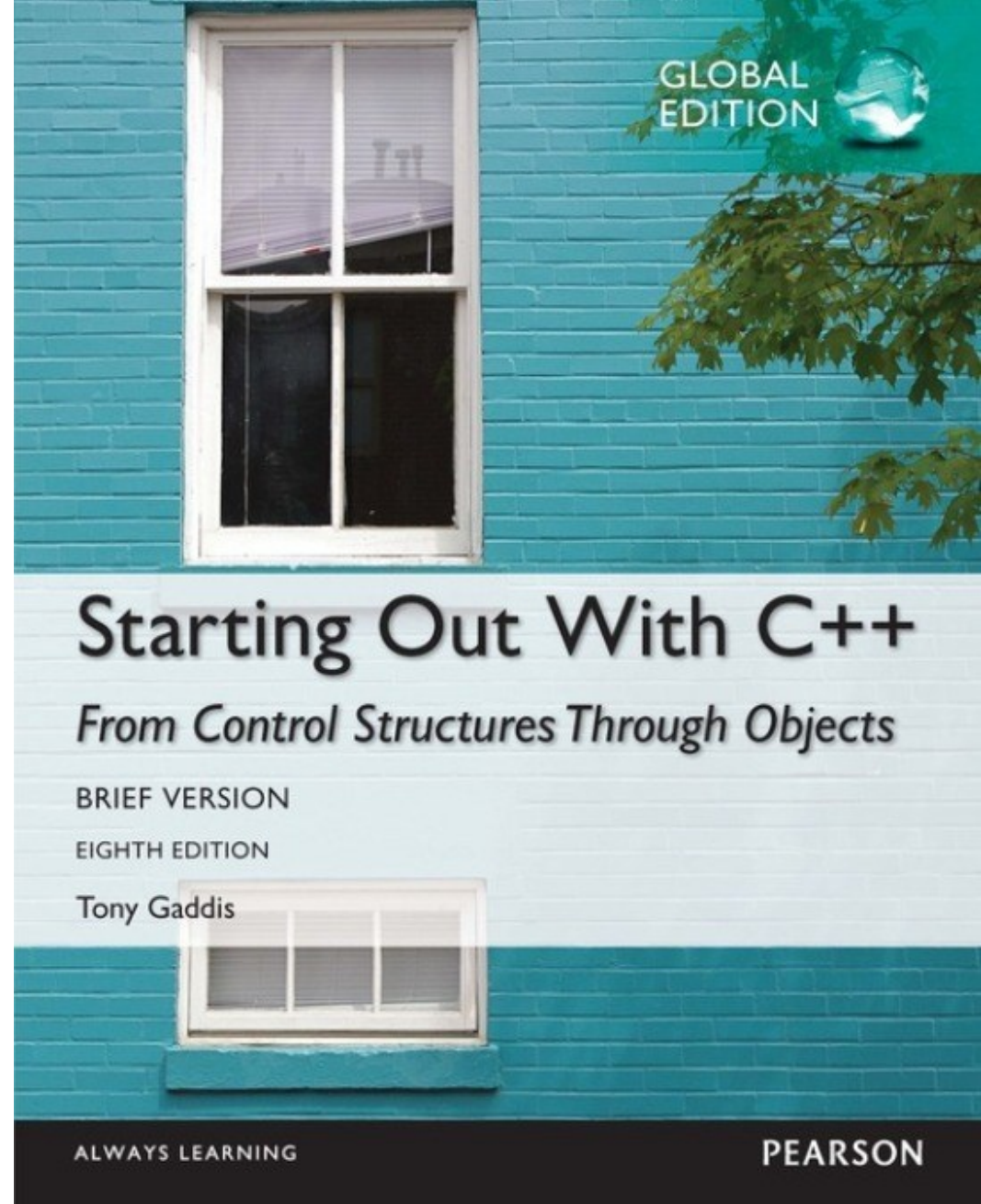


Chapter 6:

Functions



Modular Programming

- Modular programming: breaking a program up into smaller, manageable functions or modules
- Function: a collection of statements to perform a task
- Motivation for modular programming:
 - Improves maintainability of programs
 - Simplifies the process of writing programs

This program has one long, complex function containing all of the statements necessary to solve a problem.

[illegible]

In this program the problem has been divided into smaller problems, each of which is handled by a separate function.

```
int main()
{
    statement;
    statement;
    statement;
}
```

main function

```
void function2()
{
    statement;
    statement;
    statement;
}
```

function 2

```
void function3()
{
    statement;
    statement;
    statement;
}
```

function 3

```
void function4()
{
    statement;
    statement;
    statement;
}
```

function 4

Defining and Calling Functions

- Function definition: statements that make up a function
- Function call: statement causes a function to execute

Function Definition

● Definition includes:

- return type: data type of the value that function returns to the part of the program that called it
- name: name of the function. Function names follow same rules as variables
- parameter list: variables containing values passed to the function
- body: statements that perform the function's task, enclosed in { }

Function Definition

```
Return type      Parameter list (This one is empty)
  ↓              ↓
Function name
  ↓
int main ()
{
    cout << "Hello World\n";
    return 0;
}
```

The diagram illustrates the structure of a C++ function definition. It shows the code `int main () { cout << "Hello World\n"; return 0; }` with four arrows pointing to its components: 'Return type' points to `int`, 'Function name' points to `main`, 'Parameter list (This one is empty)' points to `()`, and 'Function body' points to the code inside the curly braces.

Note: The line that reads `int main ()` is the *function header*.

Function Return Type

- If a function returns a value, the type of the value must be indicated:

```
int main()
```

- If a function does not return a value, its return type is `void`:

```
void printHeading()  
{  
    cout << "Monthly Sales\n";  
}
```

Calling a Function

- To call a function, use the function name followed by `()` and `;`
`printHeading();`
- When called, program executes the body of the called function
- After the function terminates, execution resumes in the calling function at point of call.

Functions in Program 6-1

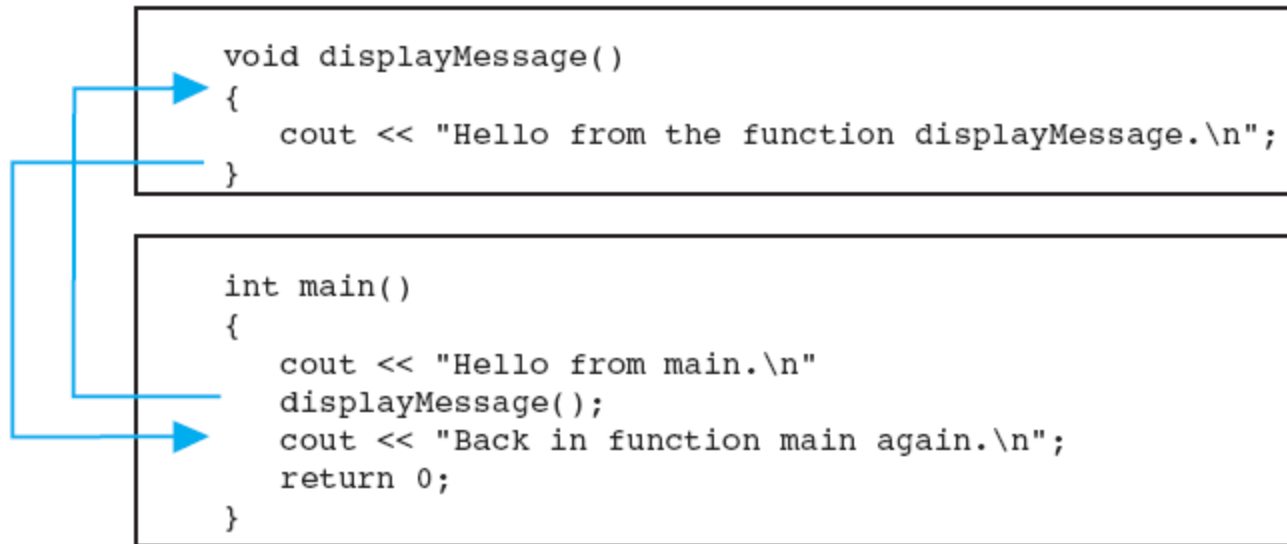
Program 6-1

```
1  // This program has two functions: main and displayMessage
2  #include <iostream>
3  using namespace std;
4
5  //*****
6  // Definition of function displayMessage *
7  // This function displays a greeting. *
8  //*****
9
10 void displayMessage()
11 {
12     cout << "Hello from the function displayMessage.\n";
13 }
14
15 //*****
16 // Function main *
17 //*****
18
19 int main()
20 {
21     cout << "Hello from main.\n";
22     displayMessage();
23     cout << "Back in function main again.\n";
24     return 0;
25 }
```

Program Output

```
Hello from main.
Hello from the function displayMessage.
Back in function main again.
```

Flow of Control in Program 6-1



Calling Functions

- `main` can call any number of functions
- Functions can call other functions
- Compiler must know the following about a function before it is called:
 - name
 - return type
 - number of parameters
 - data type of each parameter

Function Prototypes

- Ways to notify the compiler about a function before a call to the function:
 - Place function definition before calling function's definition
 - Use a function prototype (function declaration) – like the function definition without the body
 - Header: `void printHeading()`
 - Prototype: `void printHeading();`

Function Prototypes in Program 6-5

Program 6-5

```
1  // This program has three functions: main, First, and Second.
2  #include <iostream>
3  using namespace std;
4
5  // Function Prototypes
6  void first();
7  void second();
8
9  int main()
10 {
11     cout << "I am starting in function main.\n";
12     first();    // Call function first
13     second();   // Call function second
14     cout << "Back in function main again.\n";
15     return 0;
16 }
17
```

(Program Continues)

Function Prototypes in Program 6-5

```
18  //*****
19  // Definition of function first.      *
20  // This function displays a message.  *
21  //*****
22
23  void first()
24  {
25      cout << "I am now inside the function first.\n";
26  }
27
28  //*****
29  // Definition of function second.     *
30  // This function displays a message.  *
31  //*****
32
33  void second()
34  {
35      cout << "I am now inside the function second.\n";
36  }
```

Prototype Notes

- Place prototypes near top of program
- Program must include either prototype or full function definition before any call to the function – compiler error otherwise
- When using prototypes, can place function definitions in any order in source file

Sending Data into a Function

- Can pass values into a function at time of call:

```
void displayValue(int num)
{
    cout << "The value is " << num << endl;
}
```

- Values passed to function are arguments
- Variables in a function that hold the values passed as arguments are parameters

Function with a Parameter in Program 6-6

Program 6-6

```
1  // This program demonstrates a function with a parameter.
2  #include <iostream>
3  using namespace std;
4
5  // Function Prototype
6  void displayValue(int);
7
8  int main()
9  {
10     cout << "I am passing 5 to displayValue.\n";
11     displayValue(5); // Call displayValue with argument 5
12     cout << "Now I am back in main.\n";
13     return 0;
14 }
15
```

(Program Continues)

Function with a Parameter in Program 6-6

Program 6-6 *(continued)*

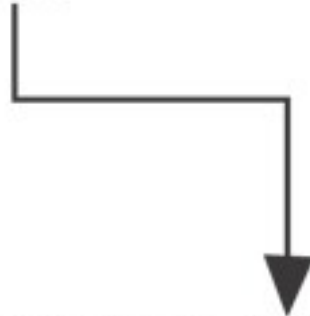
```
16  /*******
17  // Definition of function displayValue.          *
18  // It uses an integer parameter whose value is displayed. *
19  /*******
20
21  void displayValue(int num)
22  {
23      cout << "The value is " << num << endl;
24  }
```

Program Output

```
I am passing 5 to displayValue.
The value is 5
Now I am back in main.
```

Function with a Parameter in Program 6-6

```
displayValue(5);
```



```
void displayValue(int num)
{
    cout << "The value is " << num << endl;
}
```

- Value of argument is copied into parameter when the function is called
- The value 5 is passed as an argument to the function.

Parameters, Prototypes, and Function Headers

- For each function argument,
 - the prototype must include the data type of each parameter inside its parentheses
 - the header must include a declaration for each parameter in its ()

```
void evenOrOdd(int);    //prototype  
void evenOrOdd(int num) //header  
evenOrOdd(val);        //call
```

Passing Multiple Arguments

When calling a function and passing multiple arguments:

- the number of arguments in the call must match the prototype and definition
- the first argument will be used to initialize the first parameter, the second argument to initialize the second parameter, etc.

Passing Multiple Arguments in Program 6-8

Program 6-8

```
1  // This program demonstrates a function with three parameters.
2  #include <iostream>
3  using namespace std;
4
5  // Function Prototype
6  void showSum(int, int, int);
7
8  int main()
9  {
10     int value1, value2, value3;
11
12     // Get three integers.
13     cout << "Enter three integers and I will display ";
14     cout << "their sum: ";
15     cin >> value1 >> value2 >> value3;
16
17     // Call showSum passing three arguments.
18     showSum(value1, value2, value3);
19     return 0;
20 }
21
```

(Program Continues)

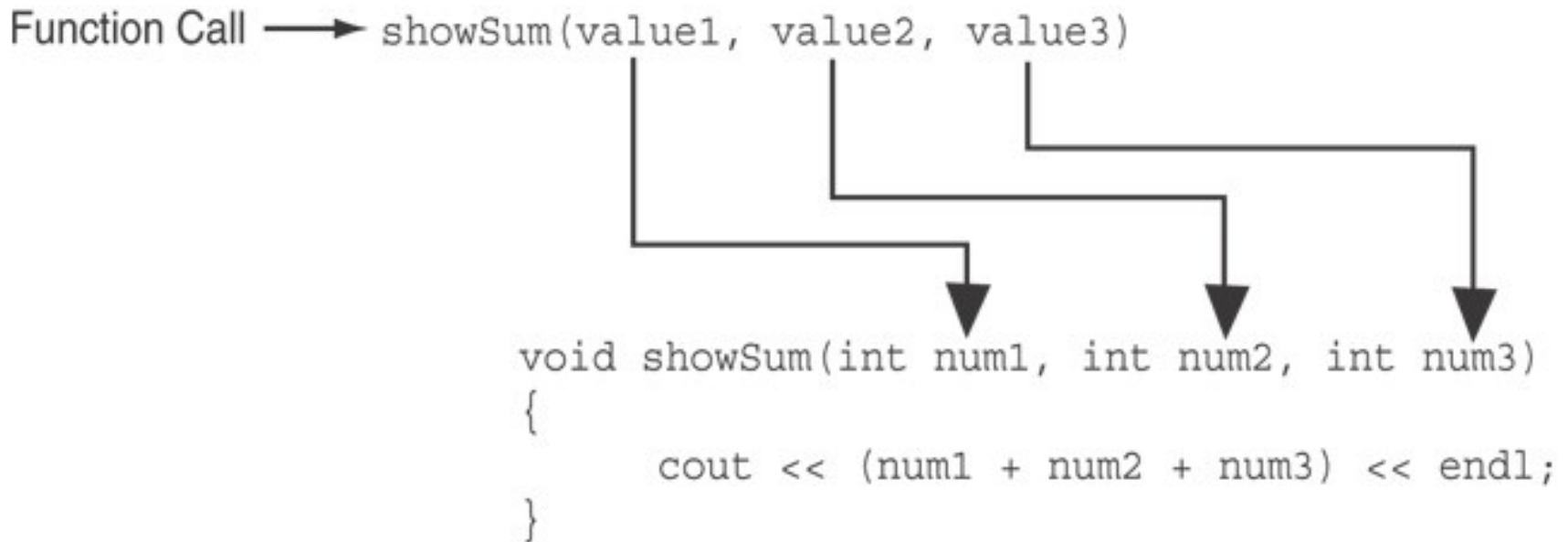
Passing Multiple Arguments in Program 6-8

```
22  /*******
23  // Definition of function showSum.
24  // It uses three integer parameters. Their sum is displayed.
25  /*******
26
27  void showSum(int num1, int num2, int num3)
28  {
29      cout << (num1 + num2 + num3) << endl;
30  }
```

Program Output with Example Input Shown in Bold

```
Enter three integers and I will display their sum: 4 8 7 [Enter]
19
```

Passing Multiple Arguments in Program 6-8



The function call in line 18 passes value1, value2, and value3 as arguments to the function.

Passing Data by Value

- Pass by value: when an argument is passed to a function, its value is copied into the parameter.
- Changes to the parameter in the function do not affect the value of the argument

Passing Information to Parameters by Value

🍊 **Example:** `int val=5;`
`evenOrOdd(val);`



🍊 `evenOrOdd` can change variable `num`, but it will have no effect on variable `val`

The `return` Statement

- Used to end execution of a function
- Statements that follow the `return` statement will not be executed
- A function can return a value back to the statement that called the function.
- In a `void` function without a `return` statement, the function ends at its last `}`

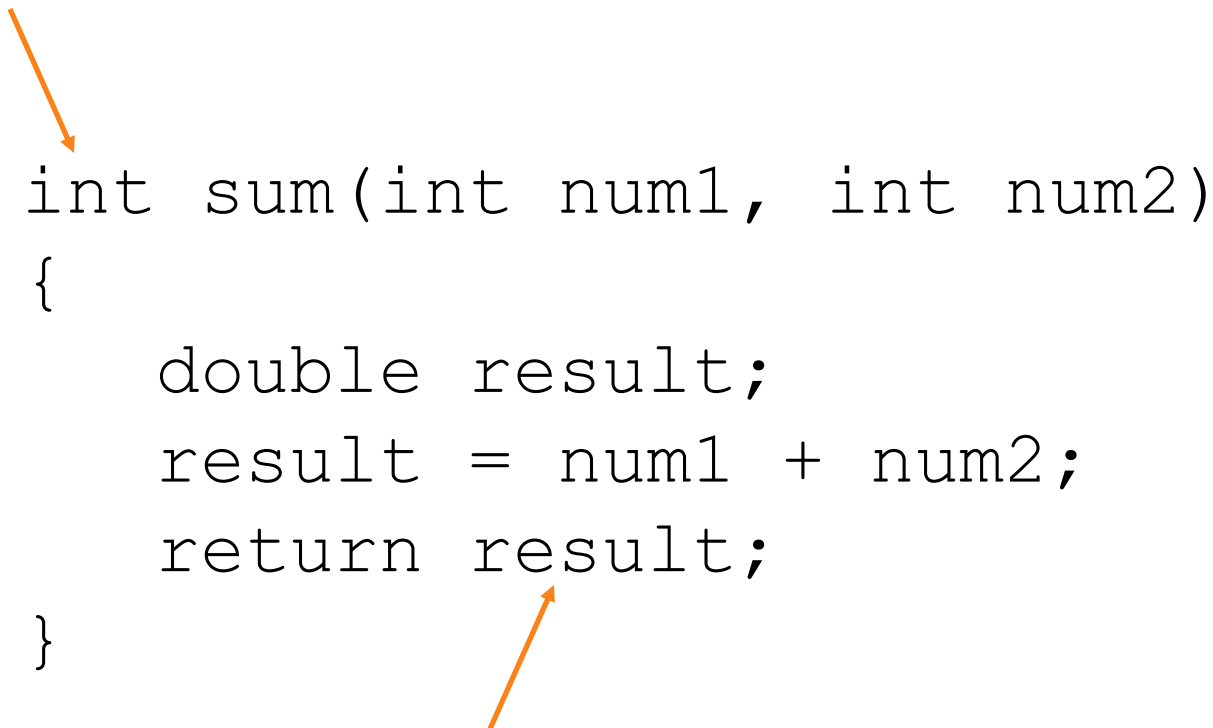
Returning a Value From a Function

- 🍊 In a value-returning function, the `return` statement can be used to return a value from function to the point of call. Example:

```
int sum(int num1, int num2)
{
    double result;
    result = num1 + num2;
    return result;
}
```

A Value-Returning Function

Return Type



```
int sum(int num1, int num2)
{
    double result;
    result = num1 + num2;
    return result;
}
```

The diagram illustrates the components of a value-returning function. An orange arrow points from the text 'Return Type' to the 'int' at the beginning of the function signature. Another orange arrow points from the text 'Value Being Returned' to the 'result' variable in the return statement.

Value Being Returned

A Value-Returning Function

```
int sum(int num1, int num2)
{
    return num1 + num2;
}
```

Functions can return the values of expressions, such as `num1 + num2`

Function Returning a Value in Program 6-12

Program 6-12

```
1  // This program uses a function that returns a value.
2  #include <iostream>
3  using namespace std;
4
5  // Function prototype
6  int sum(int, int);
7
8  int main()
9  {
10     int value1 = 20,    // The first value
11         value2 = 40,    // The second value
12         total;          // To hold the total
13
14     // Call the sum function, passing the contents of
15     // value1 and value2 as arguments. Assign the return
16     // value to the total variable.
17     total = sum(value1, value2);
18
19     // Display the sum of the values.
20     cout << "The sum of " << value1 << " and "
21         << value2 << " is " << total << endl;
22     return 0;
23 }
```

(Program Continues)

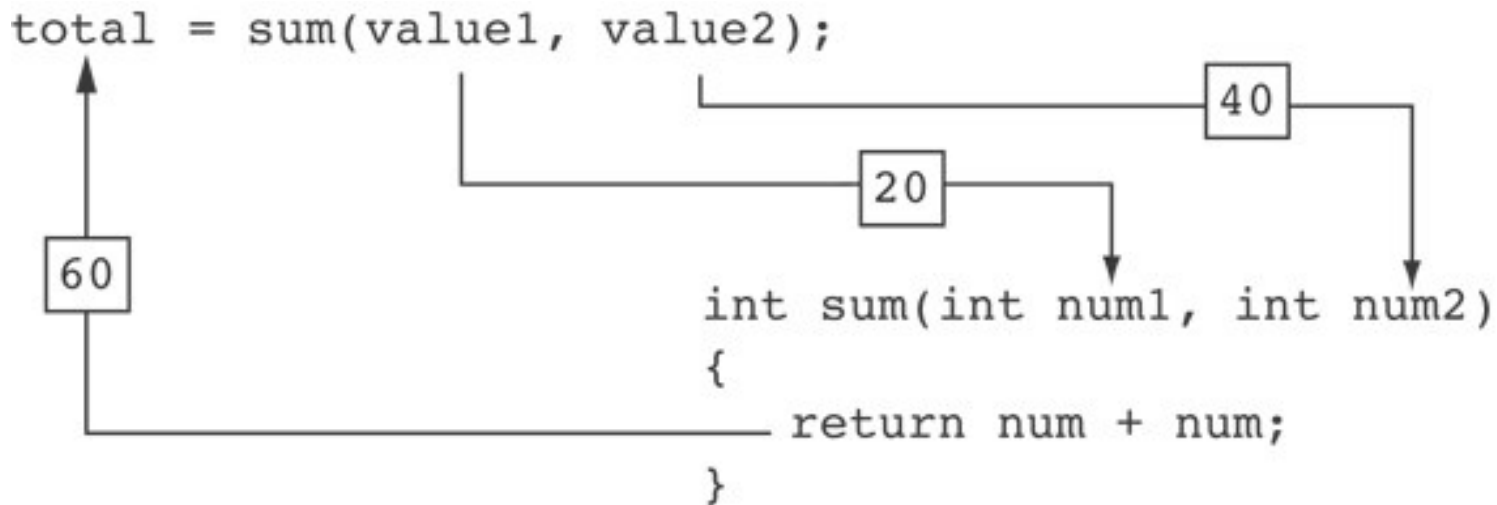
Function Returning a Value in Program 6-12

```
24
25  /*******
26  // Definition of function sum. This function returns *
27  // the sum of its two parameters.                    *
28  /*******
29
30  int sum(int num1, int num2)
31  {
32      return num1 + num2;
33  }
```

Program Output

The sum of 20 and 40 is 60

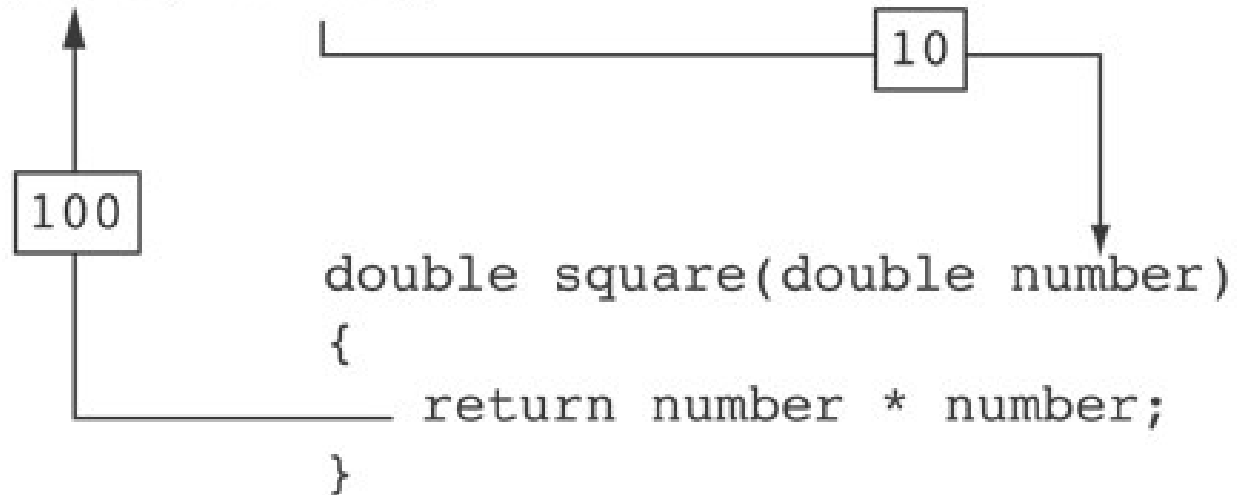
Function Returning a Value in Program 6-12



The statement in line 17 calls the `sum` function, passing `value1` and `value2` as arguments. The return value is assigned to the `total` variable.

Another Example from Program 6-13

```
area = PI * square(radius);
```



Returning a Boolean Value

- Function can return `true` or `false`
- Declare return type in function prototype and heading as `bool`
- Function body must contain `return` statement(s) that return `true` or `false`

Returning a Boolean Value in Program 6-15

Program 6-15

```
1  // This program uses a function that returns true or false.
2  #include <iostream>
3  using namespace std;
4
5  // Function prototype
6  bool isEven(int);
7
8  int main()
9  {
10     int val;
11
12     // Get a number from the user.
13     cout << "Enter an integer and I will tell you ";
14     cout << "if it is even or odd: ";
15     cin >> val;
16
17     // Indicate whether it is even or odd.
18     if (isEven(val))
19         cout << val << " is even.\n";
20     else
21         cout << val << " is odd.\n";
22     return 0;
23 }
24
```

(Program Continues)

Returning a Boolean Value in Program 6-15

```
25  //*****
26  // Definition of function isEven. This function accepts an      *
27  // integer argument and tests it to be even or odd. The function *
28  // returns true if the argument is even or false if the argument *
29  // is odd. The return value is a bool.                            *
30  //*****
31
32  bool isEven(int number)
33  {
34      bool status;
35
36      if (number % 2 == 0)
37          status = true; // The number is even if there is no remainder.
38      else
39          status = false; // Otherwise, the number is odd.
40      return status;
41  }
```

Program Output with Example Input Shown in Bold

Enter an integer and I will tell you if it is even or odd: **5 [Enter]**
5 is odd.

Local Variables

- Variables defined inside a function are *local* to that function. They are hidden from the statements in other functions, which normally cannot access them.
- Because the variables defined in a function are hidden, other functions may have separate, distinct variables with the same name.

Local Variables in Program 6-16

Program 6-16

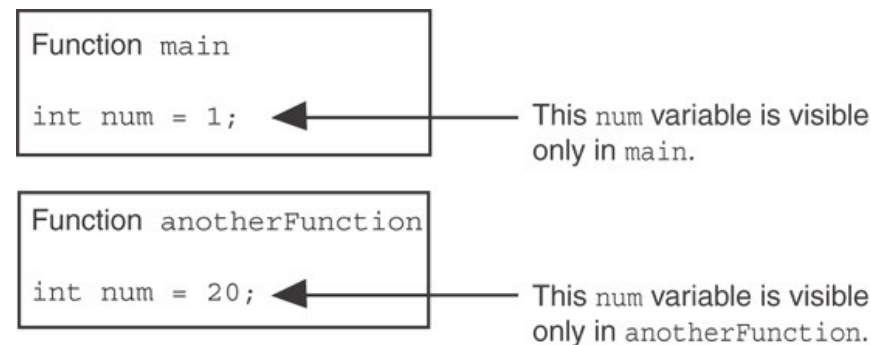
```
1  // This program shows that variables defined in a function
2  // are hidden from other functions.
3  #include <iostream>
4  using namespace std;
5
6  void anotherFunction(); // Function prototype
7
8  int main()
9  {
10     int num = 1;    // Local variable
11
12     cout << "In main, num is " << num << endl;
13     anotherFunction();
14     cout << "Back in main, num is " << num << endl;
15     return 0;
16 }
17
18 //*****
19 // Definition of anotherFunction *
20 // It has a local variable, num, whose initial value *
21 // is displayed. *
22 //*****
23
24 void anotherFunction()
25 {
26     int num = 20;    // Local variable
27
28     cout << "In anotherFunction, num is " << num << endl;
29 }
```

Local Variables in Program 6-16

Program Output

```
In main, num is 1  
In anotherFunction, num is 20  
Back in main, num is 1
```

When the program is executing in `main`, the `num` variable defined in `main` is visible. When `anotherFunction` is called, however, only variables defined inside it are visible, so the `num` variable in `main` is hidden.



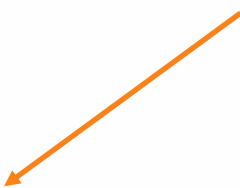
Global Variables and Global Constants

- A global variable is any variable defined outside all the functions in a program.
- The scope of a global variable is the portion of the program from the variable definition to the end.
- This means that a global variable can be accessed by *all* functions that are defined after the global variable is defined.

Global Constants in Program 6-19

Program 6-19

Global constants defined for values that do not change throughout the program's execution.



```
1  // This program calculates gross pay.
2  #include <iostream>
3  #include <iomanip>
4  using namespace std;
5
6  // Global constants
7  const double PAY_RATE = 22.55;    // Hourly pay rate
8  const double BASE_HOURS = 40.0;   // Max non-overtime hours
9  const double OT_MULTIPLIER = 1.5; // Overtime multiplier
10
11 // Function prototypes
12 double getBasePay(double);
13 double getOvertimePay(double);
14
15 int main()
16 {
17     double hours,           // Hours worked
18           basePay,          // Base pay
19           overtime = 0.0,   // Overtime pay
20           totalPay;         // Total pay
```

Initializing Local and Global Variables

- Local variables are not automatically initialized. They must be initialized by programmer.
- Global variables (not constants) are automatically initialized to 0 (numeric) or NULL (character) when the variable is defined.

Static Local Variables

- Local variables only exist while the function is executing. When the function terminates, the contents of local variables are lost.
- `static` local variables retain their contents between function calls.
- `static` local variables are defined and initialized only the first time the function is executed. `0` is the default initialization value.

Local Variables Do Not Retain Values Between Function calls in Program 6-21

Program 6-21

```
1  // This program shows that local variables do not retain
2  // their values between function calls.
3  #include <iostream>
4  using namespace std;
5
6  // Function prototype
7  void showLocal();
8
9  int main()
10 {
11     showLocal();
12     showLocal();
13     return 0;
14 }
15
```

(Program Continues)

Local Variables Do Not Retain Values Between Function calls in Program 6-21

Program 6-21 *(continued)*

```
16  //*****
17  // Definition of function showLocal. *
18  // The initial value of localNum, which is 5, is displayed. *
19  // The value of localNum is then changed to 99 before the *
20  // function returns. *
21  //*****
22
23  void showLocal()
24  {
25      int localNum = 5; // Local variable
26
27      cout << "localNum is " << localNum << endl;
28      localNum = 99;
29  }
```

Program Output

```
localNum is 5
localNum is 5
```

In this program, each time `showLocal` is called, the `localNum` variable is re-created and initialized with the value 5.

A Different Approach, Using a Static Variable in Program 6-22

Program 6-22

```
1  // This program uses a static local variable.
2  #include <iostream>
3  using namespace std;
4
5  void showStatic(); // Function prototype
6
7  int main()
8  {
9      // Call the showStatic function five times.
10     for (int count = 0; count < 5; count++)
11         showStatic();
12     return 0;
13 }
14
```

(Program Continues)

A Different Approach, Using a Static Variable in Program 6-22

Program 6-22 (continued)

```
15  /*******
16  // Definition of function showStatic.
17  // statNum is a static local variable. Its value is displayed
18  // and then incremented just before the function returns.
19  /*******
20
21  void showStatic()
22  {
23      static int statNum;
24
25      cout << "statNum is " << statNum << endl;
26      statNum++;
27  }
```

Program Output

```
statNum is 0
statNum is 1
statNum is 2
statNum is 3
statNum is 4
```

← statNum is automatically initialized to 0. Notice that it retains its value between function calls.

Default Arguments

- A Default argument is an argument that is passed automatically to a parameter if the argument is missing on the function call.
- Multi-parameter functions may have default arguments for some or all of them:

```
int getSum(int, int=0, int=0);
```

- If not all parameters to a function have default values, the defaultless ones are declared first in the parameter list:

```
int getSum(int, int=0, int=0); // OK
```

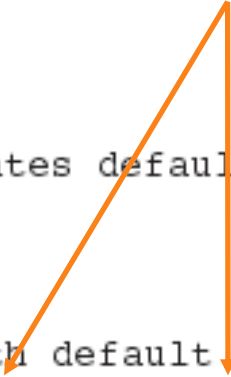
```
int getSum(int, int=0, int); // NO
```

Default Arguments in Program 6-24

Default arguments specified in the prototype

Program 6-24

```
1  // This program demonstrates default function arguments.
2  #include <iostream>
3  using namespace std;
4
5  // Function prototype with default arguments
6  void displayStars(int = 10, int = 1);
7
8  int main()
9  {
10     displayStars();           // Use default values for cols and rows.
11     cout << endl;
12     displayStars(5);          // Use default value for rows.
13     cout << endl;
14     displayStars(7, 3);       // Use 7 for cols and 3 for rows.
15     return 0;
16 }
```



(Program Continues)

Default Arguments in Program 6-24

```
18  /*******
19  // Definition of function displayStars.          *
20  // The default argument for cols is 10 and for rows is 1.*
21  // This function displays a square made of asterisks.    *
22  /*******
23
24  void displayStars(int cols, int rows)
25  {
26      // Nested loop. The outer loop controls the rows
27      // and the inner loop controls the columns.
28      for (int down = 0; down < rows; down++)
29      {
30          for (int across = 0; across < cols; across++)
31              cout << "*";
32          cout << endl;
33      }
34  }
```

Program Output

Using Reference Variables as Parameters

- A mechanism that allows a function to work with the original argument from the function call, not a copy of the argument
- Changes to a reference variable are made to the variable it refers to
- Defined with an ampersand (&)

```
void getDimensions(int&, int&);
```

Passing a Variable By Reference in Program 6-25

Program 6-25

The & here in the prototype indicates that the parameter is a reference variable.

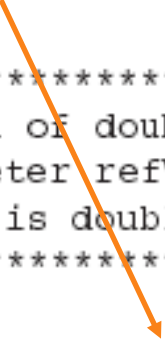
```
1  // This program uses a reference variable as a function
2  // parameter.
3  #include <iostream>
4  using namespace std;
5
6  // Function prototype. The parameter is a reference variable.
7  void doubleNum(int &);
8
9  int main()
10 {
11     int value = 4;
12
13     cout << "In main, value is " << value << endl;
14     cout << "Now calling doubleNum..." << endl;
15     doubleNum(value);
16     cout << "Now back in main. value is " << value << endl;
17     return 0;
18 }
19
```

Here we are passing value by reference.

(Program Continues)

Passing a Variable By Reference in Program 6-25

The & also appears here in the function header.



```
20  /*******
21  // Definition of doubleNum.
22  // The parameter refVar is a reference variable. The value
23  // in refVar is doubled.
24  /*******
25
26  void doubleNum (int &refVar)
27  {
28      refVar *= 2;
29  }
```

Program Output

```
In main, value is 4
Now calling doubleNum...
Now back in main. value is 8
```

Reference Variable Notes

- Each reference parameter must contain &
- Space between type and & is unimportant
- Must use & in both prototype and header
- Argument passed to reference parameter must be a variable – cannot be an expression or constant

Overloading Functions

- Overloaded functions have the same name but different parameter lists
- Can be used to create functions that perform the same task but take different parameter types or different number of parameters
- Compiler will determine which version of function to call by argument and parameter lists

Function Overloading Examples

Using these overloaded functions,

```
void getDimensions(int);           // 1
void getDimensions(int, int);      // 2
void getDimensions(int, double);   // 3
void getDimensions(double, double); // 4
```

the compiler will use them as follows:

```
int length, width;
double base, height;
getDimensions(length);           // 1
getDimensions(length, width);    // 2
getDimensions(length, height);   // 3
getDimensions(height, base);     // 4
```

Function Overloading in Program 6-27

Program 6-27

```
1 // This program uses overloaded functions.
2 #include <iostream>
3 #include <iomanip>
4 using namespace std;
5
6 // Function prototypes
7 int square(int); ←
8 double square(double); ←
9
10 int main()
11 {
12     int userInt;
13     double userFloat;
14
15     // Get an int and a double.
16     cout << fixed << showpoint << setprecision(2);
17     cout << "Enter an integer and a floating-point value: ";
18     cin >> userInt >> userFloat;
19
20     // Display their squares.
21     cout << "Here are their squares: ";
22     cout << square(userInt) << " and " << square(userFloat);
23     return 0;
24 }
```

The overloaded functions have different parameter lists

Passing a double

Passing an int

(Program Continues)

Function Overloading in Program 6-27

```
26  /*******
27  // Definition of overloaded function square.          *
28  // This function uses an int parameter, number. It returns the *
29  // square of number as an int.                          *
30  /*******
31
32  int square(int number)
33  {
34      return number * number;
35  }
36
37  /*******
38  // Definition of overloaded function square.          *
39  // This function uses a double parameter, number. It returns      *
40  // the square of number as a double.                      *
41  /*******
42
43  double square(double number)
44  {
45      return number * number;
46  }
```

Program Output with Example Input Shown in Bold

Enter an integer and a floating-point value: **12 4.2 [Enter]**
Here are their squares: 144 and 17.64

The `exit()` Function

- Terminates the execution of a program
- Can be called from any function
- Can pass an `int` value to operating system to indicate status of program termination
- Usually used for abnormal termination of program
- Requires `cstdlib` header file
- Example:

```
exit(0);
```