Topic 4
Arrays and Pointers
Lecture 4b (chapter 8)

CSCI 140: C++ Language & Objects

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Book: C++: How to Program 10 ed.

Agenda

- What are Pointers
- Declare and initialize pointers
- Use reference and dereferencing operators
- Compare pointers and references
- Using pointers as arguments to functions
- Built-in arrays
- Const with pointers
- sizeof operator
- Pointer expressions and arithmetic
- Pointer based strings
- nullptr and *begin* and *end* in the standard library

8.1 Introduction

- Pointers are one of the most powerful, yet challenging to use, C++ capabilities.
- We'll discuss when it's appropriate to use pointers, and show how to use them correctly and responsibly.
- Pointers also enable pass-by-reference and can be used to create and manipulate pointer-based dynamic data structures.
- We also show the intimate relationship among built-in arrays and pointers.
- In new software development projects, you should favor array and vector objects to built-in arrays.

8.2 Pointer Variable Declarations and Initialization

- A pointer contains the memory address of a variable that, in turn, contains a specific value.
- In this sense, a variable name directly references a value, and a pointer indirectly references a value.
- Referencing a value through a pointer is called indirection.
- Diagrams typically represent a pointer as an arrow from the variable that contains an address to the variable located at that address in memory.

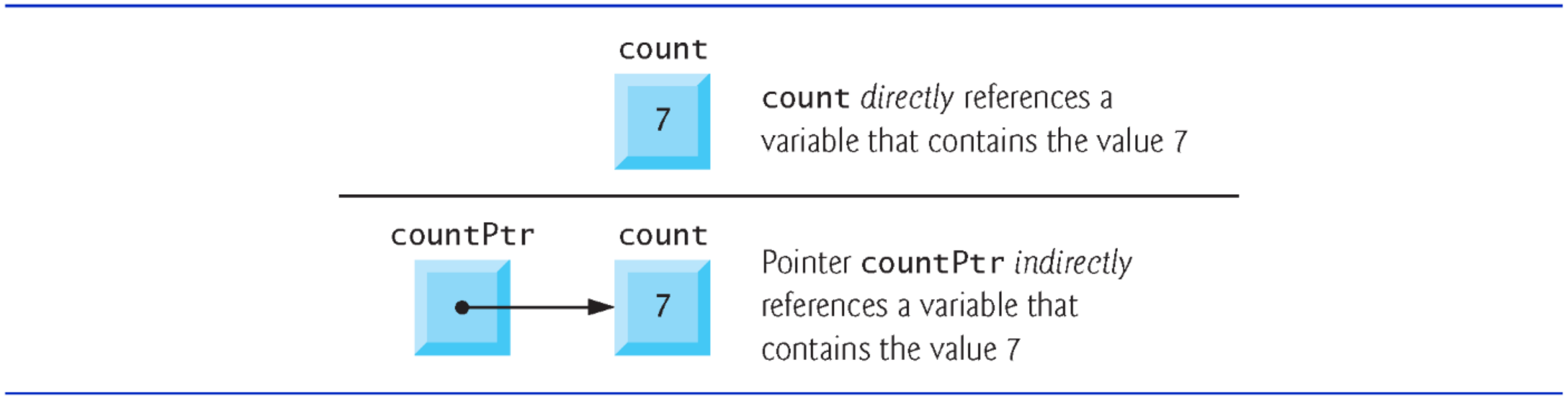

count
7
count *directly* references a variable that contains the value 7
countPtr
count
7
Pointer countPtr *indirectly* references a variable that contains the value 7

Fig. 8.1 | Directly and indirectly referencing a variable.

8.2.1 Delcaring Pointers

- The declaration
    - int* countPtr{nullptr}, count{0};
- declares the variable countPtr to be of type int* (i.e., a pointer to an int value) and is read (right to left), “countPtr is a pointer to int.”
    - Variable count in the preceding declaration is declared to be an int, not a pointer to an int.
    - The * in the declaration applies only to countPtr.
    - Each variable being declared as a pointer must be preceded by an asterisk (*).
- When * appears in a declaration, it is not an operator—it indicates that the variable being declared is a pointer.
- Pointers can be declared to point to objects of any type.
- A common mistake is to assume that *count* is also a pointer but it isn’t
    - Many C++ programmers will write this statement as: int *countPtr, count;

8.2.2 Initializing Pointers

- Pointers should be initialized to nullptr (new in C++11) or to a memory address either when they’re declared or in an assignment.
- A pointer with the value nullptr “points to nothing” and is known as a “null pointer”.
- From this point forward, when we refer to a “null pointer” we mean a pointer with the value nullptr.

Error-Prevention Tip 8.1

Initialize all pointers to prevent pointing to unknown or uninitialized areas of memory.

8.2.3 Null Pointers Prior to C++11

- In earlier versions of C++, the value specified for a null pointer was 0 or NULL.
- NULL is defined in several standard library headers to represent the value 0.
- Initializing a pointer to NULL is equivalent to initializing a pointer to 0, but prior to C++11, 0 was used by convention.
- The value 0 is the only integer value that can be assigned directly to a pointer variable without first casting the integer to a pointer type.

8.3 Pointer Operators

The unary operators & and * are used to create pointer values and “dereference” pointers, respectively.

8.3.1 Address (&) Operator

- The unary operators & and * are used to create pointer values and “dereference” pointers, respectively.
- The address operator (&) is a unary operator that obtains the memory address of its operand, it helps to call this unary operator the “address-of” operator.
- Assuming the declarations
  - int y{5}; // declare variable y
    int* yPtr{nullptr}; // declare pointer variable yPtr
- the statement
  - yPtr = &y; // assign address of y to yPtr
- Assigns the address of the variable y to pointer variable yPtr.
- Figure 8.2 shows a representation of memory after the preceding assignment.

8.3.1 Address (&) Operator

- Figure 8.3 shows another pointer representation in memory with integer variable y stored at memory location 600000 and pointer variable yPtr stored at location 500000.
- The operand of the address operator must be an lvalue—the address operator cannot be applied to constants or to expressions that result in temporary values (like the results of calculations).

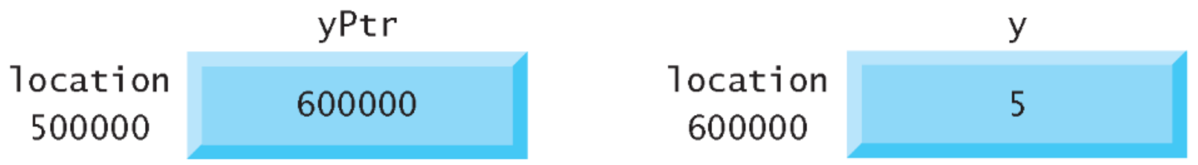


Fig. 8.3 | Representation of `y` and `yPtr` in memory.

8.3.2 Indirection (*) Operator

- The unary * operator—commonly referred to as the indirection operator or **dereferencing operator**—returns an lvalue representing the object to which its pointer operand points.
  - Known as dereferencing a pointer
- A dereferenced pointer can also be used as an lvalue on the left side of an assignment.

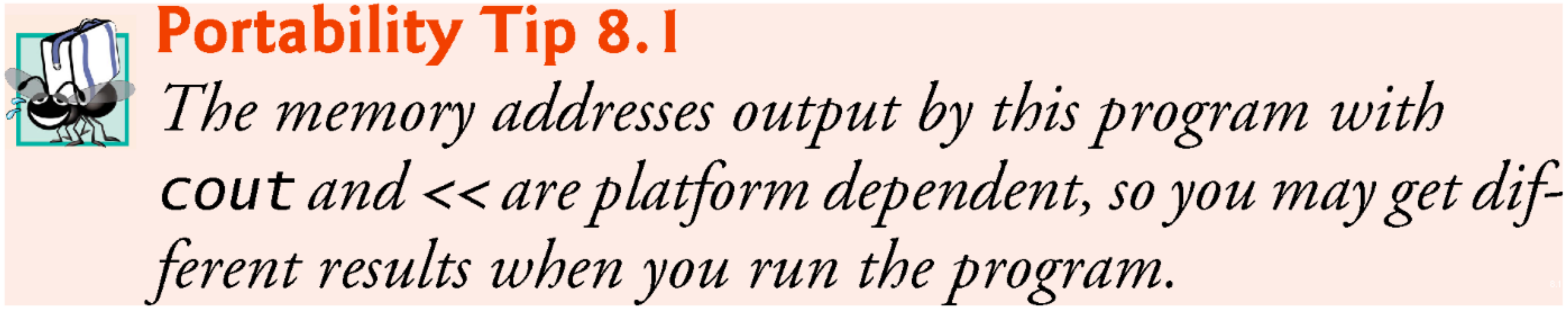
8.3.3 Using the Address (&) and Indirection (*) Operators

- The program in Fig. 8.4 demonstrates the & and * pointer operators.

```cpp
// Fig. 8.4: fig08_04.cpp
// Pointer operators & and *.
#include <iostream>
using namespace std;

int main() {
   int a{7}; // initialize a with 7
   int* aPtr = &a; // initialize aPtr with the address of int variable a

   cout << "The address of a is " << &a
      << "\nThe value of aPtr is " << aPtr;
   cout << "\n\nThe value of a is " << a
      << "\nThe value of *aPtr is " << *aPtr << endl;
}
```

```
The address of a is 002DFD80
The value of aPtr is 002DFD80

The value of a is 7
The value of *aPtr is 7
```

Fig. 8.4 | Pointer operators & and *.



Portability Tip 8.1

The memory addresses output by this program with `cout` *and* `<<` *are platform dependent, so you may get different results when you run the program.*

8.3.3 Using the Address (&) and Indirection (*) Operators

- Precedence and Associativity of the Operators Discussed So Far
- Figure 8.5 lists the precedence and associativity of the operators introduced to this point.
- The address (&) and dereferencing operator (*) are unary operators on the fourth level.

Operators	Associativity	Type
`::` `()`	left to right *[See caution in Fig. 2.10 regarding grouping parentheses.]*	primary
`()` `[]` `++` `--` `static_cast<`*type*`>(`*operand*`)`	left to right	postfix
`++` `--` `+` `-` `!` `&` `*`	right to left	unary (prefix)
`*` `/` `%`	left to right	multiplicative
`+` `-`	left to right	additive
`<<` `>>`	left to right	stream 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. 8.5 | Operator precedence and associativity of the operators discussed so far.

8.4 Pass-by-Reference with Pointers

- There are three ways in C++ to pass arguments to a function
  - pass-by-value
  - pass-by-reference with reference arguments
  - pass-by-reference with pointer arguments.

8.5 Built-In Arrays

8.5.1 Declaring and Accessing a Built-In Array

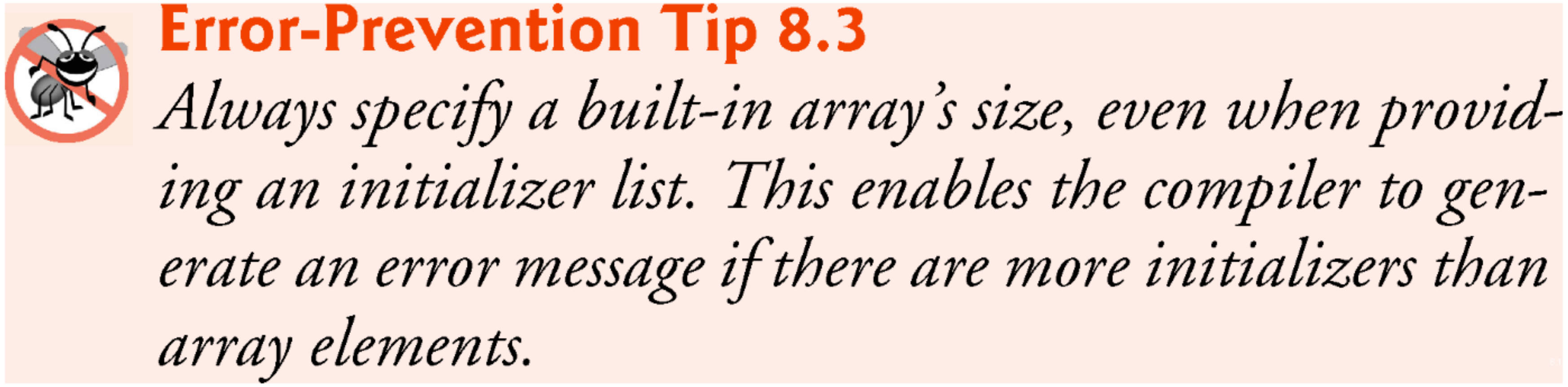
- Here we present built-in arrays, which are also fixed-size data structures.
- To specify the type of the elements and the number of elements required by a built-in array, use a declaration of the form:
  - type arrayName[arraySize];
- The compiler reserves the appropriate amount of memory.
- arraySize must be an integer constant greater than zero.
- To reserve 12 elements for built-in array of ints named c, use the declaration
  - int c[12];
- As with array objects, you use the subscript ([]) operator to access the individual elements of a built-in array.

8.5.2 Initializing Built-In Arrays

- You can initialize the elements of a built-in array using an initializer list as in
  - int n[5]{50, 20, 30, 10, 40};
  - creates a built-in array of five ints and initializes them to the values in the initializer list.
- If you provide fewer initializers
  - the number of elements, the remaining elements are value initialized—fundamental numeric types are set to 0, bools are set to false, pointers are set to nullptr and class objects are initialized by their default constructors.
- If you provide too many initializers a compilation error occurs.

8.5.2 Initializing Built-In Arrays

- If a built-in array’s size is omitted from a declaration with an initializer list, the compiler sizes the built-in array to the number of elements in the initializer list.
- For example,
  - int n[]{50, 20, 30, 10, 40};
- creates a five-element array.

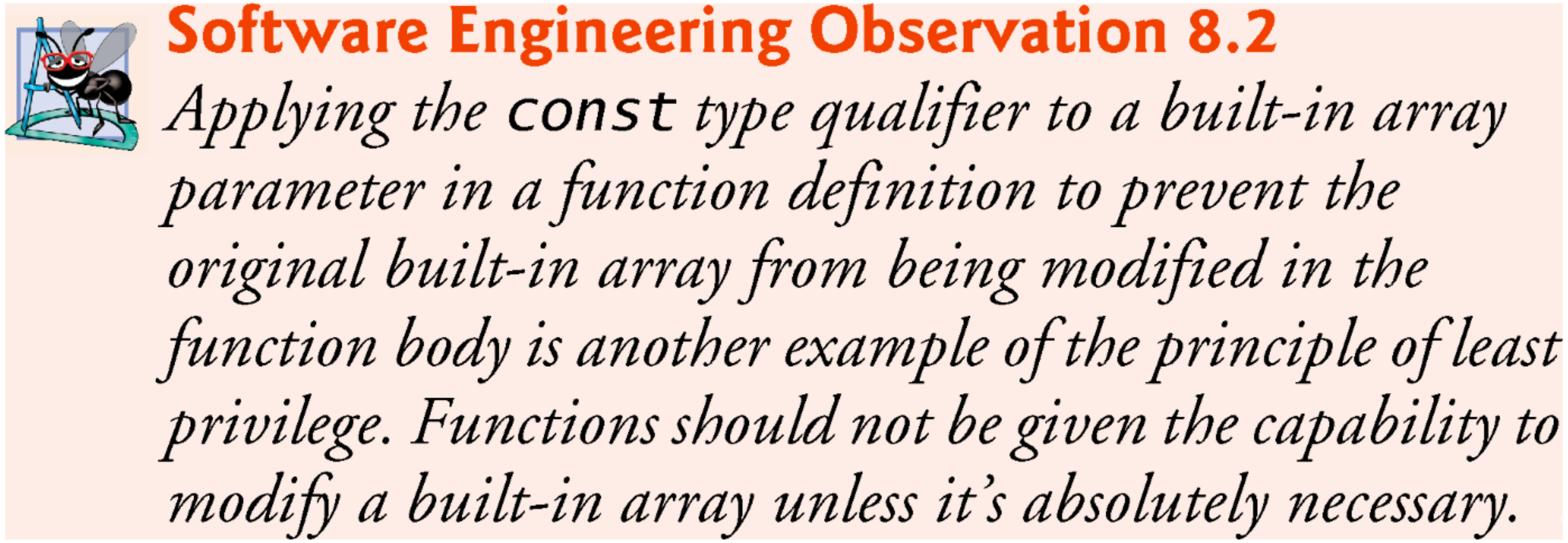


Error-Prevention Tip 8.3

Always specify a built-in array's size, even when providing an initializer list. This enables the compiler to generate an error message if there are more initializers than array elements.

8.5.3 Passing Built-In Arrays to Functions

- The value of a built-in array’s name is implicitly convertible to the address of the built-in array’s first element.
  - So arrayName is implicitly convertible to &arrayName[0].
- You don’t need to take the address (&) of a built-in array to pass it to a function—you simply pass the built-in array’s name.
- For built-in arrays, the called function can modify all the elements of a built-in array in the caller—unless the function precedes the corresponding built-in array parameter with const to indicate that the elements should not be modified.



Software Engineering Observation 8.2

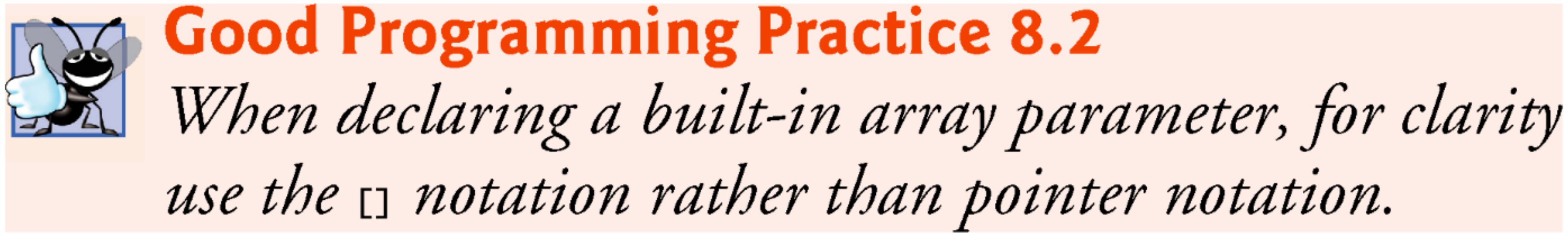
Applying the `const` *type qualifier to a built-in array parameter in a function definition to prevent the original built-in array from being modified in the function body is another example of the principle of least privilege. Functions should not be given the capability to modify a built-in array unless it's absolutely necessary.*

8.5.4 Declaring Built-In Array Parameters

- You can declare a built-in array parameter in a function header, as follows:
  - int sumElements(const int values[], const size_t
    numberOfElements)
- This indicates that the function's first argument should be a one-dimensional built-in array of ints that should not be modified by the function.
- The preceding header can also be written as:
  - int sumElements(const int* values, const size_t
    numberOfElements)

8.5.4 Declaring Built-In Array Parameters

- The compiler does not differentiate between a function that receives a pointer and a function that receives a built-in array.
  - The function must “know” when it’s receiving a built-in array or simply a single variable that’s being passed by reference.
- When the compiler encounters a function parameter for a one-dimensional built-in array of the form const int values[], the compiler converts the parameter to the pointer notation const int* values.
  - These forms of declaring a one-dimensional built-in array parameter are interchangeable.



Good Programming Practice 8.2

When declaring a built-in array parameter, for clarity use the `[]` *notation rather than pointer notation.*

8.5.5 C++11: Standard Library Functions begin and end

- In Section 7.7, we showed how to sort an array object with the C++ Standard Library function sort.
- We sorted an array of strings called colors as follows:
  - // sort contents of colors
  - sort(colors.begin(), colors.end());
- The array class's begin and end functions specified that the entire array should be sorted.

8.5.5 C++11: Standard Library Functions begin and end

- Function sort (and many other C++ Standard Library functions) can also be applied to built-in arrays.
- For example, to sort the built-in array n shown earlier in this section, you can write:
  - // sort contents of built-in array n
  - sort(begin(n), end(n));
- C++11's new begin and end functions (from header <iterator>) each receive a built-in array as an argument and return a pointer that can be used to represent ranges of elements to process in C++ Standard Library functions like sort.

8.5.6 Built-In Array Limitations

- Built-in arrays have several limitations:
  - They cannot be compared using the relational and equality operators—you must use a loop to compare two built-in arrays element by element.
  - They cannot be assigned to one another.
  - They don’t know their own size—a function that processes a built-in array typically receives both the built-in array’s name and its size as arguments.
  - They don’t provide automatic bounds checking—you must ensure that array-access expressions use subscripts that are within the built-in array’s bounds.

8.5.7 Built-In Arrays Sometimes Are Required

- There are cases in which built-in arrays must be used, such as processing a program’s command-line arguments.
- You supply command-line arguments to a program by placing them after the program’s name when executing it from the command line. Such arguments typically pass options to a program.

8.5.7 Built-In Arrays Sometimes Are Required

- On a Windows computer, the command
  - dir /p
- uses the /p argument to list the contents of the current directory, pausing after each screen of information.
- On Linux or OS X, the following command uses the -la argument to list the contents of the current directory with details about each file and directory:
  - ls -la

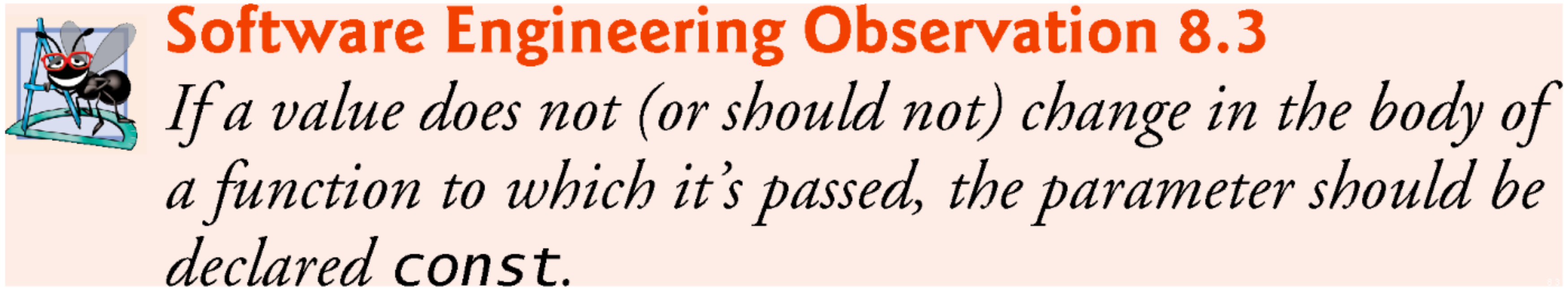
8.6 Using const with Pointers

8.6 Using const with Pointers (cont.)

- Many possibilities exist for using (or not using) const with function parameters.
- Principle of least privilege
  - Always give a function enough access to the data in its parameters to accomplish its specified task, but no more.
- There are four ways to pass a pointer to a function

▪ a nonconstant pointer to nonconstant data	void process(int* value){ …
▪ a nonconstant pointer to constant data (Fig. 8.10)	void process(const int* value){ …
▪ a constant pointer to nonconstant data (Fig. 8.11)	void process(int* const value){ …
▪ a constant pointer to constant data (Fig. 8.12)	void process(const int* const value){ …

- Each combination provides a different level of access privilege.



Software Engineering Observation 8.3

If a value does not (or should not) change in the body of a function to which it's passed, the parameter should be declared `const`.

8.6.1 Nonconstant Pointer to Nonconstant Data

- The highest access is granted by a nonconstant pointer to nonconstant data
  - The data can be modified through the dereferenced pointer
  - The pointer can be modified to point to other data.
- Such a pointer's declaration (e.g., int* countPtr) does not include const.

8.6.2 Nonconstant Pointer to Constant Data

- Nonconstant pointer to constant data
  - A pointer that can be modified to point to any item of the appropriate type
  - The data to which it points cannot be modified through that pointer
- Sample declaration:
    - const int* countPtr;
  - Read from right to left as “countPtr is a pointer to an integer constant” or more precisely, “countPtr is a non-constant pointer to an integer constant.”
- Figure 8.10 demonstrates GNU C++’s compilation error message produced when attempting to compile a function that receives a nonconstant pointer to constant data, then tries to use that pointer to modify the data.

```cpp
// Fig. 8.10: fig08_10.cpp
// Attempting to modify data through a
// nonconstant pointer to constant data.

void f(const int*); // prototype

int main() {
   int y{0};

   f(&y); // f will attempt an illegal modification
}

// constant variable cannot be modified through xPtr
void f(const int* xPtr) {
   *xPtr = 100; // error: cannot modify a const object
}
```

GNU C++ compiler error message:

```
fig08_10.cpp: In function ‘void f(const int*)’:
fig08_10.cpp:17:12: error: assignment of read-only location ‘* xPtr’
```

Fig. 8.10 | Attempting to modify data through a nonconstant pointer to `const` data.

8.6.3 Constant Pointer to Nonconstant Data

- Constant pointer to nonconstant data
- int* const countPtr{&a};
  - always points to the same memory location
  - the data at that location can be modified through the pointer
- Pointers that are declared const must be initialized when they're declared.
- If the pointer is a function parameter, it's initialized with a pointer that's passed to the function.
- Fig. 8.11 attempts to modify a constant pointer.

```
// Fig. 8.11: fig08_11.cpp
// Attempting to modify a constant pointer to nonconstant data.

int main() {
   int x, y;

   // ptr is a constant pointer to an integer that can be modified
   // through ptr, but ptr always points to the same memory location.
   int* const ptr{&x}; // const pointer must be initialized

   *ptr = 7; // allowed: *ptr is not const
   ptr = &y; // error: ptr is const; cannot assign to it a new address
}
```

Microsoft Visual C++ compiler error message:

```
'ptr': you cannot assign to a variable that is const
```

Fig. 8.11 | Attempting to modify a constant pointer to nonconstant data.

8.6.4 Constant Pointer to Constant Data

- The minimum access privilege is granted by a constant pointer to constant data.
  - Such a pointer always points to the same memory location
  - The data at that location cannot be modified via the pointer.
- This is how a built-in array should be passed to a function that only reads from the built-in array, using array subscript notation, and does not modify the built-in array.
- const int* const
  - Read from right to left as "ptr is a constant pointer to an integer constant."
- Fig. 8.12 shows the Xcode LLVM compiler's error messages that are generated when an attempt is made to modify the data to which ptr points and when an attempt is made to modify the address stored in the pointer variable—these show up on the lines of code with the errors in the Xcode text editor.

```cpp
// Fig. 8.12: fig08_12.cpp
// Attempting to modify a constant pointer to constant data.
#include <iostream>
using namespace std;

int main() {
   int x{5}, y;

   // ptr is a constant pointer to a constant integer.
   // ptr always points to the same location; the integer
   // at that location cannot be modified.
   const int* const ptr{&x};

   cout << *ptr << endl;

   *ptr = 7; // error: *ptr is const; cannot assign new value
   ptr = &y; // error: ptr is const; cannot assign new address
}
```

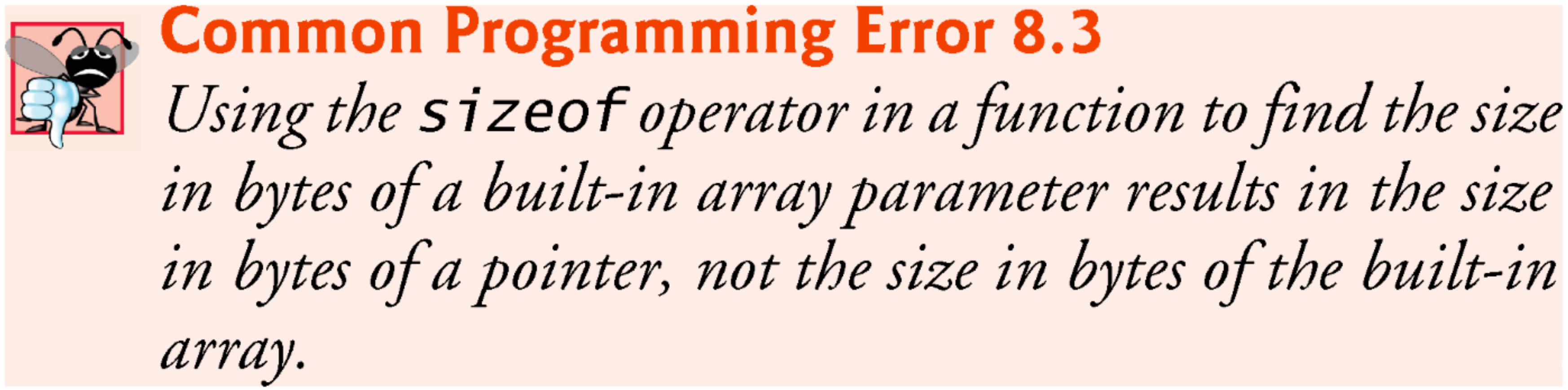
Xcode LLVM compiler error message:

```
Read-only variable is not assignable
Read-only variable is not assignable
```

Fig. 8.12 | Attempting to modify a constant pointer to constant data.

8.7 sizeof Operator

- The unary operator sizeof determines the size in bytes of a built-in array or of any other data type, variable or constant during program compilation.
- When applied to a built-in array's name, as in Fig. 8.13, the sizeof operator returns the total number of bytes in the built-in array as a value of type size_t.
- When applied to a pointer parameter in a function that receives a built-in array as an argument, the sizeof operator returns the size of the pointer in bytes—not the built-in array's size.



Common Programming Error 8.3

Using the `sizeof` *operator in a function to find the size in bytes of a built-in array parameter results in the size in bytes of a pointer, not the size in bytes of the built-in array.*

```cpp
// Fig. 8.13: fig08_13.cpp
// Sizeof operator when used on a built-in array's name
// returns the number of bytes in the built-in array.
#include <iostream>
using namespace std;

size_t getSize(double*); // prototype

int main() {
   double numbers[20]; // 20 doubles; occupies 160 bytes on our system

   cout << "The number of bytes in the array is " << sizeof(numbers);

   cout << "\nThe number of bytes returned by getSize is "
      << getSize(numbers) << endl;
}

// return size of ptr
size_t getSize(double* ptr) {
   return sizeof(ptr);
}
```

Fig. 8.13 | `sizeof` operator when applied to a built-in array's name returns the number of bytes in the built-in array. (Part 1 of 2.)

```
The number of bytes in the array is 160
The number of bytes returned by getSize is 4
```

Fig. 8.13 | `sizeof` operator when applied to a built-in array's name returns the number of bytes in the built-in array. (Part 2 of 2.)

8.7 sizeof Operator (cont.)

- To determine the number of elements in the built-in array numbers, use the following expression (which is evaluated at compile time) :
  - sizeof numbers / sizeof(numbers[0])
- The expression divides the number of bytes in numbers by the number of bytes in the built-in array’s zeroth element.

8.7 sizeof Operator (cont.)

- Operator sizeof can be applied to any expression or type name.
- When sizeof is applied to a variable name (which is not a built-in array’s name) or other expression, the number of bytes used to store the specific type of the expression is returned.
- The parentheses used with sizeof are required only if a type name is supplied as its operand.

8.8 Pointer Expressions and Pointer Arithmetic

- Pointers are valid operands in arithmetic expressions, assignment expressions and comparison expressions.
- C++ enables pointer arithmetic—a few arithmetic operations may be performed on pointers:
  - increment (++)
  - decremented (--)
  - an integer may be added to a pointer (+ or +=)
  - an integer may be subtracted from a pointer (- or -=)
  - one pointer may be subtracted from another of the same type—this particular operation is appropriate only for two pointers that point to elements of the same built-in array

8.8 Pointer Expressions and Pointer Arithmetic

- Assume that int v[5] has been declared and that its first element is at memory location 3000.
- Assume that pointer vPtr has been initialized to point to v[0] (i.e., the value of vPtr is 3000).
- Figure 8.15 diagrams this situation for a machine with four-byte integers. Variable vPtr can be initialized to point to v with either of the following statements:
  - int* vPtr{v};
  - int* vPtr{&v[0]};

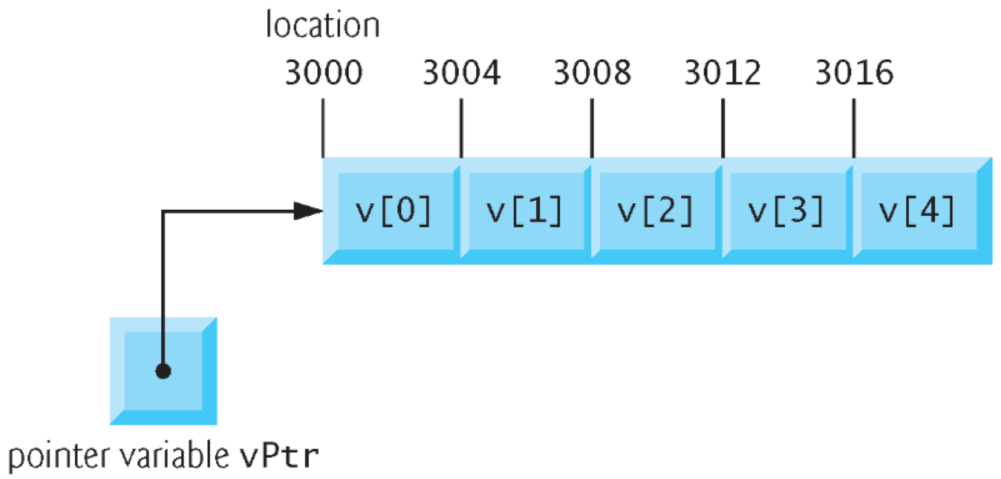


Fig. 8.15 | Built-in array v and a pointer variable int* vPtr that points to v.

8.8.1 Adding Integers to and Subtracting Integers from Pointers

- In conventional arithmetic, the addition 3000 + 2 yields the value 3002.
- This is normally not the case with pointer arithmetic.
- When an integer is added to, or subtracted from, a pointer, the pointer is not simply incremented or decremented by that integer, but by that integer times the size of the memory object to which the pointer refers.
- The number of bytes depends on the memory object’s data type.

8.8.1 Adding Integers to and Subtracting Integers from Pointers

- vPtr += 2;
  - would produce 3008 (from the calculation 3000 + 2 * 4), assuming that an int is stored in four bytes of memory.
- In the built-in array v, vPtr would now point to v[2] (Fig. 8.16).
- If an integer is stored in eight bytes of memory, then the preceding calculation would result in memory location 3016 (3000 + 2 * 8).

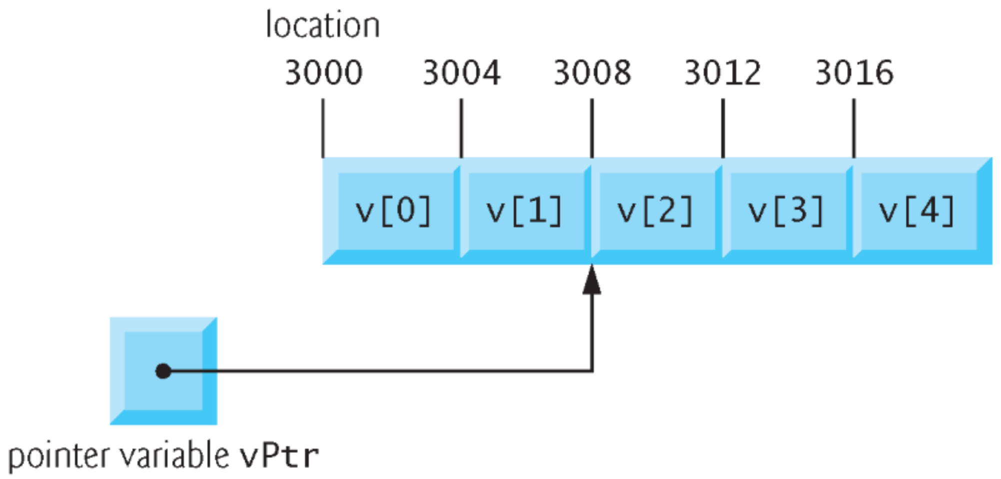
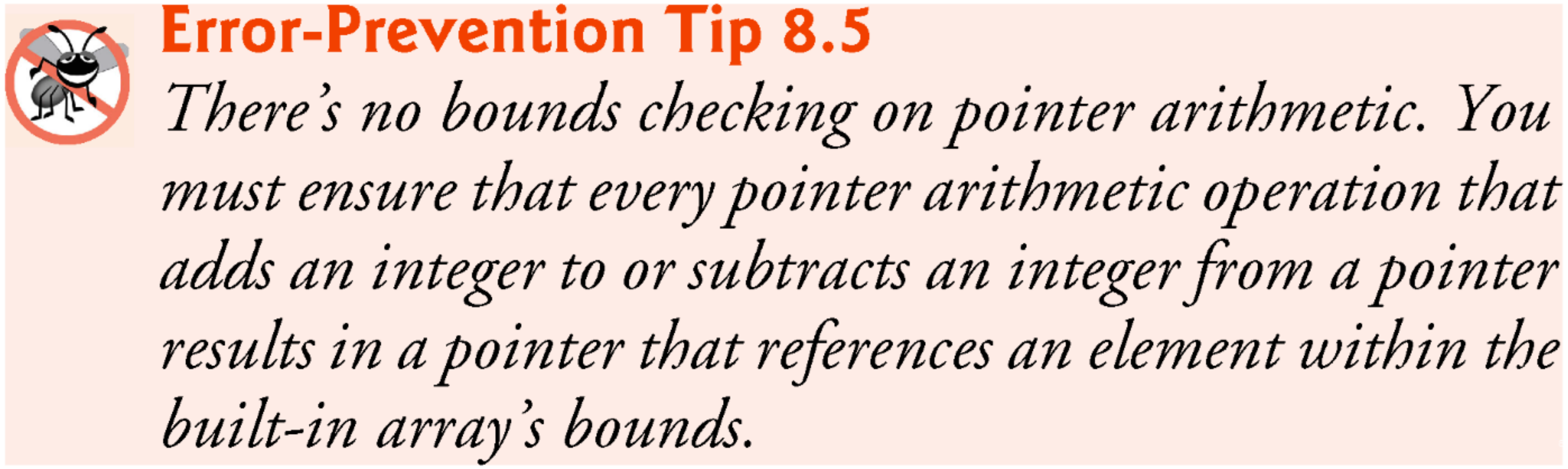


Fig. 8.16 | Pointer `vPtr` after pointer arithmetic.



Error-Prevention Tip 8.5

There's no bounds checking on pointer arithmetic. You must ensure that every pointer arithmetic operation that adds an integer to or subtracts an integer from a pointer results in a pointer that references an element within the built-in array's bounds.

8.8.3 Subtracting Pointers

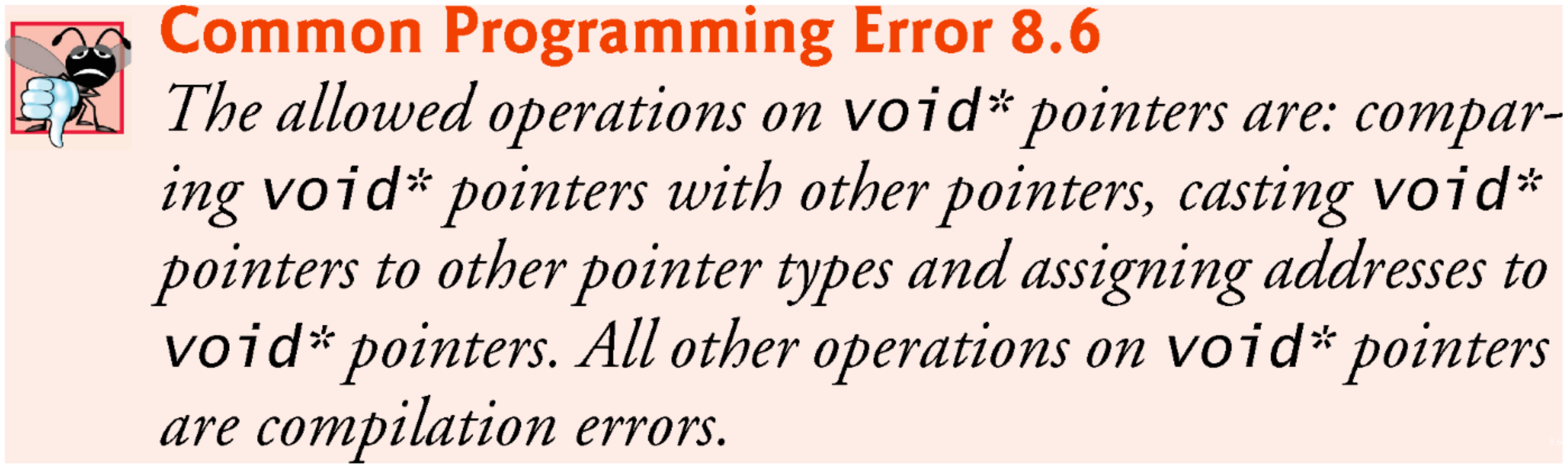
- Pointer variables pointing to the same built-in array may be subtracted from one another.
- For example, if vPtr contains the address 3000 and v2Ptr contains the address 3008, the statement
  - x = v2Ptr - vPtr;
- would assign to x the number of built-in array elements from vPtr to v2Ptr—in this case, 2.
- Pointer arithmetic is meaningful only on a pointer that points to a built-in array.

8.8.3 Pointer Assignment

- A pointer can be assigned to another pointer if both pointers are of the same type.
- Otherwise, a cast operator (normally a reinterpret_cast; discussed in Section 14.7) must be used to convert the value of the pointer on the right of the assignment to the pointer type on the left of the assignment.
  - **Exception to this rule is the pointer to void (i.e., void*).**
- Any pointer to a fundamental type or class type can be assigned to a pointer of type void* without casting.

8.8.4 Cannot Dereference a void*

- A void* pointer cannot be dereferenced.
- The compiler "knows" that an int* points to four bytes of memory on a machine with four-byte integers—dereferencing an int* creates an lvalue that is an alias for the int's four bytes in memory.
- A void* simply contains a memory address for an unknown data type.
  - You cannot dereference a void* because the compiler does not know the type of the data to which the pointer refers and thus not the number of bytes.



Common Programming Error 8.6

The allowed operations on `void*` *pointers are: comparing* `void*` *pointers with other pointers, casting* `void*` *pointers to other pointer types and assigning addresses to* `void*` *pointers. All other operations on* `void*` *pointers are compilation errors.*

8.8.5 Comparing Pointers

- Pointers can be compared using equality and relational operators.
  - Comparisons using relational operators are meaningless unless the pointers point to elements of the same built-in array.
  - Pointer comparisons compare the addresses stored in the pointers.
- A common use of pointer comparison is determining whether a pointer has the value nullptr, 0 or NULL (i.e., the pointer does not point to anything).

8.9 Relationship Between Pointers and Built-In Arrays

8.9 Relationship Between Pointers and Built-In Arrays

- Pointers can be used to do any operation involving array subscripting.
- Assume the following declarations:
  - // create 5-element int array b; b is a const pointer
  - int b[5];
    // create int pointer bPtr, which isn't a const pointer
  - int* bPtr;
- We can set bPtr to the address of the first element in the built-in array b with the statement
  - // assign address of built-in array b to bPtr
  - bPtr = b;
- This is equivalent to assigning the address of the first element as follows:
  - // also assigns address of built-in array b to bPtr
  - bPtr = &b[0];

8.9.1 Pointer/Offset Notation

- Built-in array element b[3] can alternatively be referenced with the pointer expression
  - *(bPtr + 3)
- The 3 in the preceding expression is the offset to the pointer.
- This notation is referred to as pointer/offset notation.
  - The parentheses are necessary, because the precedence of * is higher than that of +.

8.9 Relationship Between Pointers and Built-In Arrays (cont.)

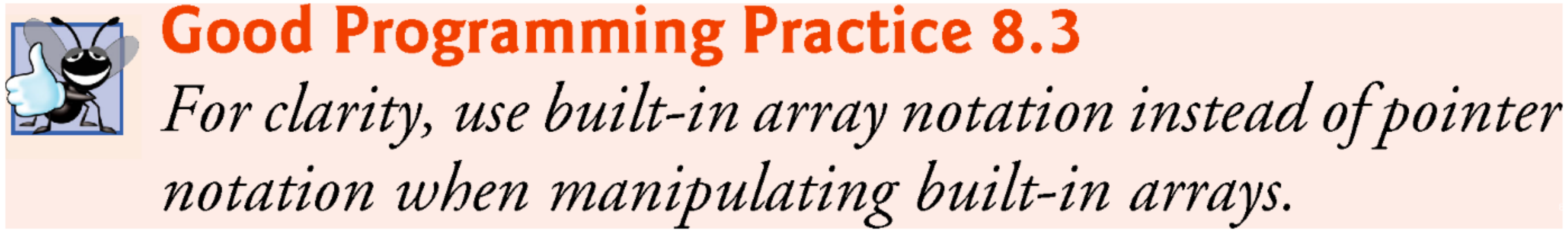
- Just as the built-in array element can be referenced with a pointer expression, the address
  - &b[3]
- can be written with the pointer expression
  - bPtr + 3

8.9.2 Pointer/Offset Notation with the Built-In Array’s Name as the Pointer

- The built-in array name can be treated as a pointer and used in pointer arithmetic.
- For example, the expression
  - *(b + 3)
- also refers to the element b[3].
- In general, all subscripted built-in array expressions can be written with a pointer and an offset.

8.9.3 Pointer/Subscript Notation

- Pointers can be subscripted exactly as built-in arrays can.
- For example, the expression
  - bPtr[1]
- refers to b[1]; this expression uses pointer/subscript notation.



Good Programming Practice 8.3

For clarity, use built-in array notation instead of pointer notation when manipulating built-in arrays.

8.9.4 Demonstrating the Relationship Between Pointers and Built-In Arrays

- Figure 8.17 uses the four notations we just discussed
  - array subscript notation
  - pointer/offset notation with the built-in array's name as a pointer
  - pointer subscript notation
  - pointer/offset notation with a pointer
- to accomplish the same task, namely displaying the four elements of the built-in array of ints named b.

```cpp
// Fig. 8.17: fig08_17.cpp
// Using subscripting and pointer notations with built-in arrays.
#include <iostream>
using namespace std;

int main() {
   int b[]{10, 20, 30, 40}; // create 4-element built-in array b
   int* bPtr{b}; // set bPtr to point to built-in array b

   // output built-in array b using array subscript notation
   cout << "Array b displayed with:\n\nArray subscript notation\n";

   for (size_t i{0}; i < 4; ++i) {
      cout << "b[" << i << "] = " << b[i]   << '\n';
   }

   // output built-in array b using array name and pointer/offset notation
   cout << "\nPointer/offset notation where "
      << "the pointer is the array name\n";

   for (size_t offset1{0}; offset1 < 4; ++offset1) {
      cout << "*(b + " << offset1 << ") = " << *(b + offset1)   << '\n';
   }
```

Fig. 8.17 | Using subscripting and pointer notations with built-in arrays. (Part 1 of 3.)

```

   // output built-in array b using bPtr and array subscript notation
   cout << "\nPointer subscript notation\n";

   for (size_t j{0}; j < 4; ++j) {
      cout << "bPtr[" << j << "] = " << bPtr[j] << '\n';
   }

   cout << "\nPointer/offset notation\n";

   // output built-in array b using bPtr and pointer/offset notation
   for (size_t offset2{0}; offset2 < 4; ++offset2) {
      cout << "*(bPtr + " << offset2 << ") = "
         << *(bPtr + offset2) << '\n';
   }
}
```

Fig. 8.17 | Using subscripting and pointer notations with built-in arrays. (Part 2 of 3.)

```
Array b displayed with:

Array subscript notation
b[0] = 10
b[1] = 20
b[2] = 30
b[3] = 40

Pointer/offset notation where the pointer is the array name
*(b + 0) = 10
*(b + 1) = 20
*(b + 2) = 30
*(b + 3) = 40

Pointer subscript notation
bPtr[0] = 10
bPtr[1] = 20
bPtr[2] = 30
bPtr[3] = 40

Pointer/offset notation
*(bPtr + 0) = 10
*(bPtr + 1) = 20
*(bPtr + 2) = 30
*(bPtr + 3) = 40
```

Fig. 8.17 | Using subscripting and pointer notations with built-in arrays. (Part 3 of 3.)

8.10 Pointer-Based Strings

- This section introduces C-style, pointer-based strings, which we’ll simply call C strings.
- C++’s string class is preferred
  - it eliminates many of the security problems that can be caused by manipulating C strings.
- We cover C strings for a deeper understanding of arrays, and because there are some cases in which C string processing is required.
- Also, if you work with legacy C and C++ programs, you’re likely to encounter pointer-based strings.

8.10 Pointer-Based Strings (cont.)

- Characters and Character Constants
- Characters are the fundamental building blocks of C++ source programs.
- Character constant
  - An integer value represented as a character in single quotes.
  - The value of a character constant is the integer value of the character in the machine’s character set.

8.10 Pointer-Based Strings (cont.)

- Strings
- A string is a series of characters treated as a single unit.
  - May include letters, digits and various special characters such as +, -, *, /and $.
- String literals, or string constants, in C++ are written in double quotation marks

8.10 Pointer-Based Strings (cont.)

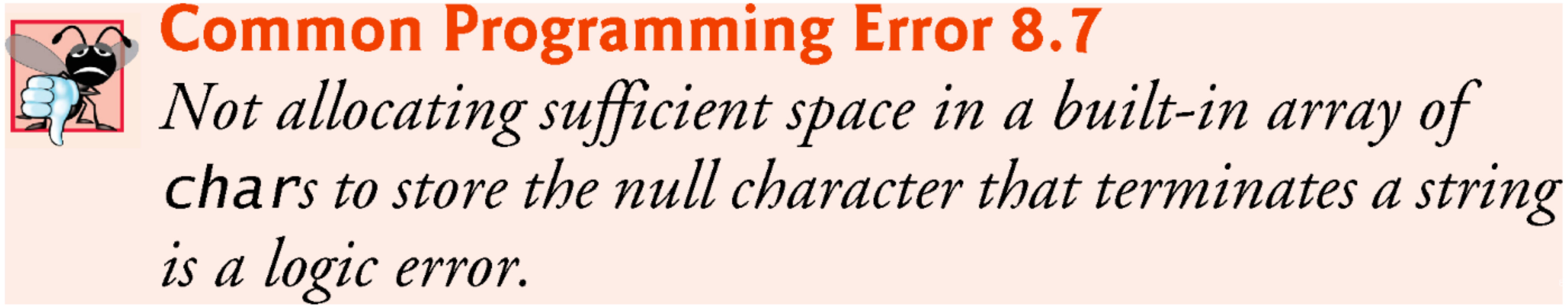
- Pointer-Based Strings
- A pointer-based string is a built-in array of characters ending with a null character ('\0').
- A string is accessed via a pointer to its first character.
- The sizeof a string literal is the length of the string including the terminating null character.

8.10 Pointer-Based Strings (cont.)

- String Literals as Initializers
- A string literal may be used as an initializer in the declaration of either a built-in array of chars or a variable of type const char*.
- String literals exist for the duration of the program and may be shared if the same string literal is referenced from multiple locations in a program.

8.10 Pointer-Based Strings (cont.)

- Character Constants as Initializers
- When declaring a built-in array of chars to contain a string, the built-in array must be large enough to store the string and its terminating null character.

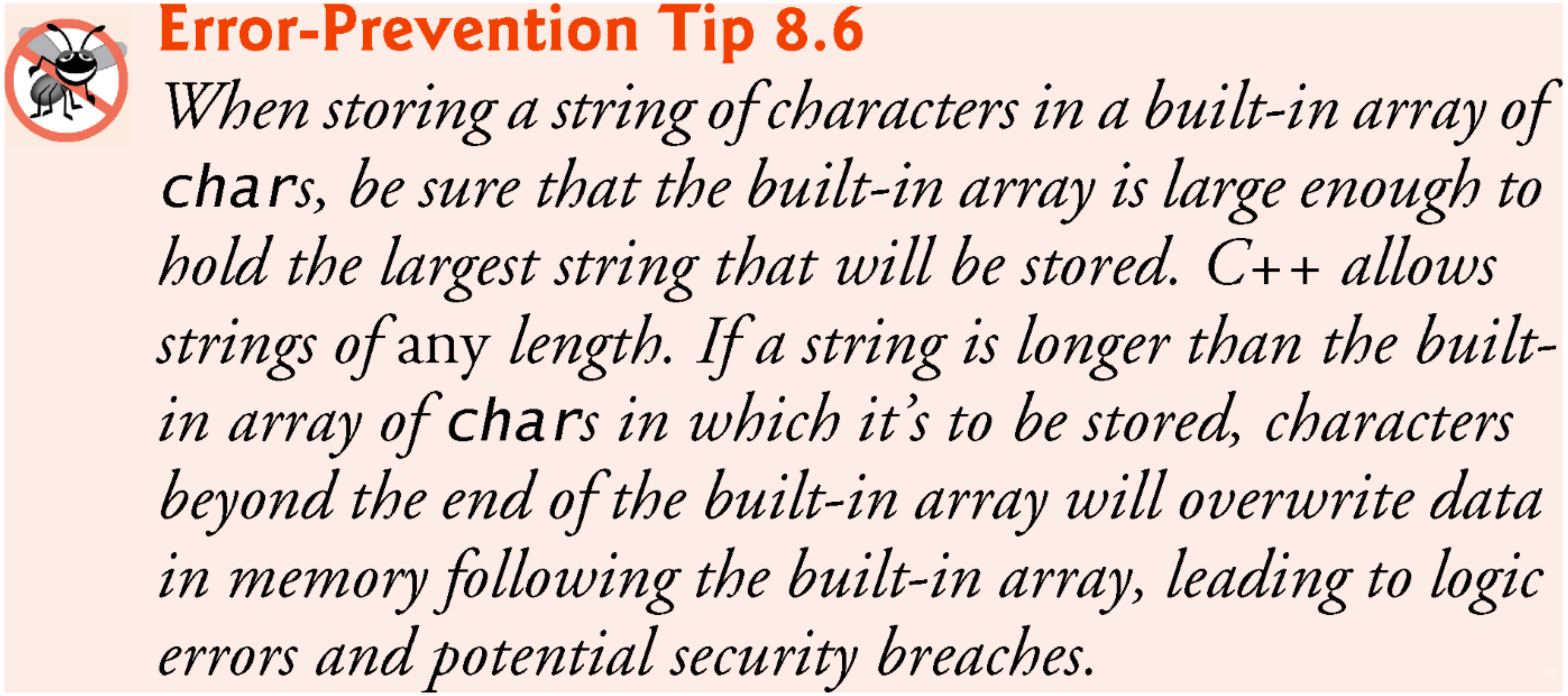


Common Programming Error 8.7

Not allocating sufficient space in a built-in array of `char`*s to store the null character that terminates a string is a logic error.*

Common Programming Error 8.8

Creating or using a C string that does not contain a terminating null character can lead to logic errors.



Error-Prevention Tip 8.6

When storing a string of characters in a built-in array of `char`*s, be sure that the built-in array is large enough to hold the largest string that will be stored. C++ allows strings of* any *length. If a string is longer than the built-in array of* `char`*s in which it's to be stored, characters beyond the end of the built-in array will overwrite data in memory following the built-in array, leading to logic errors and potential security breaches.*

8.10 Pointer-Based Strings (cont.)

- Accessing Characters in a C String
- Because a C string is a built-in array of characters, we can access individual characters in a string directly with array subscript notation.

8.10 Pointer-Based Strings (cont.)

- Reading Strings into Built-In Arrays of char with cin
- A string can be read into a built-in array of chars using stream extraction with cin.
- The setw stream manipulator can be used to ensure that the string read into word does not exceed the size of the built-in array.
  - Applies only to the next value being input.

8.10 Pointer-Based Strings (cont.)

- Reading Lines of Text into Built-In Arrays of char with cin.getline
- In some cases, it’s desirable to input an entire line of text into a built-in array of chars.
- For this purpose, the cin object provides the member function getline, which takes three arguments—a built-in array of chars in which the line of text will be stored, a length and a delimiter character.
- The function stops reading characters when the delimiter character '\n' is encountered, when the end-of-file indicator is entered or when the number of characters read so far is one less than the length specified in the second argument.
- The third argument to cin.getline has '\n' as a default value.

8.10 Pointer-Based Strings (cont.)

- Displaying C Strings
- A built-in array of chars representing a null-terminated string can be output with cout and <<.
- The characters are output until a terminating null character is encountered; the null character is not displayed.
- cin and cout assume that built-in arrays of chars should be processed as strings terminated by null characters; cin and cout do not provide similar input and output processing capabilities for other built-in array types.

8.10 Pointer-Based Strings (cont.)

- Displaying C Strings
- A built-in array of chars representing a null-terminated string can be output with cout and <<.
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8.11 Note About Smart Pointers

- Later in the book, we introduce dynamic memory management with pointers, which allows you at execution time to create and destroy objects as needed.
- Improperly managing this process is a source of subtle errors.
- We’ll discuss “smart pointers,” which help you avoid dynamic memory management errors by providing additional functionality beyond that of built-in pointers.