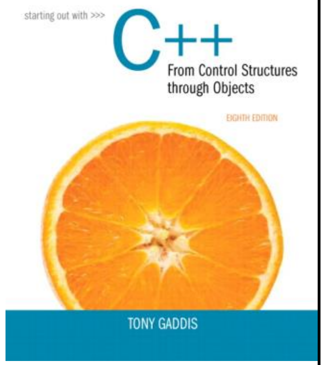
Chapter 7:

Arrays



7.1

Arrays Hold Multiple Values

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:

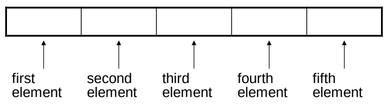
```
int tests[5];
```

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 size declarator. It shows the number of elements in the array.
- The size of an array is (number of elements) * (size of each element)

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];
```

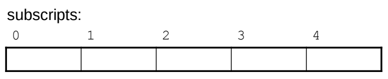
- This eases program maintenance when the size of the array needs to be changed.

7.2

Accessing Array Elements

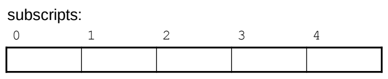
Accessing Array Elements

- 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

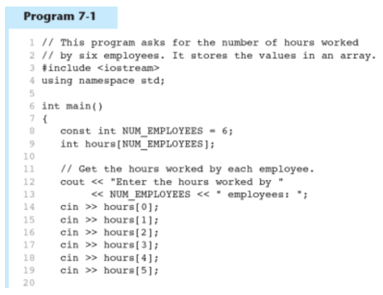
- Array elements can be used as regular variables:

```
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

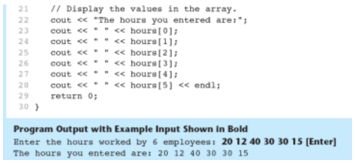


Program 7-1

```
// This program asks for the number of hours worked
// by six employees. It stores the values in an array.
#include <iostream>
using namespace std;

int main()
{
   const int NUM_EMPLOYEES = 6;
   int hours[NUM_EMPLOYEES];

   // Get the hours worked by each employee.
   cout << "Enter the hours worked by "
        << NUM_EMPLOYEES << " employees: ";
   cin >> hours[0];
   cin >> hours[1];
   cin >> hours[2];
   cin >> hours[3];
   cin >> hours[4];
   cin >> hours[5];

```

(Program Continues)

Accessing Array Elements in Program 7-1

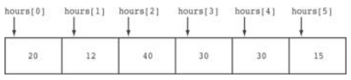


```
    // Display the values in the array.
    cout << "The hours you entered are:";
    cout << " " << hours[0];
    cout << " " << hours[1];
    cout << " " << hours[2];
    cout << " " << hours[3];
    cout << " " << hours[4];
    cout << " " << hours[5] << endl;
    return 0;
}
```

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:

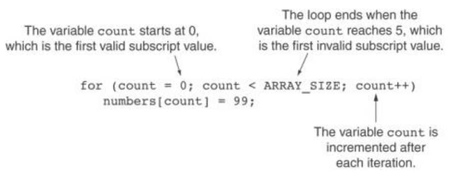
```
int i = 5;
cout << tests[i] << endl;
```

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


The variable count starts at 0, which is the first valid subscript value.
The loop ends when the variable count reaches 5, which is the first invalid subscript value.
The variable count is incremented after each iteration.

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

Default Initialization

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

7.3

No Bounds Checking in C++

No Bounds Checking in C++

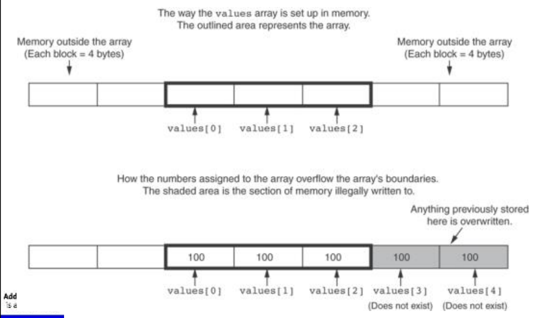
- When you use a value as an array subscript, C++ does not check it to make sure it is a *valid* subscript.
- In other words, you can use subscripts that are beyond the bounds of the array.

Code From Program 7-5

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

```
const int SIZE = 3;   // Constant for the array size
int values[SIZE];     // An array of 3 integers
int count;            // Loop counter variable

// Attempt to store five numbers in the three-element array.
cout << "I will store 5 numbers in a 3 element array!\n";
for (count = 0; count < 5; count++)
   values[count] = 100;
```

What the Code Does


The way the values array is set up in memory.
The outlined area represents the array.
Memory outside the array
(Each block = 4 bytes)
Memory outside the array
(Each block = 4 bytes)
values[0]
values[1]
values[2]
How the numbers assigned to the array overflow the array's boundaries.
The shaded area is the section of memory illegally written to.
Anything previously stored
here is overwritten.
100
100
100
100
100
values[0]
values[1]
values[2]
values[3]
(Does not exist)
values[4]
(Does not exist)

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;
```

7.4

Array Initialization

Array Initialization

- Arrays can be initialized with an <u>initialization list</u>:

```
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

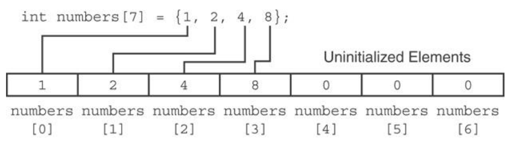
```
const int MONTHS = 12;
int days[MONTHS] = { 31, 28, 31, 30,
                     31, 30, 31, 31,
                     30, 31, 30, 31};

for (int count = 0; count < MONTHS; count++)
{
   cout << "Month " << (count + 1) << " has ";
   cout << days[count] << " days.\n";
}
```

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

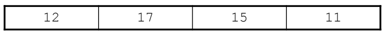
- If array is initialized with fewer initial values than the size declarator, the remaining elements will be set to `0`:



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

7.5

The Range-Based `for` Loop

The Range-Based `for` Loop

- C++ 11 provides a specialized version of the `for` loop that, in many circumstances, simplifies array processing.
- *The range-based `for` loop is a loop that iterates once for each element in an array.*
- *Each time the loop iterates, it copies an element from the array to a built-in variable, known as the range variable.*
- The range-based `for` loop automatically knows the number of elements in an array.
  - You do not have to use a counter variable.
  - You do not have to worry about stepping outside the bounds of the array.

The Range-Based `for` Loop

- Here is the general format of the range-based for loop:

```
for (dataType rangeVariable : array)
            statement;
```

- ***dataType*** is the data type of the range variable.
- ***rangeVariable*** is the name of the range variable. This variable will receive the value of a different array element during each loop iteration.
- ***array*** is the name of an array on which you wish the loop to operate.
- ***statement*** is a statement that executes during a loop iteration. If you need to execute more than one statement in the loop, enclose the statements in a set of braces.

The range-based `for` loop in Program 7-10

```
// This program demonstrates the range-based for loop.
#include <iostream>
using namespace std;

int main()
{
   // Define an array of integers.
   int numbers[] = { 10, 20, 30, 40, 50 };

   // Display the values in the array.
   for (int val : numbers)
      cout << val << endl;

   return 0;
}
```

Modifying an Array with a Range-Based `for` Loop

- As the range-based `for` loop executes, its range variable contains only a copy of an array element.
- You cannot use a range-based `for` loop to modify the contents of an array unless you declare the range variable as a reference.
- To declare the range variable as a reference variable, simply write an ampersand (`&`) in front of its name in the loop header.
- Program 7-12 demonstrates

Modifying an Array with a Range-Based `for` Loop in Program 7-12

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

// Get values for the array.
for (int &val : numbers)
{
   cout << "Enter an integer value: ";
   cin >> val;
}

// Display the values in the array.
cout << "Here are the values you entered:\n";
for (int val : numbers)
   cout << val << endl;
```

Modifying an Array with a Range-Based `for` Loop

You can use the `auto` key word with a reference range variable. For example, the code in lines 12 through 16 in Program 7-12 could have been written like this:

```
for (auto &val : numbers)
{
   cout << "Enter an integer value: ";
   cin >> val;
}
```

The Range-Based `for` Loop versus the Regular `for` Loop

- The range-based for loop can be used in any situation where you need to step through the elements of an array, and you do not need to use the element subscripts.
- If you need the element subscript for some purpose, use the regular `for` loop.

7.6

Processing Array Contents

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;
```

Printing the Contents of an Array

- In C++ 11 you can use the range-based `for` loop to display an array's contents, as shown here:

```
for (int val : numbers)
   cout << val << 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;
```

Summing and Averaging Array Elements

- In C++ 11 you can use the range-based `for` loop, as shown here:

```
double total = 0;  // Initialize accumulator
double average;    // Will hold the average
for (int val : scores)
    total += val;
average = total / NUM_SCORES;
```

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.

Partially-Filled Arrays

- If it is unknown how much data an array will be holding:
  - Make the array large enough to hold the largest expected number of elements.
  - Use a counter variable to keep track of the number of items stored in the 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";
```

7.7

Using Parallel Arrays

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;
}
```

Parallel Arrays in Program 7-15

Program 7-15

```
// This program uses two parallel arrays: one for hours
// worked and one for pay rate.
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
   const int NUM_EMPLOYEES = 5;   // Number of employees
   int hours[NUM_EMPLOYEES];      // Holds hours worked
   double payRate[NUM_EMPLOYEES]; // Holds pay rates

   // Input the hours worked and the hourly pay rate.
   cout << "Enter the hours worked by " << NUM_EMPLOYEES
        << " employees and their\n"
        << "hourly pay rates.\n";
   for (int index = 0; index < NUM_EMPLOYEES; index++)
   {
      cout << "Hours worked by employee #" << (index+1) << ": ";
      cin >> hours[index];
      cout << "Hourly pay rate for employee #" << (index+1) << ": ";
      cin >> payRate[index];
   }

```

(Program Continues)

Parallel Arrays in Program 7-15

```
   // Display each employee's gross pay.
   cout << "Here is the gross pay for each employee:\n";
   cout << fixed << showpoint << setprecision(2);
   for (int index = 0; index < NUM_EMPLOYEES; index++)
   {
      double grossPay = hours[index] * payRate[index];
      cout << "Employee #" << (index + 1);
      cout << ": $" << grossPay << endl;
   }
   return 0;
}
```

Program Output with Example Input Shown in Bold

```
Enter the hours worked by 5 employees and their
hourly pay rates.
Hours worked by employee #1: 10 [Enter]
Hourly pay rate for employee #1: 9.75 [Enter]
Hours worked by employee #2: 15 [Enter]
Hourly pay rate for employee #2: 8.62 [Enter]
Hours worked by employee #3: 20 [Enter]
Hourly pay rate for employee #3: 10.50 [Enter]
Hours worked by employee #4: 40 [Enter]
Hourly pay rate for employee #4: 18.75 [Enter]
Hours worked by employee #5: 40 [Enter]
Hourly pay rate for employee #5: 15.65 [Enter]
```

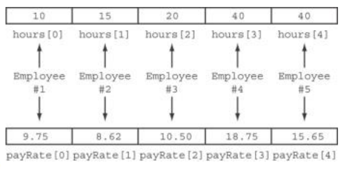
(program output continues)

Parallel Arrays in Program 7-15

Program 7-15 *(continued)*

```
Here is the gross pay for each employee:
Employee #1: $97.50
Employee #2: $129.30
Employee #3: $210.00
Employee #4: $750.00
Employee #5: $626.00
```

The `hours` and `payRate` arrays are related through their subscripts:



7.8

Arrays as Function Arguments

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

```
// This program demonstrates an array being passed to a function.
#include <iostream>
using namespace std;

void showValues(int [], int); // Function prototype

int main()
{
   const int ARRAY_SIZE = 8;
   int numbers[ARRAY_SIZE] = {5, 10, 15, 20, 25, 30, 35, 40};

   showValues(numbers, ARRAY_SIZE);
   return 0;
}

```

(Program Continues)

Passing an Array to a Function in Program 7-17

```
//**************************************************
// Definition of function showValue.               *
// This function accepts an array of integers and  *
// the array's size as its arguments. The contents *
// of the array are displayed.                     *
//**************************************************

void showValues(int nums[], int size)
{
   for (int index = 0; index < size; index++)
      cout << nums[index] << " ";
   cout << endl;
}
```

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

- Need to exercise caution that array is not inadvertently changed by a function

7.9

Two-Dimensional Arrays

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];
```

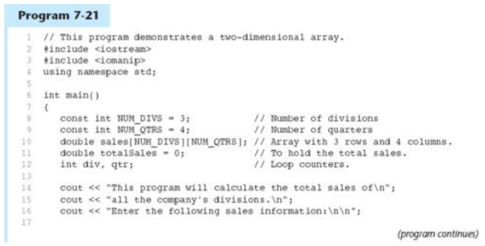
columns

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;
```

A Two-dimensional Array in Program 7-21

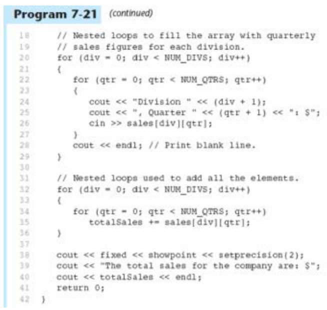


Program 7-21

```
// This program demonstrates a two-dimensional array.
#include <iostream>
#include <iomanip>
using namespace std;

int main()
{
   const int NUM_DIVS = 3;            // Number of divisions
   const int NUM_QTRS = 4;            // Number of quarters
   double sales[NUM_DIVS][NUM_QTRS]; // Array with 3 rows and 4 columns.
   double totalSales = 0;             // To hold the total sales.
   int div, qtr;                      // Loop counters.

   cout << "This program will calculate the total sales of\n";
   cout << "all the company's divisions.\n";
   cout << "Enter the following sales information:\n\n";

```

(program continues)

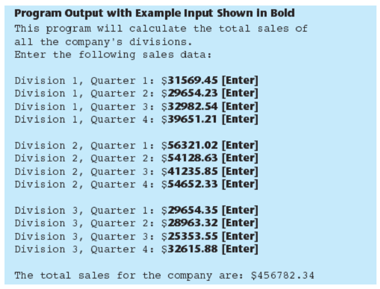
A Two-dimensional Array in Program 7-21



Program 7-21 *(continued)*

```
   // Nested loops to fill the array with quarterly
   // sales figures for each division.
   for (div = 0; div < NUM_DIVS; div++)
   {
      for (qtr = 0; qtr < NUM_QTRS; qtr++)
      {
         cout << "Division " << (div + 1);
         cout << ", Quarter " << (qtr + 1) << ": $";
         cin >> sales[div][qtr];
      }
      cout << endl; // Print blank line.
   }

   // Nested loops used to add all the elements.
   for (div = 0; div < NUM_DIVS; div++)
   {
      for (qtr = 0; qtr < NUM_QTRS; qtr++)
         totalSales += sales[div][qtr];
   }

   cout << fixed << showpoint << setprecision(2);
   cout << "The total sales for the company are: $";
   cout << totalSales << endl;
   return 0;
}
```

A Two-dimensional Array in Program 7-21



Program Output with Example Input Shown in Bold

```
This program will calculate the total sales of
all the company's divisions.
Enter the following sales data:

Division 1, Quarter 1: $31569.45 [Enter]
Division 1, Quarter 2: $29654.23 [Enter]
Division 1, Quarter 3: $32982.54 [Enter]
Division 1, Quarter 4: $39651.21 [Enter]

Division 2, Quarter 1: $56321.02 [Enter]
Division 2, Quarter 2: $54128.63 [Enter]
Division 2, Quarter 3: $41235.85 [Enter]
Division 2, Quarter 4: $54652.33 [Enter]

Division 3, Quarter 1: $29654.35 [Enter]
Division 3, Quarter 2: $28963.32 [Enter]
Division 3, Quarter 3: $25353.55 [Enter]
Division 3, Quarter 4: $32615.88 [Enter]

The total sales for the company are: $456782.34
```

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`

Two-Dimensional Array as Parameter, Argument

- Use array name as argument in function call:

```
getExams(exams, 2);
```

- Use empty `[]` for row, size declarator for column in prototype, header:

```
const int COLS = 2;
// Prototype
void getExams(int [][COLS], int);

// Header
void getExams(int exams[][COLS], int rows)
```

Example – The `showArray` Function from Program 7-22

```
//*****************************************************************
// Function Definition for showArray                              *
// The first argument is a two-dimensional int array with COLS    *
// columns. The second argument, rows, specifies the number of    *
// rows in the array. The function displays the array's contents. *
//*****************************************************************

void showArray(int array[][COLS], int rows)
{
   for (int x = 0; x < rows; x++)
   {
      for (int y = 0; y < COLS; y++)
      {
         cout << setw(4) << array[x][y] << " ";
      }
      cout << endl;
   }
}
```

How `showArray` is Called

```
int table1[TBL1_ROWS][COLS] = {{1, 2, 3, 4},
                               {5, 6, 7, 8},
                               {9, 10, 11, 12}};
int table2[TBL2_ROWS][COLS] = {{10, 20, 30, 40},
                               {50, 60, 70, 80},
                               {90, 100, 110, 120},
                               {130, 140, 150, 160}};

cout << "The contents of table1 are:\n";
showArray(table1, TBL1_ROWS);
cout << "The contents of table2 are:\n";
showArray(table2, TBL2_ROWS);
```

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;
```

Summing the Rows of a Two-Dimensional Array

- Given the following definitions:

```
const int NUM_STUDENTS = 3;
const int NUM_SCORES = 5;
double total;   // Accumulator
double average; // To hold average scores
double scores[NUM_STUDENTS][NUM_SCORES] =
     {{88, 97, 79, 86, 94},
      {86, 91, 78, 79, 84},
      {82, 73, 77, 82, 89}};
```

Summing the Rows of a Two-Dimensional Array

```
// Get each student's average score.
for (int row = 0; row < NUM_STUDENTS; row++)
{
   // Set the accumulator.
   total = 0;
   // Sum a row.
   for (int col = 0; col < NUM_SCORES; col++)
      total += scores[row][col];
   // Get the average
   average = total / NUM_SCORES;
   // Display the average.
   cout << "Score average for student "
        << (row + 1) << " is " << average <<endl;
}
```

Summing the Columns of a Two-Dimensional Array

- Given the following definitions:

```
const int NUM_STUDENTS = 3;
const int NUM_SCORES = 5;
double total;   // Accumulator
double average; // To hold average scores
double scores[NUM_STUDENTS][NUM_SCORES] =
     {{88, 97, 79, 86, 94},
      {86, 91, 78, 79, 84},
      {82, 73, 77, 82, 89}};
```

Summing the Columns of a Two-Dimensional Array

```
// Get the class average for each score.
for (int col = 0; col < NUM_SCORES; col++)
{
   // Reset the accumulator.
   total = 0;
   // Sum a column
   for (int row = 0; row < NUM_STUDENTS; row++)
      total += scores[row][col];
   // Get the average
   average = total / NUM_STUDENTS;
   // Display the class average.
   cout << "Class average for test " << (col + 1)
        << " is " << average << endl;
}
```

7.10

Arrays with Three or More Dimensions

Arrays with Three or More Dimensions

- Can define arrays with any number of dimensions:

```
short rectSolid[2][3][5];
double timeGrid[3][4][3][4];
```

- When used as parameter, specify all but 1st dimension in prototype, heading:

```
void getRectSolid(short [][3][5]);
```

7.12

Introduction to the STL `vector`

Introduction to the STL `vector`

- A data type defined in the Standard Template Library (covered more in Chapter 16)
- Can hold values of any type:
  `vector<int> scores;`
- Automatically adds space as more is needed – no need to determine size at definition
- Can use `[]` to access elements

Declaring Vectors

- You must `#include<vector>`
- Declare a vector to hold `int` element:
  `vector<int> scores;`
- Declare a vector with initial size 30:
  `vector<int> scores(30);`
- Declare a vector and initialize all elements to 0:
  `vector<int> scores(30, 0);`
- Declare a vector initialized to size and contents of another vector:
  `vector<int> finals(scores);`

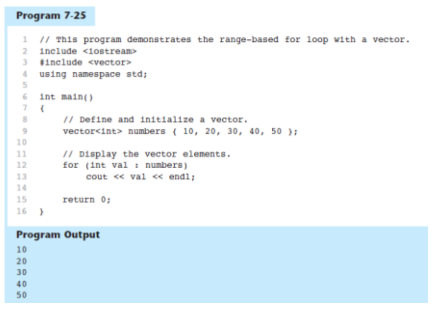
Adding Elements to a Vector

- If you are using C++ 11, you can initialize a vector with a list of values:
  `vector<int> numbers { 10, 20, 30, 40 };`
- Use `push_back` member function to add element to a full array or to an array that had no defined size:
  `scores.push_back(75);`
- Use `size` member function to determine size of a vector:
  `howbig = scores.size();`

Removing Vector Elements

- Use `pop_back` member function to remove last element from vector:
  `scores.pop_back();`
- To remove all contents of vector, use `clear` member function:
  `scores.clear();`
- To determine if vector is empty, use `empty` member function:
  `while (!scores.empty()) ...`

Using the Range-Based `for` Loop with a vector in C++ 11

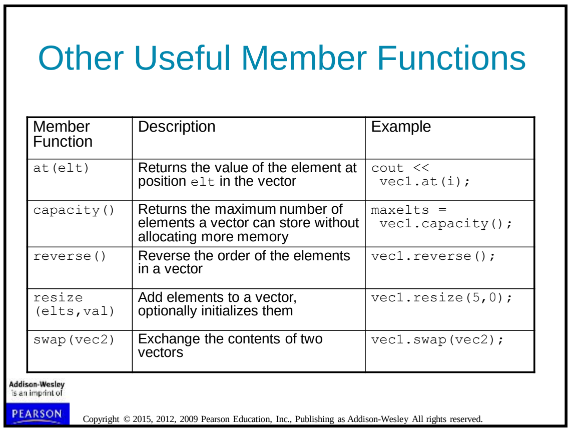


Program 7-25

```
// This program demonstrates the range-based for loop with a vector.
include <iostream>
#include <vector>
using namespace std;

int main()
{
    // Define and initialize a vector.
    vector<int> numbers { 10, 20, 30, 40, 50 };

    // Display the vector elements.
    for (int val : numbers)
        cout << val << endl;

    return 0;
}
```

Program Output

```
10
20
30
40
50
```



Other Useful Member Functions

Member Function	Description	Example
`at(elt)`	Returns the value of the element at position `elt` in the vector	`cout << vec1.at(i);`
`capacity()`	Returns the maximum number of elements a vector can store without allocating more memory	`maxelts = vec1.capacity();`
`reverse()`	Reverse the order of the elements in a vector	`vec1.reverse();`
`resize (elts,val)`	Add elements to a vector, optionally initializes them	`vec1.resize(5,0);`
`swap(vec2)`	Exchange the contents of two vectors	`vec1.swap(vec2);`