Lecture 13: Functions & Arrays

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6.14 References and Reference Parameters

- Two ways to pass arguments to functions in many programming languages are pass-by-value and pass-by-reference.
- When an argument is passed by value, a *copy of the argument's value is made and passed (on the function call stack) to the called function.*
  - Changes to the copy do not affect the original variable's value in the caller.
- To specify a reference to a constant, place the `const` qualifier before the type specifier in the parameter declaration.

6.14 References and Reference Parameters (cont.)

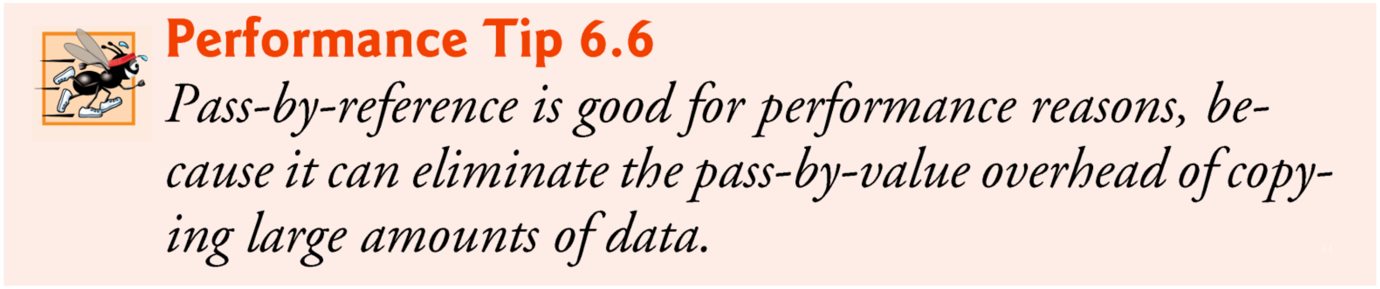
Performance Tip 6.5

One disadvantage of pass-by-value is that, if a large data item is being passed, copying that data can take a considerable amount of execution time and memory space.

6.14 References and Reference Parameters (cont.)

- With pass-by-reference, the caller gives the called function the ability to access the caller's data directly, and to modify that data.
- A reference parameter is an alias for its corresponding argument in a function call.
- To indicate that a function parameter is passed by reference, simply follow the pa-rameter's type in the function prototype by an ampersand (&); use the same convention when listing the pa-rameter's type in the function header.

6.14 References and Reference Parameters (cont.)



Performance Tip 6.6

Pass-by-reference is good for performance reasons, because it can eliminate the pass-by-value overhead of copying large amounts of data.

6.14 References and Reference Parameters (cont.)

Software Engineering Observation 6.12

Pass-by-reference can weaken security; the called function can corrupt the caller's data.

6.14 References and Reference Parameters (cont.)

Common Programming Error 6.11

Because reference parameters are mentioned only by name in the body of the called function, you might inadvertently treat reference parameters as pass-by-value parameters. This can cause unexpected side effects if the original variables are changed by the function.

6.14 References and Reference Parameters (cont.)

```
// Fig. 6.19: fig06_19.cpp
// Comparing pass-by-value and pass-by-reference with referentces.
#include <iostream>
using namespace std;

int squareByValue( int ); // function prototype (value pass)
void squareByReference( int & ); // function prototype (reference pass)

int main()
{
   int x = 2; // value to square using squareByValue
   int z = 4; // value to square using squareByReference

   // demonstrate squareByValue
   cout << "x = " << x << " before squareByValue\n";
   cout << "Value returned by squareByValue: "
      << squareByValue( x ) << endl;
   cout << "x = " << x << " after squareByValue\n" << endl;

   // demonstrate squareByReference
   cout << "z = " << z << " before squareByReference" << endl;
   squareByReference( z );
   cout << "z = " << z << " after squareByReference" << endl;
} // end main
```

Fig. 6.19 | Passing arguments by value and by reference. (Part 1 of 2.)

6.14 References and Reference Parameters (cont.)

```

// squareByValue multiplies number by itself, stores the
// result in number and returns the new value of number
int squareByValue( int number )
{
   return number *= number; // caller's argument not modified
} // end function squareByValue

// squareByReference multiplies numberRef by itself and stores the result
// in the variable to which numberRef refers in function main
void squareByReference( int &numberRef )
{
   numberRef *= numberRef; // caller's argument modified
} // end function squareByReference
```

```
x = 2 before squareByValue
Value returned by squareByValue: 4
x = 2 after squareByValue

z = 4 before squareByReference
z = 16 after squareByReference
```

Fig. 6.19 | Passing arguments by value and by reference. (Part 2 of 2.)

6.14 References and Reference Parameters (cont.)

Performance Tip 6.7

For passing large objects, use a constant reference parameter to simulate the appearance and security of pass-by-value and avoid the overhead of passing a copy of the large object.

6.14 References and Reference Parameters (cont.)

- References can also be used as aliases for other variables within a function.
- Reference variables must be initialized in their declarations and cannot be reassigned as aliases to other variables.
- Once a reference is declared as an alias for another variable, all opera-tions supposedly performed on the alias are actually performed on the original variable.

6.14 References and Reference Parameters (cont.)

```cpp
// Fig. 6.20: fig06_20.cpp
// Initializing and using a reference.
#include <iostream>
using namespace std;

int main()
{
   int x = 3;
   int &y = x; // y refers to (is an alias for) x

   cout << "x = " << x << endl << "y = " << y << endl;
   y = 7; // actually modifies x
   cout << "x = " << x << endl << "y = " << y << endl;
} // end main
```

```
x = 3
y = 3
x = 7
y = 7
```

Fig. 6.20 | Initializing and using a reference.

6.14 References and Reference Parameters (cont.)

```cpp
// Fig. 6.21: fig06_21.cpp
// References must be initialized.
#include <iostream>
using namespace std;

int main()
{
   int x = 3;
   int &y; // Error: y must be initialized

   cout << "x = " << x << endl << "y = " << y << endl;
   y = 7;
   cout << "x = " << x << endl << "y = " << y << endl;
} // end main
```

Microsoft Visual C++ compiler error message:

```
C:\cpphtp7_examples\ch06\Fig06_21\fig06_21.cpp(9) : error C2530: 'y' :
   references must be initialized
```

GNU C++ compiler error message:

```
fig06_21.cpp:9: error: 'y' declared as a reference but not initialized
```

Fig. 6.21 | Uninitialized reference causes a syntax error.

6.14 References and Reference Parameters (cont.)

- Functions can return references, but this can be dangerous.
- When return-ing a reference to a variable declared in the called function, the variable should be declared `static` in that function.

6.14 References and Reference Parameters (cont.)

Common Programming Error 6.12

Returning a reference to an automatic variable in a called function is a logic error. Some compilers issue a warning when this occurs.

6.16 Unary Scope Resolution Operator

- It’s possible to declare local and global variables of the same name.
- C++ provides the unary scope resolution operator (`::`) to access a global variable when a local variable of the same name is in scope.
- Using the unary scope resolution operator (`::`) with a given variable name is optional when the only variable with that name is a global variable.

6.16 Unary Scope Resolution Operator

```cpp
// Fig. 6.23: fig06_23.cpp
// Using the unary scope resolution operator.
#include <iostream>
using namespace std;

int number = 7; // global variable named number

int main()
{
   double number = 10.5; // local variable named number

   // display values of local and global variables
   cout << "Local double value of number = " << number
      << "\nGlobal int value of number = " << ::number << endl;
} // end main
```

```
Local double value of number = 10.5
Global int value of number = 7
```

Fig. 6.23 |

variable name is optional when the only variable with that name is a global variable.

6.16 Unary Scope Resolution Operator

Error-Prevention Tip 6.4

Avoid using variables of the same name for different purposes in a program. Although this is allowed in various circumstances, it can lead to errors.

6.17 Function Overloading

- C++ enables several functions of the same name to be defined, as long as they have different signatures.
- This is called function overloading.
- The C++ compiler selects the proper function to call by examining the number, types and order of the arguments in the call.
- Function overloading is used to create sev-eral functions of the same name that perform similar tasks, but on different data types.

6.17 Function Overloading

```cpp
// Fig. 6.24: fig06_24.cpp
// Overloaded functions.
#include <iostream>
using namespace std;

// function square for int values
int square( int x )
{
   cout << "square of integer " << x << " is ";
   return x * x;
} // end function square with int argument

// function square for double values
double square( double y )
{
   cout << "square of double " << y << " is ";
   return y * y;
} // end function square with double argument

```

Fig. 6.24 | Overloaded `square` functions. (Part 1 of 2.)

6.17 Function Overloading

```
int main()
{
   cout << square( 7 ); // calls int version
   cout << endl;
   cout << square( 7.5 ); // calls double version
   cout << endl;
} // end main
```

```
square of integer 7 is 49
square of double 7.5 is 56.25
```

Fig. 6.24 | Overloaded `square` functions. (Part 2 of 2.)

6.17 Function Overloading (cont.)

- Overloaded functions are distinguished by their signatures.
- A signature is a combination of a function's name and its parameter types (in order).

7.1 Introduction

- This chapter introduces the important topic of data structures—collections of related data items.
- Arrays are data structures consisting of related data items of the same type.
- After discussing how arrays are declared, created and initialized, we present a series of practical examples that demonstrate several common array manipulations.

7.2 Arrays

- An array is a consecutive group of memory locations that all have the same type.
- To refer to a particular location or element in the array, spec-ify the name of the array and the position number of the particular element.
- Figure 7.1 shows an integer array called `c`.
- 12 elements.
- The position number is more formally called a subscript or index `(this number specifies the number of elements from the beginning of the array).`
- The first element in every array has subscript 0 (zero) and is sometimes called the zeroth element.
- The highest subscript in array `c` is 11, which is 1 less than the number of elements in the array (12).
- A subscript must be an integer or integer expression (using any integral type).

7.2 Arrays

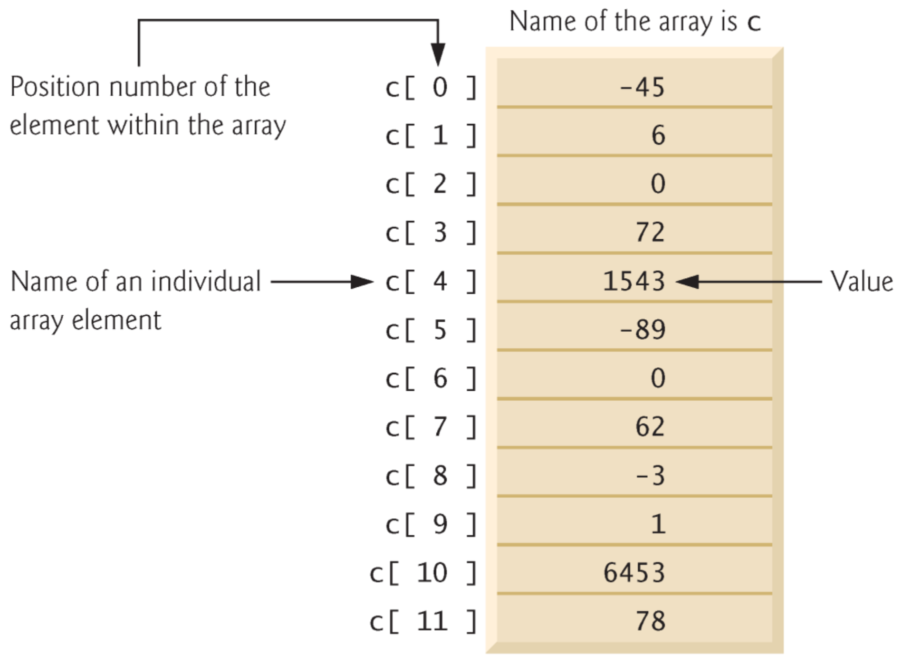
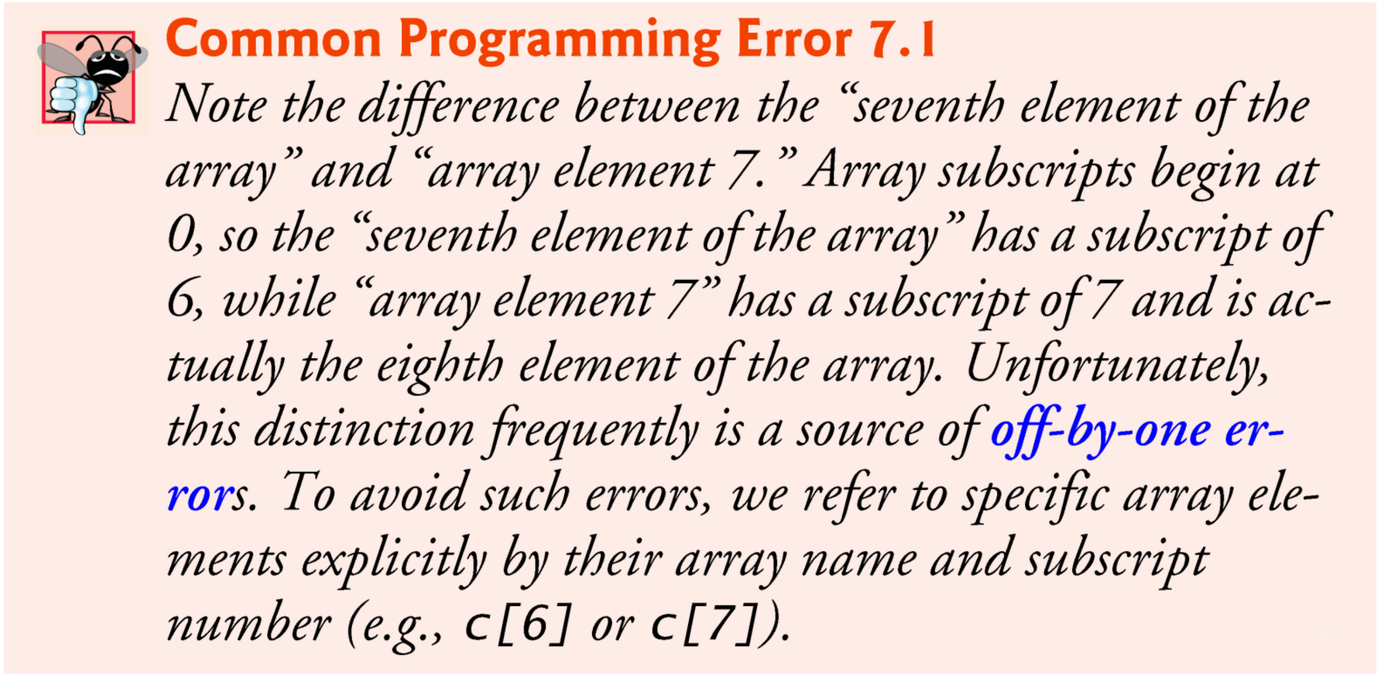


Fig. 7.1 | Array of 12 elements.

7.2 Arrays



Common Programming Error 7.1

Note the difference between the "seventh element of the array" and "array element 7." Array subscripts begin at 0, so the "seventh element of the array" has a subscript of 6, while "array element 7" has a subscript of 7 and is actually the eighth element of the array. Unfortunately, this distinction frequently is a source of ***off-by-one errors****. To avoid such errors, we refer to specific array elements explicitly by their array name and subscript number (e.g.,* `c[6]` *or* `c[7]`*).*

7.2 Arrays

Operators	Associativity	Type
`::`	left to right	scope resolution
`()` `[]`	left to right	highest
`++` `--` `static_cast<` *type* `>(` *operand* `)`	left to right	unary (postfix)
`++` `--` `+` `-` `!`	right to left	unary (prefix)
`*` `/` `%`	left to right	multiplicative
`+` `-`	left to right	additive
`<<` `>>`	left to right	insertion/extraction
`<` `<=` `>` `>=`	left to right	relational
`==` `!=`	left to right	equality
`&&`	left to right	logical AND
`||`	left to right	logical OR
`?:`	right to left	conditional
`=` `+=` `-=` `*=` `/=` `%=`	right to left	assignment
`,`	left to right	comma

Fig. 7.2 | Operator precedence and associativity.

7.3 Declaring Arrays

- Arrays occupy space in memory.
- To specify the type of the elements and the number of elements required by an array use a declaration of the form:
  - *`type arrayName[ arraySize ];`*
- The compiler reserves the appropriate amount of memory.
- Arrays can be declared to contain values of any nonreference data type.

7.4.1 Declaring an Array and Using a Loop to Initialize the Array’s Elements

```cpp
// Fig. 7.3: fig07_03.cpp
// Initializing an array.
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
   int n[ 10 ]; // n is an array of 10 integers

   // initialize elements of array n to 0
   for ( int i = 0; i < 10; i++ )
      n[ i ] = 0; // set element at location i to 0

   cout << "Element" << setw( 13 ) << "Value" << endl;

   // output each array element's value
   for ( int j = 0; j < 10; j++ )
      cout << setw( 7 ) << j << setw( 13 ) << n[ j ] << endl;
} // end main
```

Fig. 7.3 | Initializing an array’s elements to zeros and printing the array. (Part 1 of 2.)

7.4.1 Declaring an Array and Using a Loop to Initialize the Array’s Elements

```
Element          Value
      0              0
      1              0
      2              0
      3              0
      4              0
      5              0
      6              0
      7              0
      8              0
      9              0
```

Fig. 7.3 | Initializing an array’s elements to zeros and printing the array. (Part 2 of 2.)

7.4.2 Initializing an Array in a Declaration with an Initializer List

- The elements of an array also can be initialized in the array declaration by following the array name with an equals sign and a brace-delimited comma-separated list of initializers.
- The program in Fig. 7.4 uses an initializer list to initialize an integer array with 10 values (line 10) and prints the array in tabular format (lines 12–16).
- If there are fewer initializers than elements in the array, the remaining array elements are initialized to zero.
- If the array size is omitted from a declaration with an initializer list, the compiler determines the number of elements in the array by counting the number of elements in the initializer list.

7.4.2 Initializing an Array in a Declaration with an Initializer List

```cpp
// Fig. 7.4: fig07_04.cpp
// Initializing an array in a declaration.
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
   // use initializer list to initialize array n
   int n[ 10 ] = { 32, 27, 64, 18, 95, 14, 90, 70, 60, 37 };

   cout << "Element" << setw( 13 ) << "Value" << endl;

   // output each array element's value
   for ( int i = 0; i < 10; i++ )
      cout << setw( 7 ) << i << setw( 13 ) << n[ i ] << endl;
} // end main
```

Fig. 7.4 | Initializing the elements of an array in its declaration. (Part 1 of 2.)

7.4.2 Initializing an Array in a Declaration with an Initializer List

```
Element        Value
      0           32
      1           27
      2           64
      3           18
      4           95
      5           14
      6           90
      7           70
      8           60
      9           37
```

Fig. 7.4 | Initializing the elements of an array in its declaration. (Part 2 of 2.)

7.4.3 Specifying an Array's Size with a Constant Variable and Setting Array Elements with Calculations

- Figure 7.5 sets the elements of a 10-element array `s` to the even inte-gers `2`, `4`, `6`, …, `20` (lines 14–15) and prints the array in tabular format (lines 17–21).
- Line 10 uses the `const` qualifier to declare a so-called constant variable `arraySize` with the value `10`.
- Constant vari-ables must be initialized with a constant expression when they're declared and cannot be modified thereafter.
- Constant variables are also called named constants or read-only variables.

7.4.3 Specifying an Array's Size with a Constant Variable and Setting Array Elements with Calculations

```cpp
// Fig. 7.5: fig07_05.cpp
// Set array s to the even integers from 2 to 20.
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
   // constant variable can be used to specify array size
   const int arraySize = 10;

   int s[ arraySize ]; // array s has 10 elements

   for ( int i = 0; i < arraySize; i++ ) // set the values
      s[ i ] = 2 + 2 * i;

   cout << "Element" << setw( 13 ) << "Value" << endl;

   // output contents of array s in tabular format
   for ( int j = 0; j < arraySize; j++ )
      cout << setw( 7 ) << j << setw( 13 ) << s[ j ] << endl;
} // end main
```

Fig. 7.5 | Generating values to be placed into elements of an array. (Part 1 of 2.)

7.4.3 Specifying an Array's Size with a Constant Variable and Setting Array Elements with Calculations

```
Element        Value
      0            2
      1            4
      2            6
      3            8
      4           10
      5           12
      6           14
      7           16
      8           18
      9           20
```

Fig. 7.5 | Generating values to be placed into elements of an array. (Part 2 of 2.)

7.4.3 Specifying an Array’s Size with a Constant Variable and Setting Array Elements with Calculations

```cpp
// Fig. 7.6: fig07_06.cpp
// Using a properly initialized constant variable.
#include <iostream>
using namespace std;

int main()
{
   const int x = 7; // initialized constant variable

   cout << "The value of constant variable x is: " << x << endl;
} // end main
```

```
The value of constant variable x is: 7
```

Fig. 7.6 | Initializing and using a constant variable.

7.4.3 Specifying an Array's Size with a Constant Variable and Setting Array Elements with Calculations

```cpp
// Fig. 7.7: fig07_07.cpp
// A const variable must be initialized.

int main()
{
   const int x; // Error: x must be initialized

   x = 7; // Error: cannot modify a const variable
} // end main
```

Microsoft Visual C++ compiler error message:

```
C:\cpphtp7_examples\ch07\fig07_07.cpp(6) : error C2734: 'x' : const object
   must be initialized if not extern
C:\cpphtp7_examples\ch07\fig07_07.cpp(8) : error C3892: 'x' : you cannot
   assign to a variable that is const
```

GNU C++ compiler error message:

```
fig07_07.cpp:6: error: uninitialized const 'x'
fig07_07.cpp:8: error: assignment of read-only variable 'x'
```

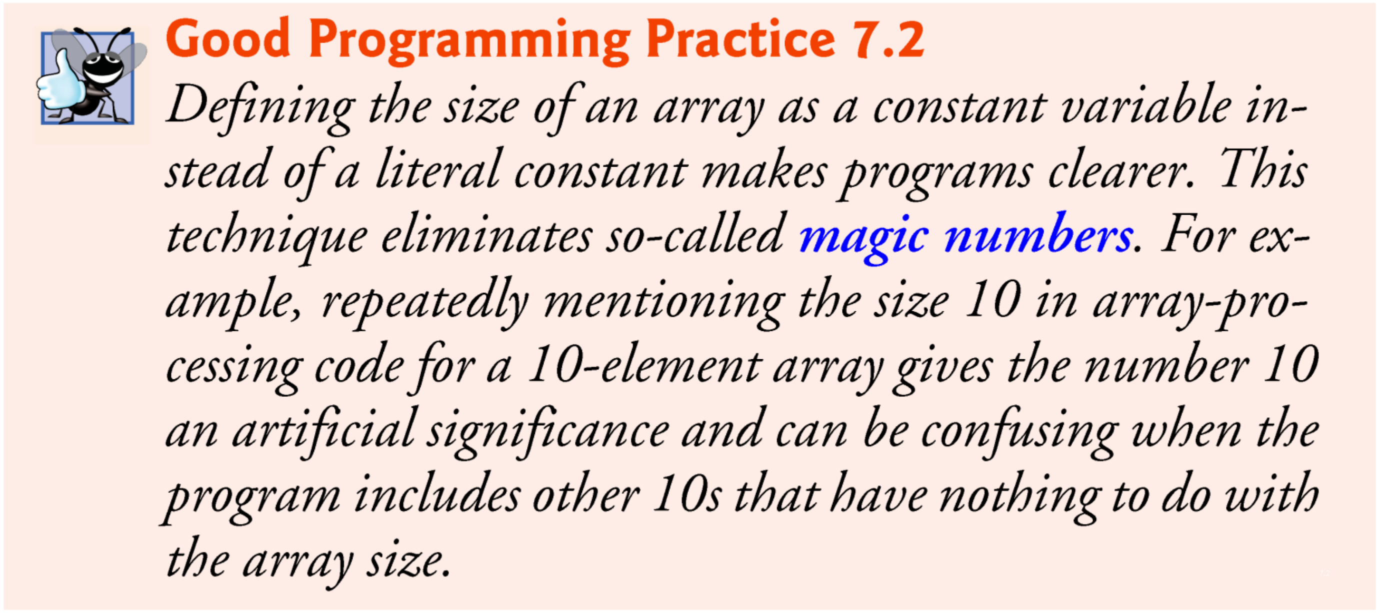
Fig. 7.7 | `const` variables must be initialized.

7.4.3 Specifying an Array's Size with a Constant Variable and Setting Array Elements with Calculations

Common Programming Error 7.5

Only constants can be used to declare the size of automatic and static arrays. Not using a constant for this purpose is a compilation error.

7.4.3 Specifying an Array's Size with a Constant Variable and Setting Array Elements with Calculations



Good Programming Practice 7.2

Defining the size of an array as a constant variable instead of a literal constant makes programs clearer. This technique eliminates so-called ***magic numbers****. For example, repeatedly mentioning the size 10 in array-processing code for a 10-element array gives the number 10 an artificial significance and can be confusing when the program includes other 10s that have nothing to do with the array size.*

7.4.4 Summing the Elements of an Array

- Often, the elements of an array represent a series of values to be used in a calculation.
- The program in Fig. 7.8 sums the values contained in the 10-element integer ar-ray `a`.

7.4.4 Summing the Elements of an Array

```cpp
// Fig. 7.8: fig07_08.cpp
// Compute the sum of the elements of the array.
#include <iostream>
using namespace std;

int main()
{
   const int arraySize = 10; // constant variable indicating size of array
   int a[ arraySize ] = { 87, 68, 94, 100, 83, 78, 85, 91, 76, 87 };
   int total = 0;

   // sum contents of array a
   for ( int i = 0; i < arraySize; i++ )
      total += a[ i ];

   cout << "Total of array elements: " << total << endl;
} // end main
```

```
Total of array elements: 849
```

Fig. 7.8 | Computing the sum of the elements of an array.

Questions

?