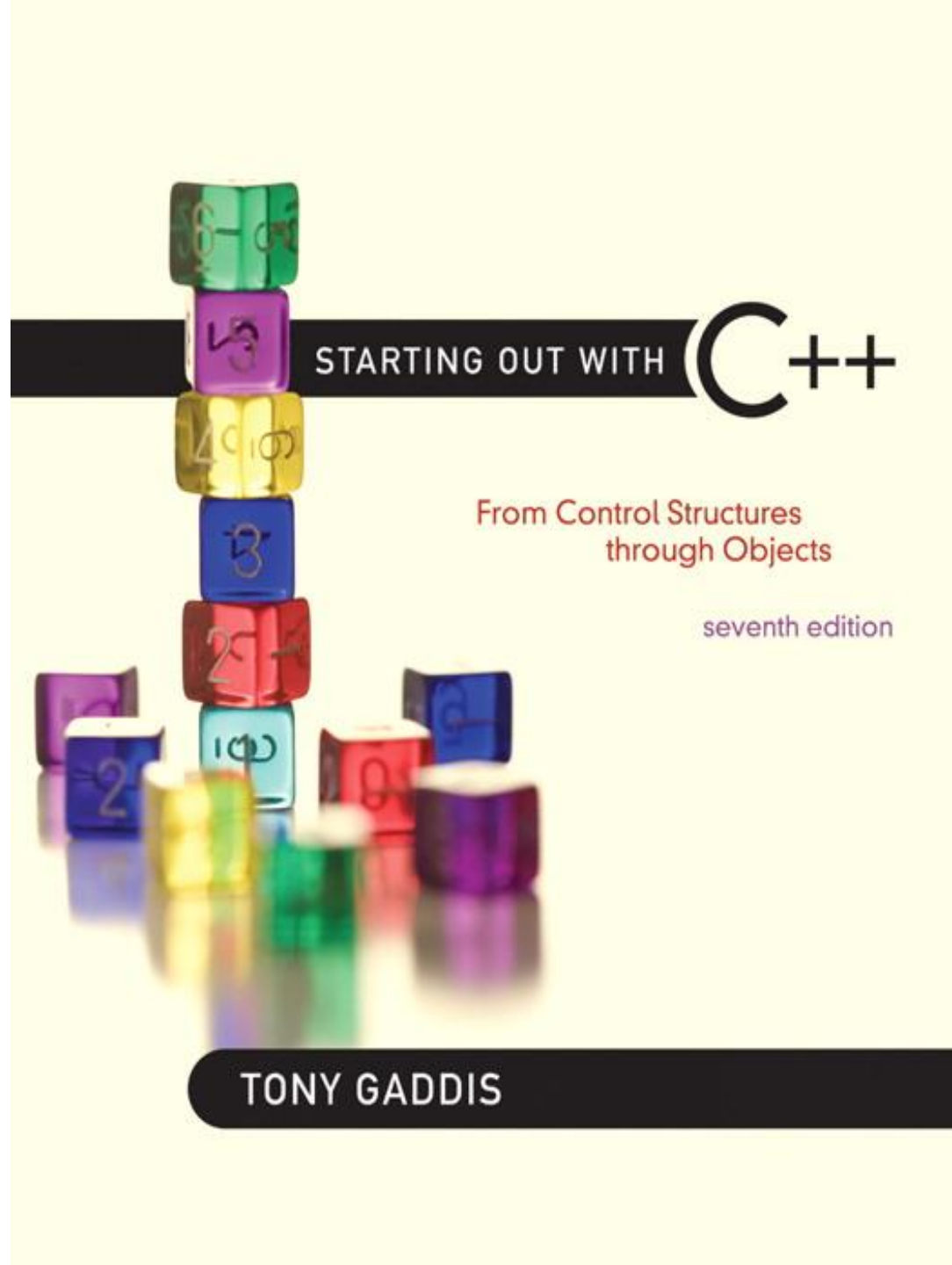


# Chapter 6:

## Functions

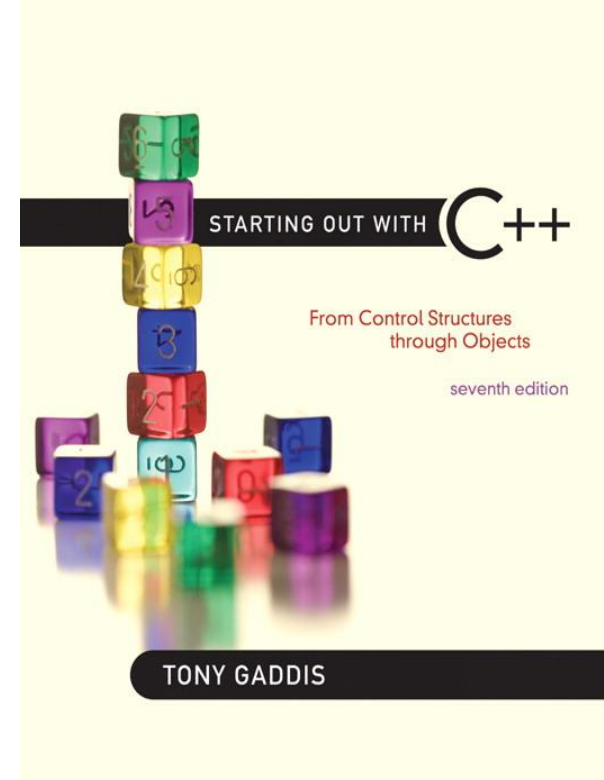


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# 6.1



## Modular Programming

# 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

[illegible]

```
graph TD; Entry(( )) --> Main; Main["int main()  
{  
    statement;  
    statement;  
    statement;  
}"] --> F2["void function2()  
{  
    statement;  
    statement;  
    statement;  
}"]; Main --> F3["void function3()  
{  
    statement;  
    statement;  
    statement;  
}"]; Main --> F4["void function4()  
{  
    statement;  
    statement;  
    statement;  
}"];
```

The diagram illustrates the execution flow of a program. It starts with a main function, which then calls three sub-functions. The flow is indicated by arrows pointing from the main function to each of the sub-functions.

**main function:**

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

**function2:**

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

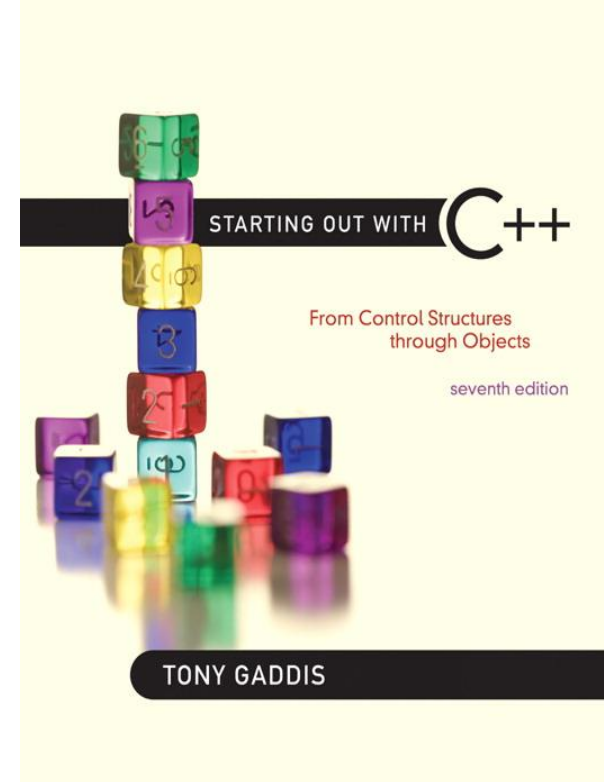
**function3:**

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

**function4:**

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

# 6.2



## Defining and Calling Functions

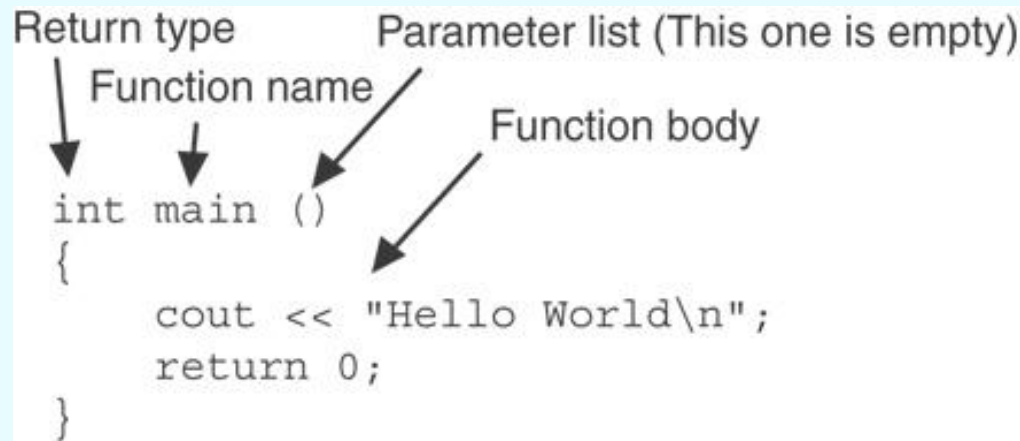
# Defining and Calling Functions

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

# 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



The diagram shows a C++ function definition for `main`. Arrows point from labels to parts of the code: '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.

```
int main ()  
{  
    cout << "Hello World\n";  
    return 0;  
}
```

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

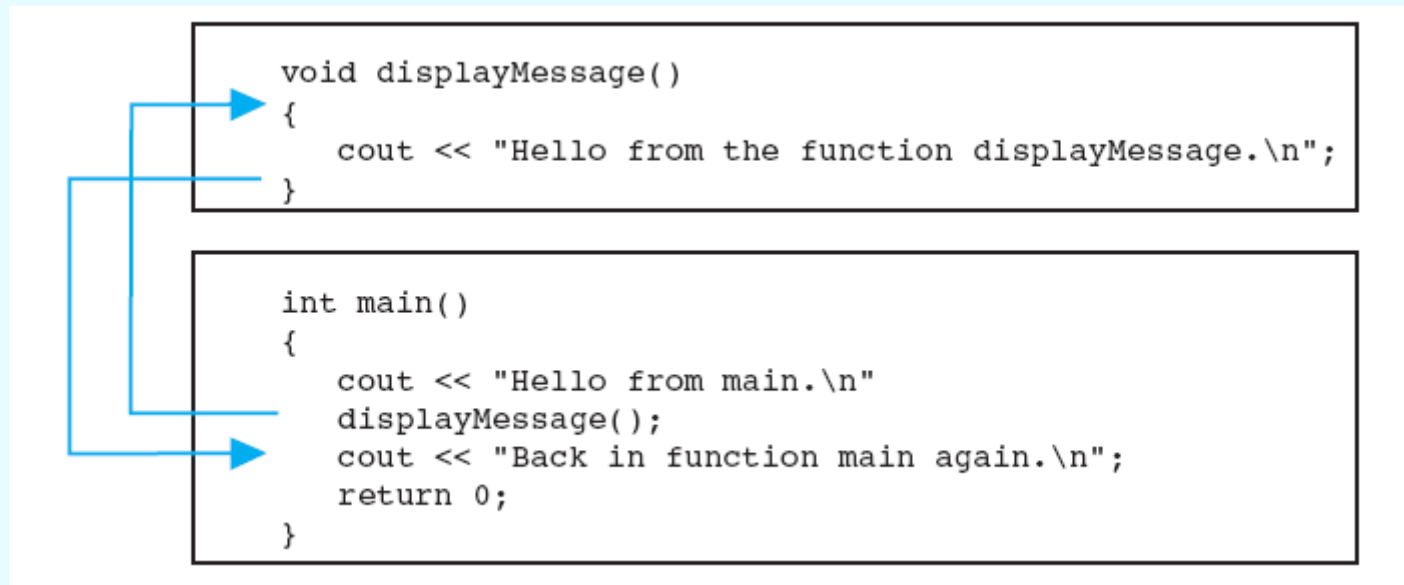
## Program 6-1

```
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

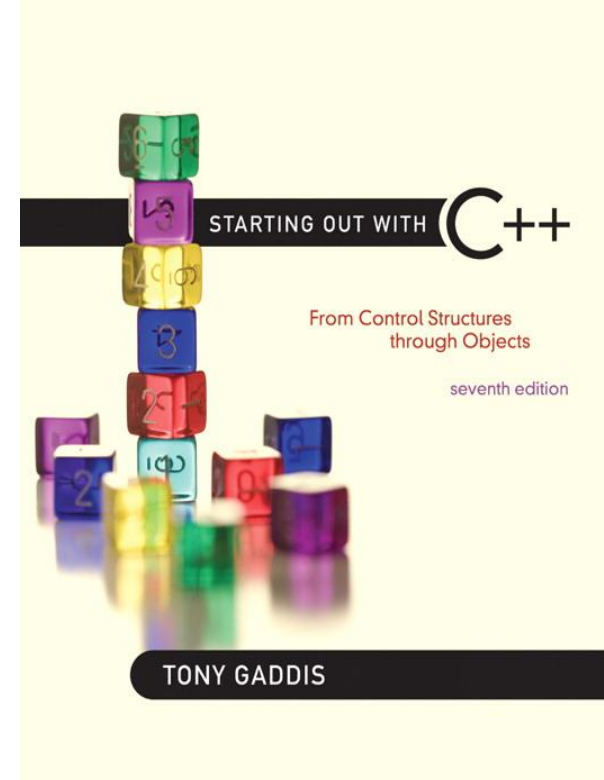


# Calling Functions

- `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

# 6.3

## Function Prototypes



# 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();`

## 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)*



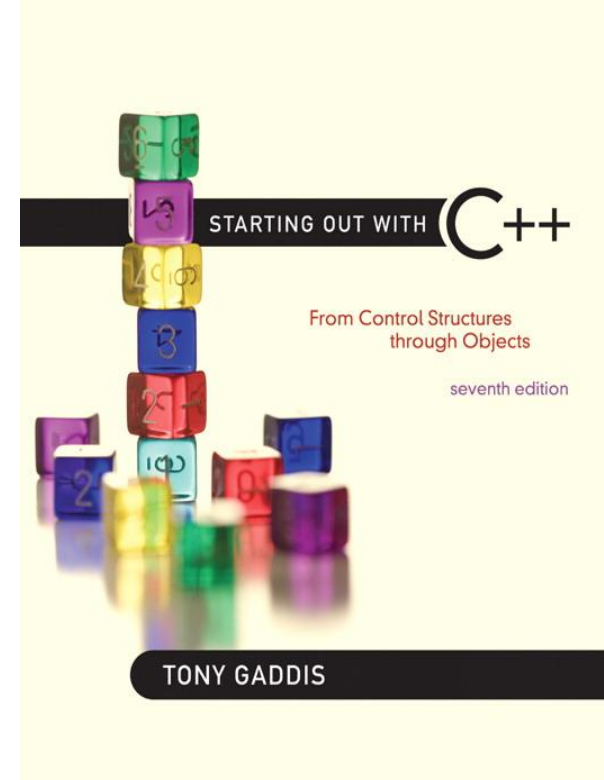
## *Program 6-5 (Continued)*

```
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

# 6.4



## Sending Data into a Function

# Sending Data into a Function

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

```
c = pow(a, b);
```

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

# A Function with a Parameter Variable

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

The integer variable `num` is a parameter.  
It accepts any integer value passed to the function.

## 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)*

## Program 6-6

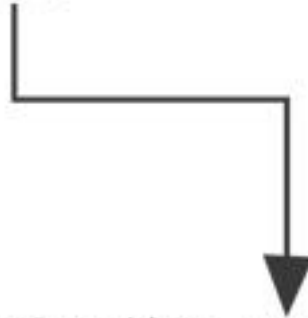
*(continued)*

```
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.
```

```
displayValue(5);
```



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

The function call in line 11 passes the value 5 as an argument to the function.



# Other Parameter Terminology

- A parameter can also be called a formal parameter or a formal argument
- An argument can also be called an actual parameter or an actual argument

# 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
```

# Function Call Notes

- Value of argument is copied into parameter when the function is called
- A parameter's scope is the function which uses it
- Function can have multiple parameters
- There must be a data type listed in the prototype `()` and an argument declaration in the function header `()` for each parameter
- Arguments will be promoted/demoted as necessary to match parameters

# 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.

## 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)*

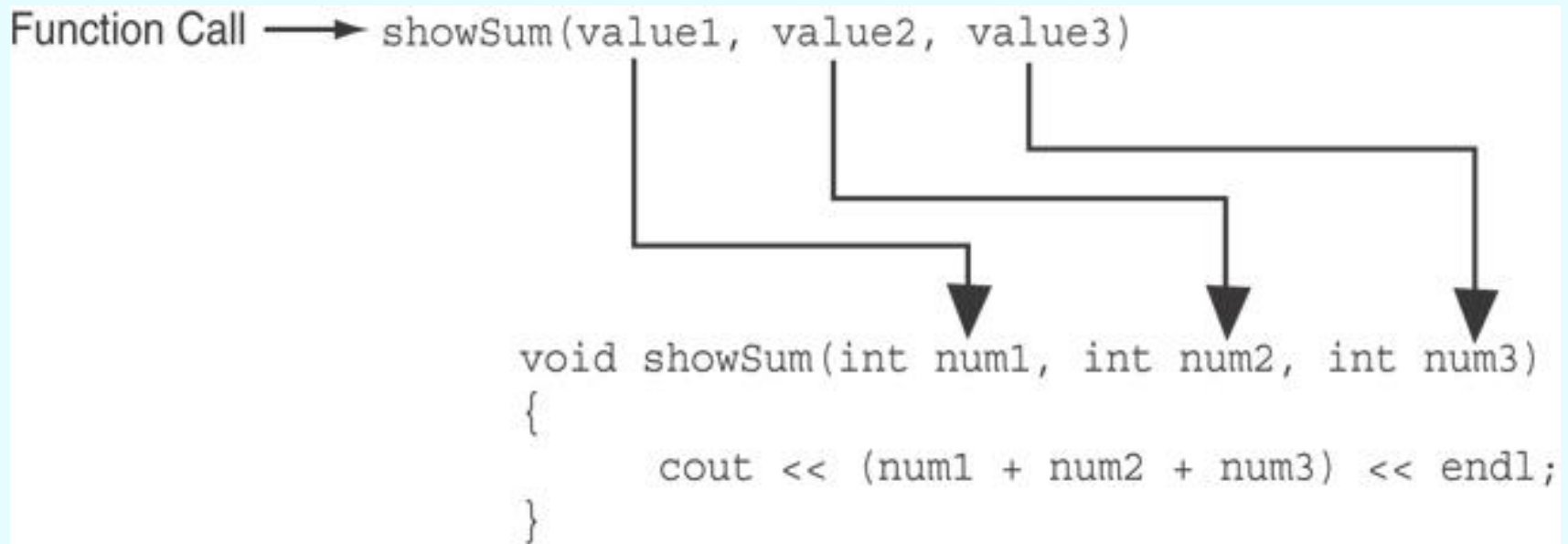
## *Program 6-8 (Continued)*

```
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**

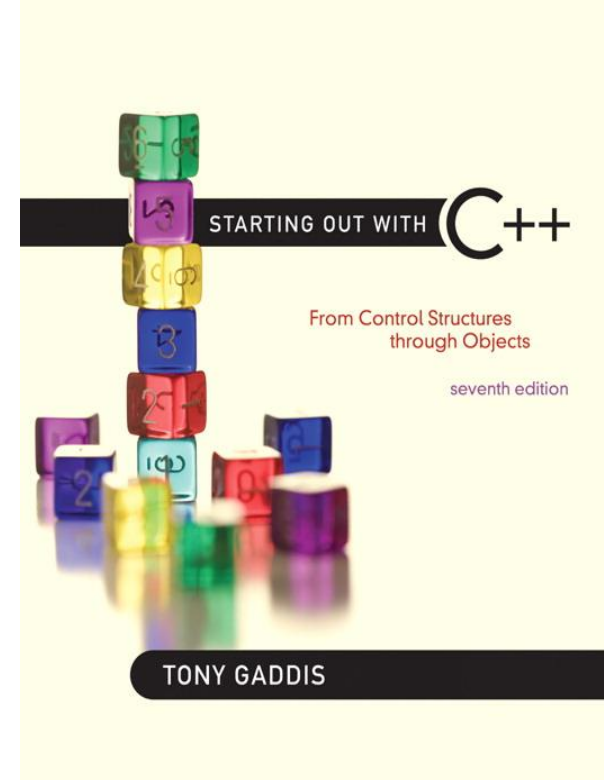
Enter three integers and I will display their sum: **4 8 7 [Enter]**

19



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

# 6.5



## Passing Data by Value

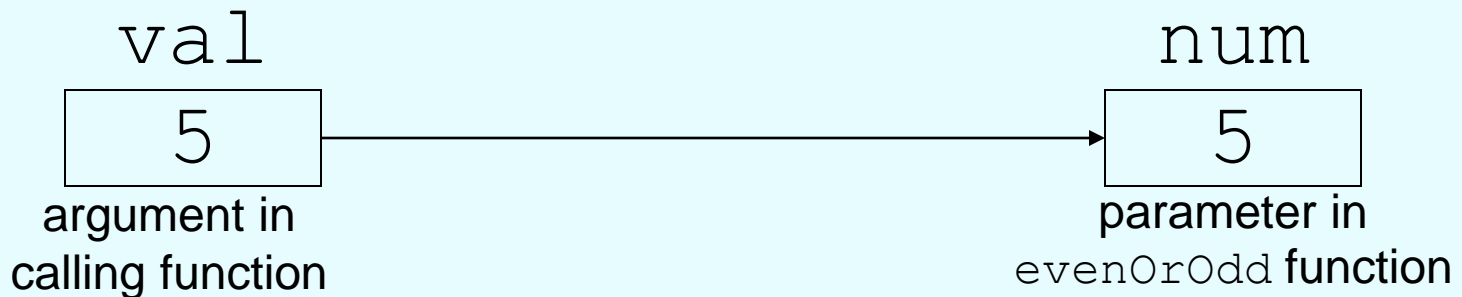


# Passing Data by Value

- 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

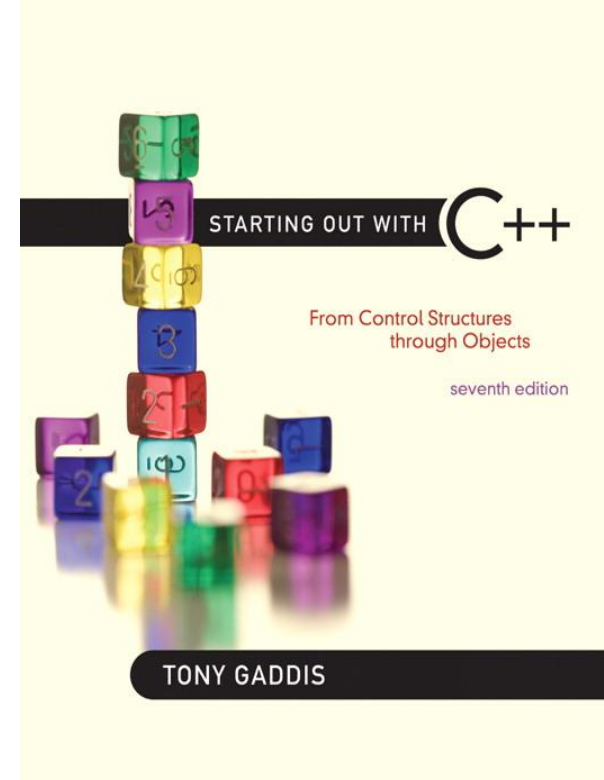
- **Example:** `int val=5;`  
`evenOrOdd(val);`



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

# 6.6

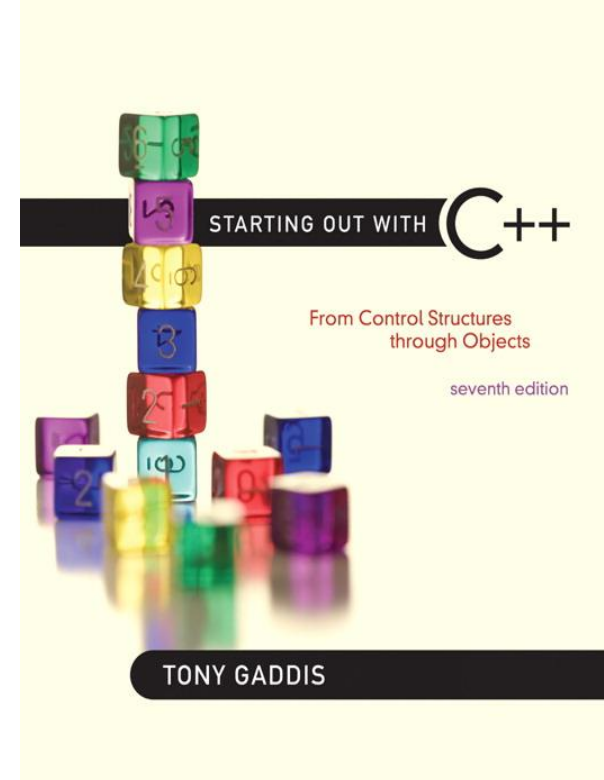
## Using Functions in Menu-Driven Programs



# Using Functions in Menu-Driven Programs

- Functions can be used
  - to implement user choices from menu
  - to implement general-purpose tasks:
    - Higher-level functions can call general-purpose functions, minimizing the total number of functions and speeding program development time
- *See Program 6-10 in the book*

# 6.7



## The `return` Statement

# The `return` Statement

- Used to end execution of a function
- Can be placed anywhere in a function
  - Statements that follow the `return` statement will not be executed
- Can be used to prevent abnormal termination of program
- In a `void` function without a `return` statement, the function ends at its last `}`

## Program 6-11

```
1  // This program uses a function to perform division. If division
2  // by zero is detected, the function returns.
3  #include <iostream>
4  using namespace std;
5
6  // Function prototype.
7  void divide(double, double);
8
9  int main()
10 {
11     double num1, num2;
12
13     cout << "Enter two numbers and I will divide the first\n";
14     cout << "number by the second number: ";
15     cin >> num1 >> num2;
16     divide(num1, num2);
17     return 0;
18 }
```

*(Program Continues)*

## Program 6-11(Continued)

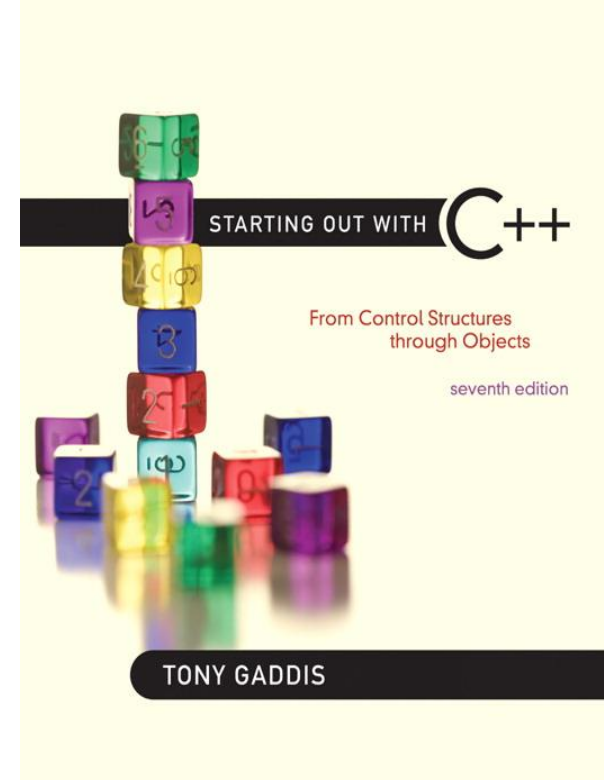
```
20  //*****
21  // Definition of function divide.
22  // Uses two parameters: arg1 and arg2. The function divides arg1*
23  // by arg2 and shows the result. If arg2 is zero, however, the *
24  // function returns.
25  //*****
26
27  void divide(double arg1, double arg2)
28  {
29      if (arg2 == 0.0)
30      {
31          cout << "Sorry, I cannot divide by zero.\n";
32          return;
33      }
34      cout << "The quotient is " << (arg1 / arg2) << endl;
35  }
```

### Program Output with Example Input Shown in Bold

Enter two numbers and I will divide the first  
number by the second number: **12 0 [Enter]**  
Sorry, I cannot divide by zero.



# 6.8



## Returning a Value From a Function

# Returning a Value From a Function

- A function can return a value back to the statement that called the function.
- You've already seen the `pow` function, which returns a value:

```
double x;  
x = pow(2.0, 10.0);
```


# 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;
}
```



## 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`

### 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 }
```

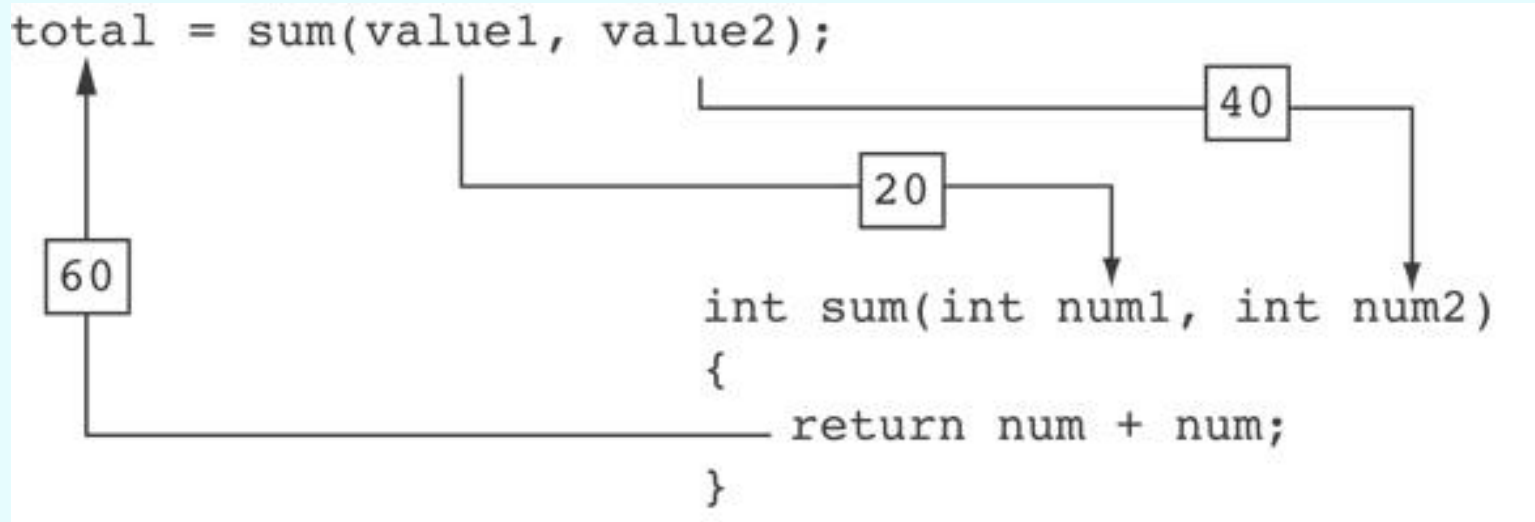
*(Program Continues)*

## *Program 6-12 (Continued)*

```
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

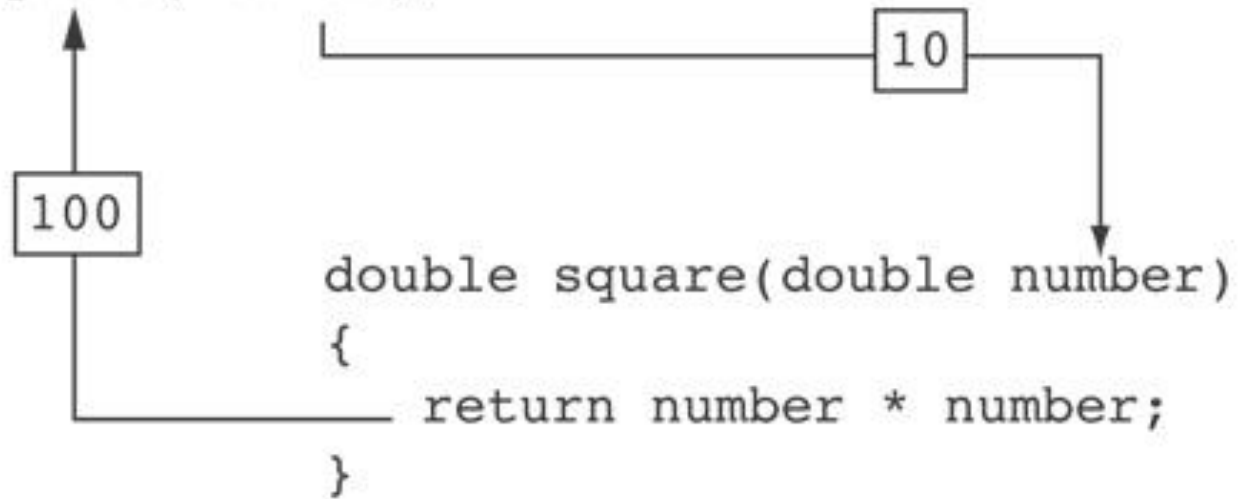


The statement in line 17 calls the `sum` function, passing `value1` and `value2` as arguments. The return value is assigned to the `total` variable.



# Another Example, from Program 6-13

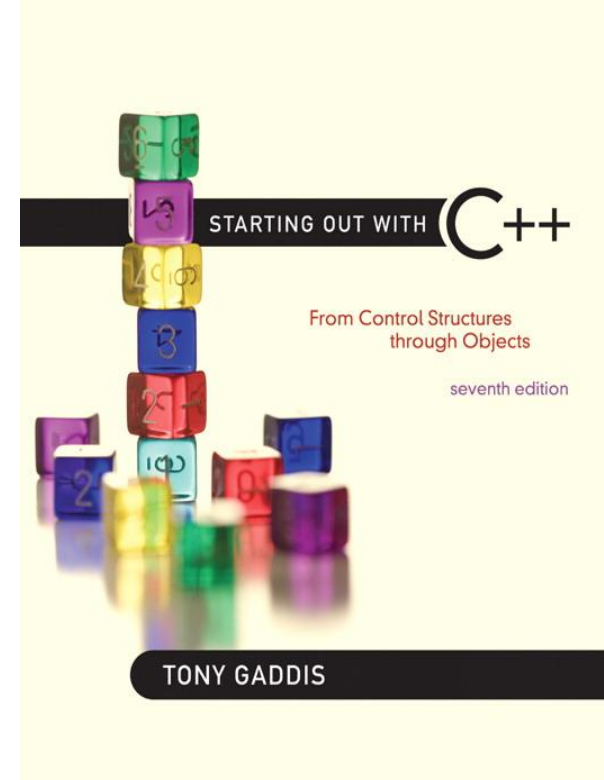
```
area = PI * square(radius);
```



# Returning a Value From a Function

- The prototype and the definition must indicate the data type of return value (not `void`)
- Calling function should use return value:
  - assign it to a variable
  - send it to `cout`
  - use it in an expression

# 6.9



## Returning a Boolean Value

# 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`
- Calling function can use return value in a relational expression

### 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)*

```

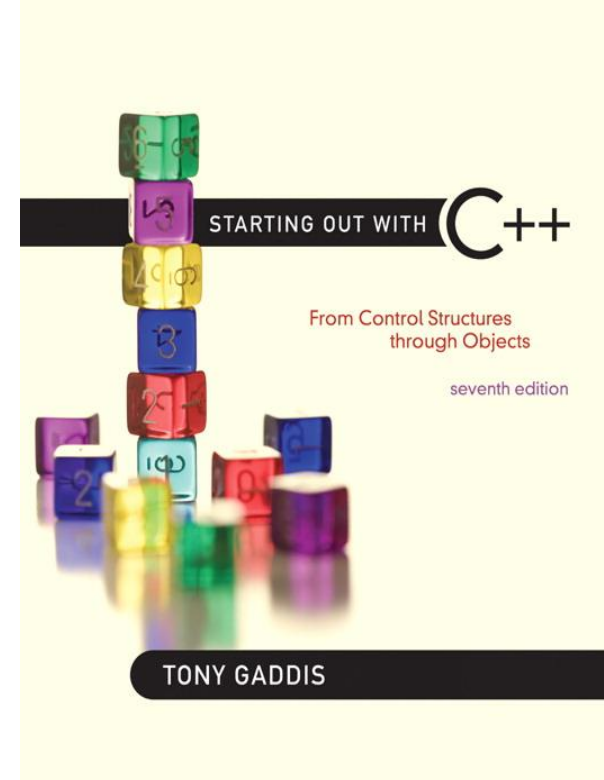
25  //*****
26  // Definition of function isEven. This function accepts an      *
27  // integer argument and tests it to be even or odd. The function *
28  // returns true if the argument is even or false if the argument  *
29  // is odd. The return value is a bool.                            *
30  //*****
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.

# 6.10



## Local and Global Variables

# Local and Global 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.



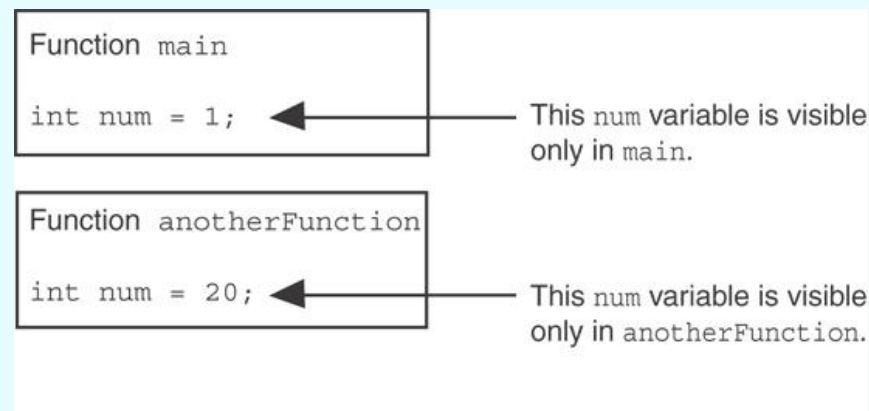
## Program 6-16

```
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 }
```

### 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.



# Local Variable Lifetime

- A function's local variables exist only while the function is executing. This is known as the *lifetime* of a local variable.
- When the function begins, its local variables and its parameter variables are created in memory, and when the function ends, the local variables and parameter variables are destroyed.
- This means that any value stored in a local variable is lost between calls to the function in which the variable is declared.

# 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.

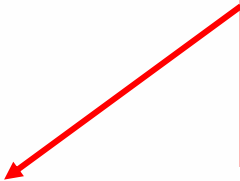
# Global Variables and Global Constants

- You should avoid using global variables because they make programs difficult to debug.
- Any global that you create should be *global constants*.

## Program 6-19

```
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
```

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



The constants are then used for those values throughout the program.

```
29      // Get overtime pay, if any.
30      if (hours > BASE_HOURS)
31          overtime = getOvertimePay(hours);
```

```
56      // Determine base pay.
57      if (hoursWorked > BASE_HOURS)
58          basePay = BASE_HOURS * PAY_RATE;
59      else
60          basePay = hoursWorked * PAY_RATE;
```

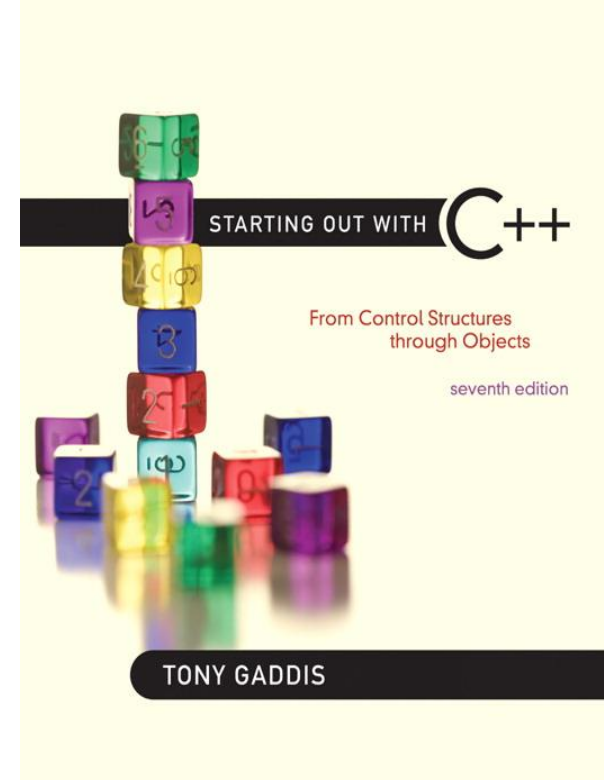
```
75      // Determine overtime pay.
76      if (hoursWorked > BASE_HOURS)
77      {
78          overtimePay = (hoursWorked - BASE_HOURS) *
79                          PAY_RATE * OT_MULTIPLIER;
--
```

# 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.



# 6.11



## Static Local Variables

# 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.

## 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)*

**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

## 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)*

## 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.**

If you do initialize a local static variable, the initialization only happens once. See Program 6-23.

```
16  //*****
17  // Definition of function showStatic. *
18  // statNum is a static local variable. Its value is displayed *
19  // and then incremented just before the function returns. *
20  //*****
21
22  void showStatic()
23  {
24      static int statNum = 5;
25
26      cout << "statNum is " << statNum << endl;
27      statNum++;
28  }
```

### Program Output

```
statNum is 5
statNum is 6
statNum is 7
statNum is 8
statNum is 9
```