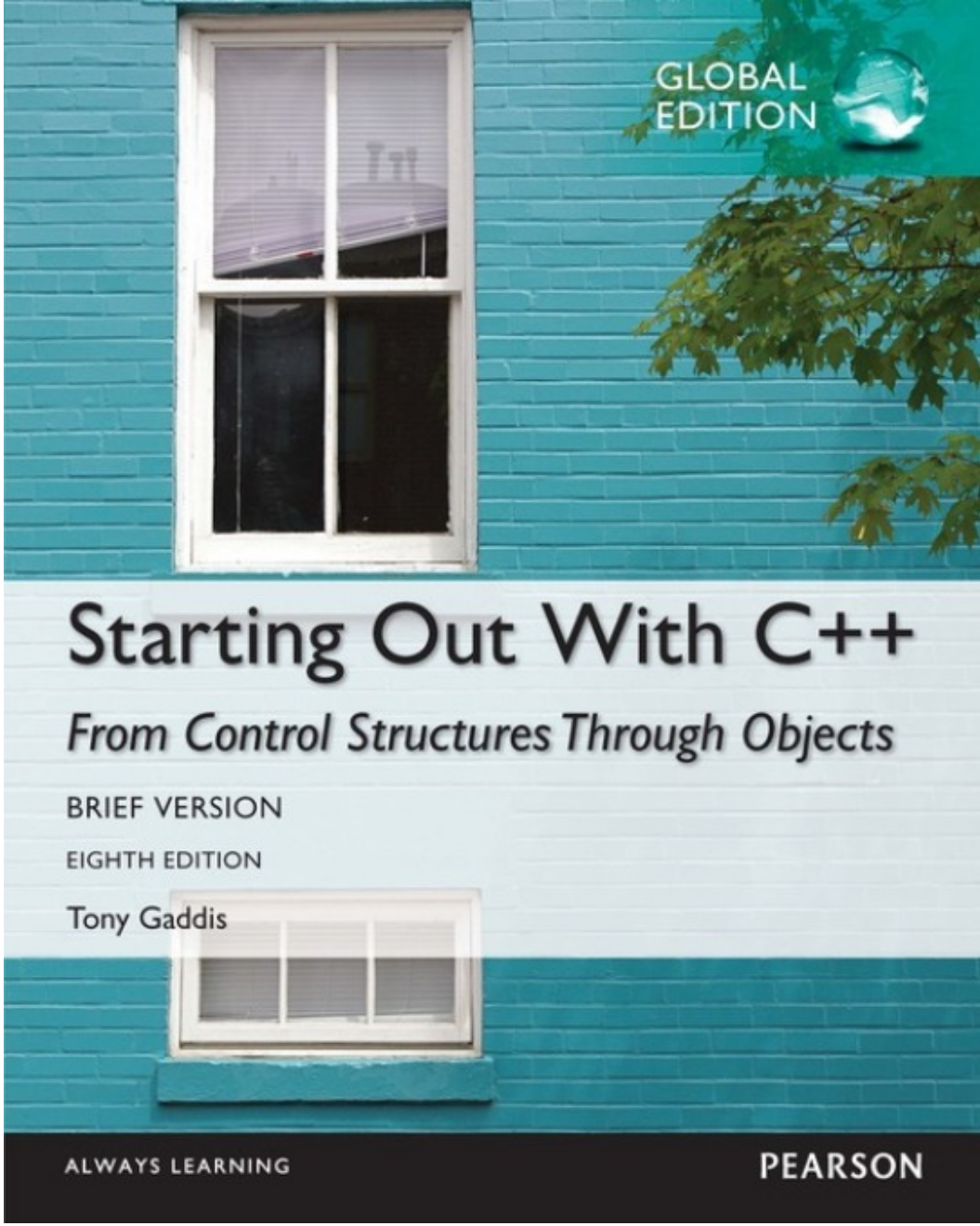
Chapter 7:

Arrays



Arrays Hold Multiple Values

- Array: variable that can store multiple values of the same type
- Values are stored in adjacent memory locations
- Declared using `[]` operator:

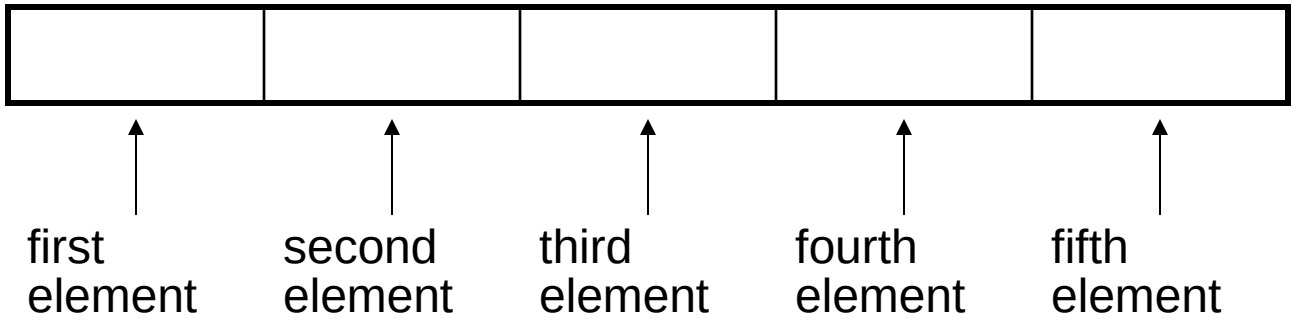
```
int tests[5];
```

Array - Memory Layout

- The definition:

```
int tests[5];
```

allocates the following memory:



Array Terminology

In the definition `int tests[5];`

- `int` is the data type of the array elements
- `tests` is the name of the array
- `5,` in `[5],` is the array size. It shows the number of elements in the array.

Array Terminology

- The size of an array is:
  - the total number of bytes allocated for it
  - (number of elements) * (number of bytes for each element)
- Examples:

  `int tests[5]` is an array of 20 bytes, assuming 4 bytes for an `int`

  `long double measures[10]`is an array of 80 bytes, assuming 8 bytes for a `long double`

Size Declarators

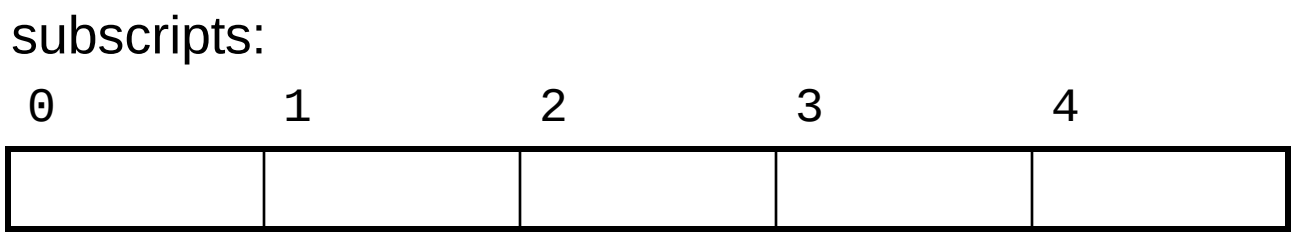
- Named constants are commonly used as size declarators.

```
const int SIZE = 5;
int tests[SIZE];
```

- This eases program maintenance when the size of the array needs to be changed.

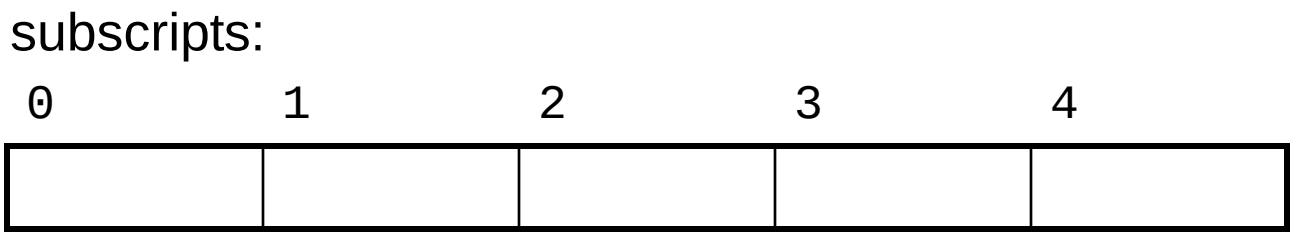
Accessing Array Elements

- Each element in an array is assigned a unique *subscript*.
- Subscripts start at 0



Accessing Array Elements

- The last element's subscript is *n*-1 where *n* is the number of elements in the array.



Accessing Array Elements

- Array elements can be used as regular variables:

```
tests[0] = 79;
cout << tests[0];
cin >> tests[1];
tests[4] = tests[0] + tests[1];
```

- Arrays must be accessed via individual elements:

```
cout << tests; // not legal
```

Accessing Array Elements in Program 7-1

Program 7-1

```
1  // This program asks for the number of hours worked
2  // by six employees. It stores the values in an array.
3  #include <iostream>
4  using namespace std;
5
6  int main()
7  {
8     const int NUM_EMPLOYEES = 6;
9     int hours[NUM_EMPLOYEES];
10
11    // Get the hours worked by each employee.
12    cout << "Enter the hours worked by "
13         << NUM_EMPLOYEES << " employees: ";
14    cin >> hours[0];
15    cin >> hours[1];
16    cin >> hours[2];
17    cin >> hours[3];
18    cin >> hours[4];
19    cin >> hours[5];
20
```

(Program Continues)

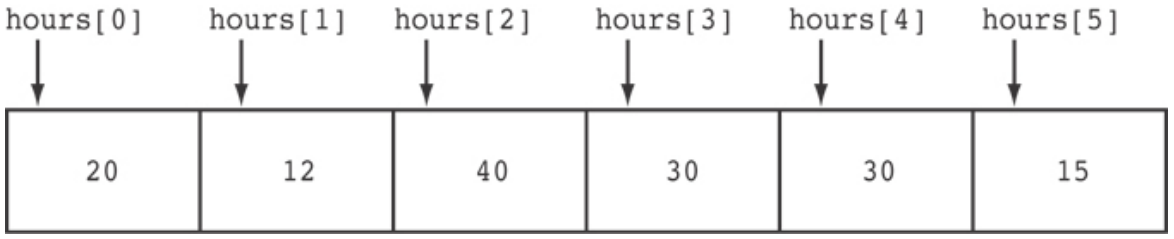
Accessing Array Elements in Program 7-1

```
21    // Display the values in the array.
22    cout << "The hours you entered are:";
23    cout << " " << hours[0];
24    cout << " " << hours[1];
25    cout << " " << hours[2];
26    cout << " " << hours[3];
27    cout << " " << hours[4];
28    cout << " " << hours[5] << endl;
29    return 0;
30 }
```

Program Output with Example Input Shown in Bold

```
Enter the hours worked by 6 employees: 20 12 40 30 30 15 [Enter]
The hours you entered are: 20 12 40 30 30 15
```

Here are the contents of the `hours` array, with the values entered by the user in the example output:



Accessing Array Contents

- Can access element with a constant or literal subscript:

```
cout << tests[3] << endl;
```

- Can use integer expression as subscript:

```
int i = 5;
cout << tests[i] << endl;
```

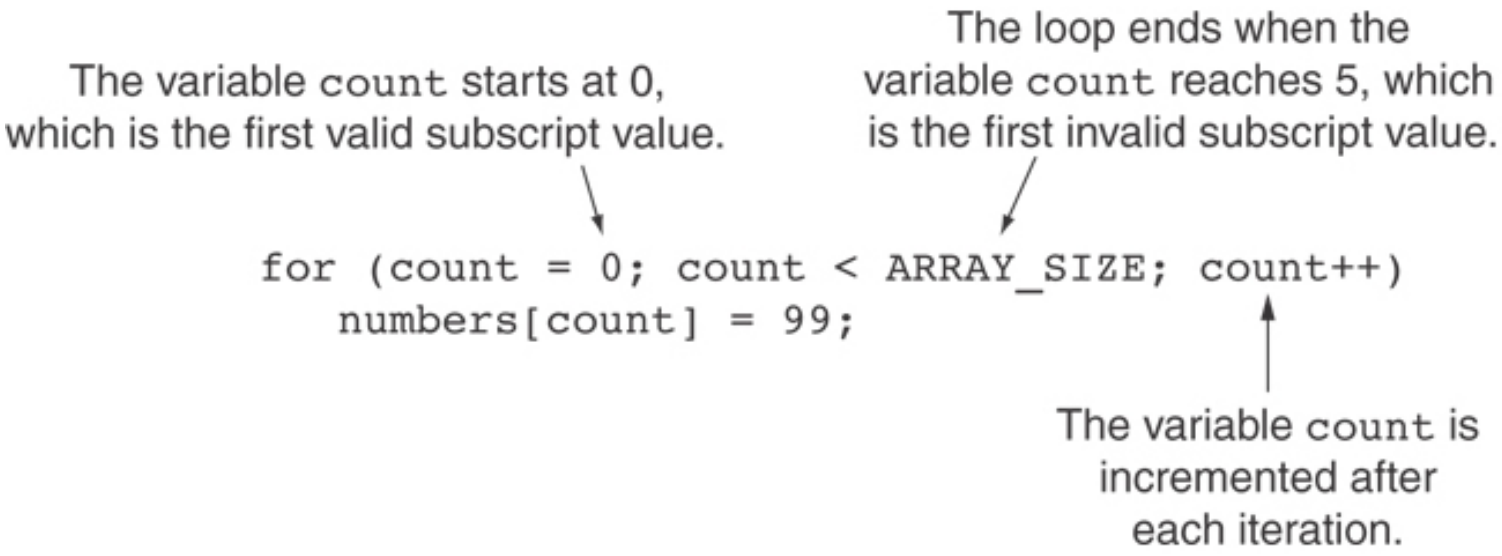
Using a Loop to Step Through an Array

- Example – The following code defines an array, `numbers`, and assigns 99 to each element:

```
const int ARRAY_SIZE = 5;
int numbers[ARRAY_SIZE];

for (int count = 0; count < ARRAY_SIZE; count++)
     numbers[count] = 99;
```

A Closer Look At the Loop



Default Initialization

- Global array → all elements initialized to `0` by default
- Local array → all elements *uninitialized* by default

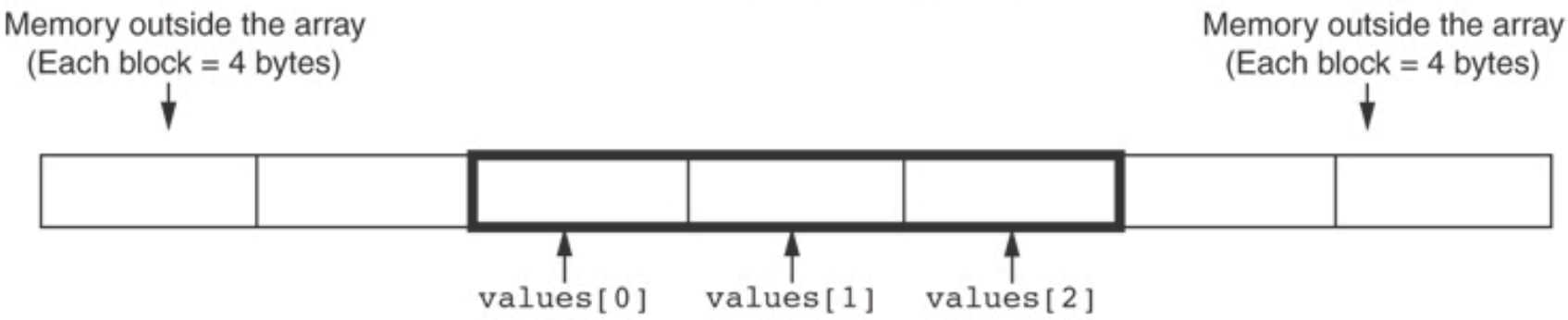
Code From Program 7-5

- The following code defines a three-element array, and then writes five values to it!

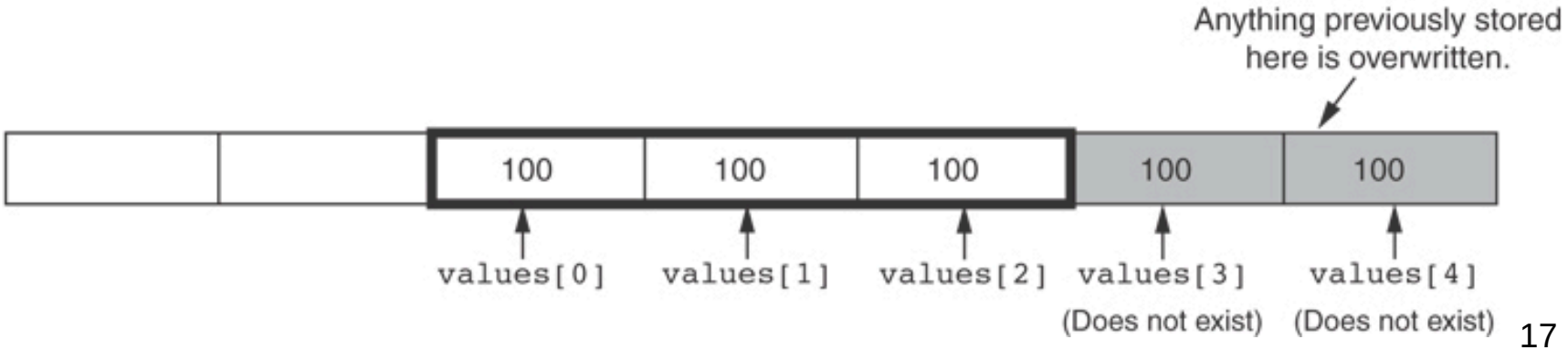
```
 9     const int SIZE = 3;  // Constant for the array size
10     int values[SIZE];    // An array of 3 integers
11     int count;           // Loop counter variable
12
13     // Attempt to store five numbers in the three-element array.
14     cout << "I will store 5 numbers in a 3 element array!\n";
15     for (count = 0; count < 5; count++)
16        values[count] = 100;
```

What the Code Does

The way the `values` array is set up in memory.
The outlined area represents the array.



How the numbers assigned to the array overflow the array's boundaries.
The shaded area is the section of memory illegally written to.



No Bounds Checking in C++

- Be careful not to use invalid subscripts.
- Doing so can corrupt other memory locations, crash program, or lock up computer, and cause elusive bugs.

Off-By-One Errors

- An off-by-one error happens when you use array subscripts that are off by one.
- This can happen when you start subscripts at 1 rather than 0:

```
// This code has an off-by-one error.
const int SIZE = 100;
int numbers[SIZE];
for (int count = 1; count <= SIZE; count++)
   numbers[count] = 0;
```

Array Initialization

- Arrays can be initialized with an initialization list:

```
const int SIZE = 5;
int tests[SIZE] = {79,82,91,77,84};
```

- The values are stored in the array in the order in which they appear in the list.
- The initialization list cannot exceed the array size.

Code From Program 7-6

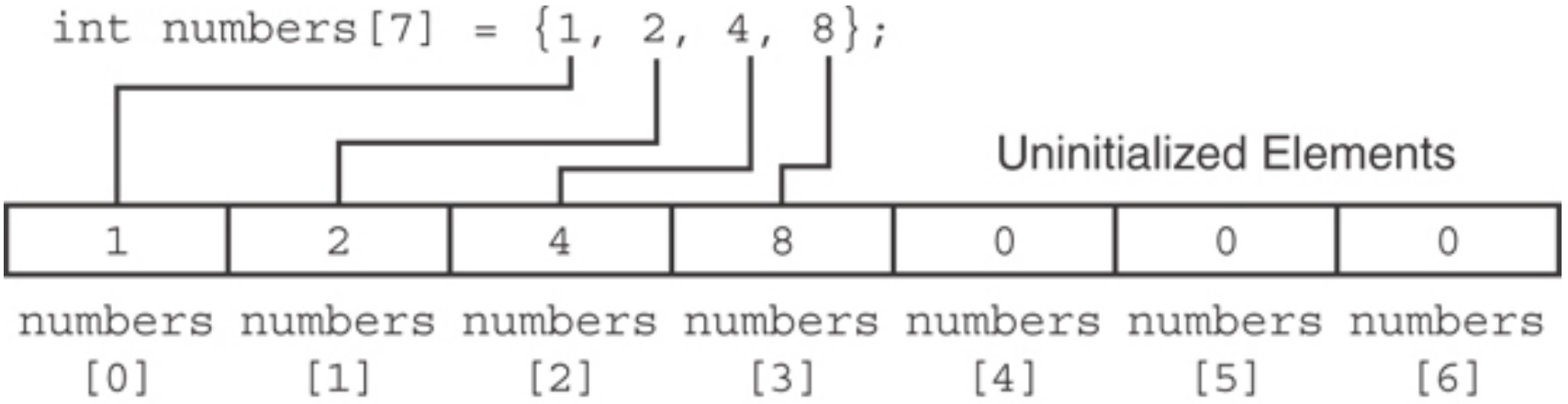
```
7     const int MONTHS = 12;
8     int days[MONTHS] = { 31, 28, 31, 30,
9                          31, 30, 31, 31,
10                         30, 31, 30, 31};
11
12    for (int count = 0; count < MONTHS; count++)
13    {
14       cout << "Month " << (count + 1) << " has ";
15       cout << days[count] << " days.\n";
16    }
```

Program Output

```
Month 1 has 31 days.
Month 2 has 28 days.
Month 3 has 31 days.
Month 4 has 30 days.
Month 5 has 31 days.
Month 6 has 30 days.
Month 7 has 31 days.
Month 8 has 31 days.
Month 9 has 30 days.
Month 10 has 31 days.
Month 11 has 30 days.
Month 12 has 31 days.
```

Partial Array Initialization

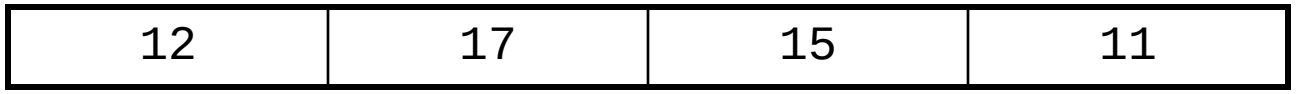
- If array is initialized with fewer initial values than the size declarator, the remaining elements will be set to `0`:



Implicit Array Sizing

- Can determine array size by the size of the initialization list:

```
int quizzes[]={12,17,15,11};
```



- Must use either array size declarator or initialization list at array definition

Processing Array Contents

- Array elements can be treated as ordinary variables of the same type as the array

- When using `++`, `--` operators, don't confuse the element with the subscript:

```
tests[i]++; // add 1 to tests[i]
tests[i++]; // increment i, no
            // effect on tests
```

Array Assignment

To copy one array to another,

- Don’t try to assign one array to the other:

```
newTests = tests;  // Won't work
```

- Instead, assign element-by-element:

```
for (i = 0; i < ARRAY_SIZE; i++)
   newTests[i] = tests[i];
```

Printing the Contents of an Array

- You can display the contents of a *character* array by sending its name to cout:

```
char fName[] = "Henry";
cout << fName << endl;
```

But, this ONLY works with character arrays!

Printing the Contents of an Array

- For other types of arrays, you must print element-by-element:

```
for (i = 0; i < ARRAY_SIZE; i++)
   cout << tests[i] << endl;
```

Summing and Averaging Array Elements

- Use a simple loop to add together array elements:

```
int tnum;
double average, sum = 0;
for(tnum = 0; tnum < SIZE; tnum++)
      sum += tests[tnum];
```

- Once summed, can compute average:

```
average = sum / SIZE;
```

Finding the Highest Value in an Array

```
int count;
int highest;
highest = numbers[0];
for (count = 1; count < SIZE; count++)
{
   if (numbers[count] > highest)
      highest = numbers[count];
}
```

When this code is finished, the `highest` variable will contains the highest value in the `numbers` array.

Finding the Lowest Value in an Array

```
int count;
int lowest;
lowest = numbers[0];
for (count = 1; count < SIZE; count++)
{
   if (numbers[count] < lowest)
      lowest = numbers[count];
}
```

When this code is finished, the `lowest` variable will contains the lowest value in the `numbers` array.

Comparing Arrays

- To compare two arrays, you must compare element-by-element:

```
const int SIZE = 5;
int firstArray[SIZE] = { 5, 10, 15, 20, 25 };
int secondArray[SIZE] = { 5, 10, 15, 20, 25 };
bool arraysEqual = true; // Flag variable
int count = 0;           // Loop counter variable
// Compare the two arrays.
while (arraysEqual && count < SIZE)
{
   if (firstArray[count] != secondArray[count])
      arraysEqual = false;
   count++;
}
if (arraysEqual)
   cout << "The arrays are equal.\n";
else
   cout << "The arrays are not equal.\n";
```

Using Parallel Arrays

- Parallel arrays: two or more arrays that contain related data
- A subscript is used to relate arrays: elements at same subscript are related
- Arrays may be of different types

Parallel Array Example

```
const int SIZE = 5;   // Array size
int id[SIZE];         // student ID
double average[SIZE]; // course average
char grade[SIZE];     // course grade
...
for(int i = 0; i < SIZE; i++)
{
   cout << "Student ID: " << id[i]
        << " average: " << average[i]
        << " grade: " << grade[i]
        << endl;
}
```

Group Activity

- Write C++ program to read an array of 10 integers, then:
- Print the elements in reverse order.
- Find how many even numbers of these elements.
- Multiply the elements by 5, then display the array elements.

Arrays as Function Arguments

- To pass an array to a function, just use the array name:

```
showScores(tests);
```

- To define a function that takes an array parameter, use empty [] for array argument:

```
void showScores(int []);
                // function prototype
void showScores(int tests[])
                // function header
```

Arrays as Function Arguments

- When passing an array to a function, it is common to pass array size so that function knows how many elements to process:

```
showScores(tests, ARRAY_SIZE);
```

- Array size must also be reflected in prototype, header:

```
void showScores(int [], int);
                // function prototype
void showScores(int tests[], int size)
                // function header
```

Passing an Array to a Function in Program 7-17

Program 7-17

```
1  // This program demonstrates an array being passed to a function.
2  #include <iostream>
3  using namespace std;
4
5  void showValues(int [], int); // Function prototype
6
7  int main()
8  {
9     const int ARRAY_SIZE = 8;
10    int numbers[ARRAY_SIZE] = {5, 10, 15, 20, 25, 30, 35, 40};
11
12    showValues(numbers, ARRAY_SIZE);
13    return 0;
14 }
15
```

(Program Continues)

Passing an Array to a Function in Program 7-17

```
16  //*********************************************
17  // Definition of function showValue.          *
18  // This function accepts an array of integers and  *
19  // the array's size as its arguments. The contents *
20  // of the array are displayed.                *
21  //*********************************************
22
23  void showValues(int nums[], int size)
24  {
25     for (int index = 0; index < size; index++)
26        cout << nums[index] << " ";
27     cout << endl;
28  }
```

Program Output

```
5 10 15 20 25 30 35 40
```

Modifying Arrays in Functions

- Array names in functions are like reference variables – changes made to array in a function are reflected in actual array in calling function

Activity

- Write a function average that receives an array of integers and its size then it returns the average of the elements in this array.

Two-Dimensional Arrays

- Can define one array for multiple sets of data
- Like a table in a spreadsheet
- Use two size declarators in definition:

```
const int ROWS = 4, COLS = 3;
int exams[ROWS][COLS];
```

- First declarator is number of rows; second is number of columns

Two-Dimensional Array Representation

```
const int ROWS = 4, COLS = 3;
int exams[ROWS][COLS];
```

columns

rows

exams[0][0]	exams[0][1]	exams[0][2]
exams[1][0]	exams[1][1]	exams[1][2]
exams[2][0]	exams[2][1]	exams[2][2]
exams[3][0]	exams[3][1]	exams[3][2]

- Use two subscripts to access element:

```
exams[2][2] = 86;
```

2D Array Initialization

- Two-dimensional arrays are initialized row-by-row:

```
const int ROWS = 2, COLS = 2;
int exams[ROWS][COLS] = { {84, 78},
                          {92, 97} };
```

84	78
92	97

- Can omit inner `{ }`, some initial values in a row – array elements without initial values will be set to `0` or `NULL`

Summing All the Elements in a Two-Dimensional Array

- Given the following definitions:

```
const int NUM_ROWS = 5; // Number of rows
const int NUM_COLS = 5; // Number of columns
int total = 0;          // Accumulator
int numbers[NUM_ROWS][NUM_COLS] =
   {{2, 7, 9, 6, 4},
    {6, 1, 8, 9, 4},
    {4, 3, 7, 2, 9},
    {9, 9, 0, 3, 1},
    {6, 2, 7, 4, 1}};
```

Summing All the Elements in a Two-Dimensional Array

```
// Sum the array elements.
for (int row = 0; row < NUM_ROWS; row++)
{
   for (int col = 0; col < NUM_COLS; col++)
      total += numbers[row][col];
}

// Display the sum.
cout << "The total is " << total << endl;
```