Chapter 8: Arrays

Starting Out with C++
Early Objects
Ninth Edition

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Topics

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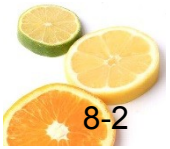

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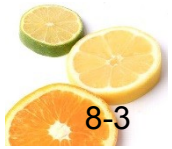
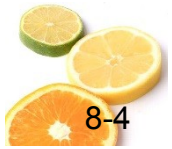


8.1 Arrays Hold Multiple Values

- Array: a variable that can store multiple values of the same type
- The values are stored in consecutive memory locations
- It is declared using `[]` operator

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

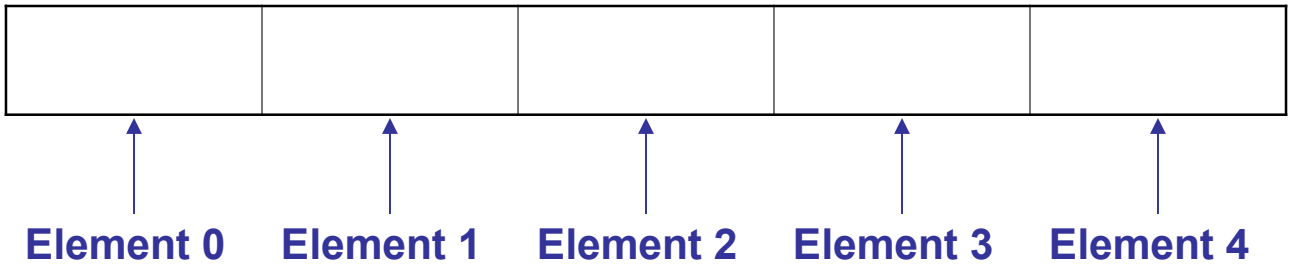


Array Storage in Memory

The definition

```
int tests[ISIZE];  // ISIZE is 5
```

allocates the following memory

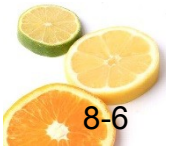


Array Terminology

In the definition `int tests[ISIZE];`

- **`int`** is the data type of the array elements
- **`tests`** is the name of the array
- **`ISIZE`**, in **`[ISIZE]`**, is the size declarator. It shows the number of elements in the array.
- The size of an array is the number of bytes allocated for it

*(number of elements) * (bytes needed for each element)*

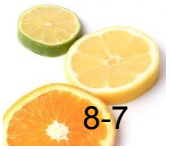


Array Terminology Examples

Examples:

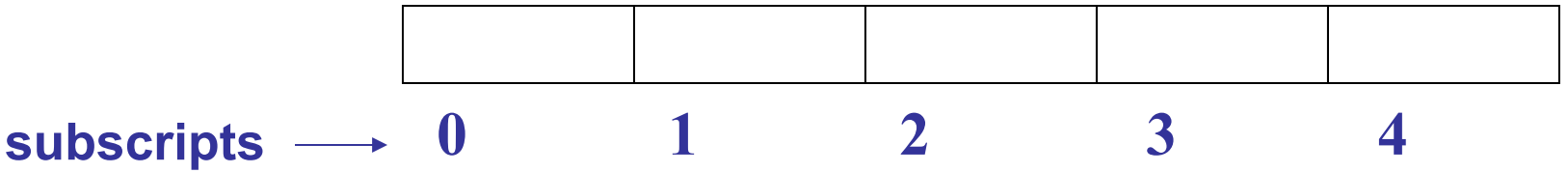
Assumes **`int`** uses 4 bytes and **`double`** uses 8 bytes

```
const int ISIZE = 5, DSIZE = 10;
int tests[ISIZE]; // holds 5 ints, array
                  // occupies 20 bytes
double volumes[DSIZE];// holds 10 doubles,
                      // array occupies
                        // 80 bytes
```



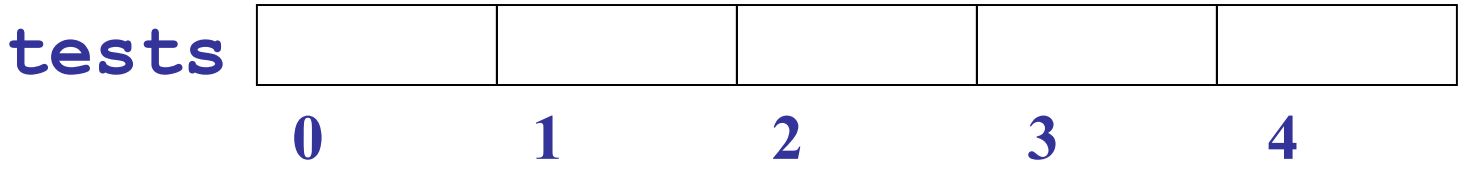
8.2 Accessing Array Elements

- Each array element has a subscript, used to access the element.
- Subscripts start at 0



Accessing Array Elements

Array elements (accessed by array name and subscript) can be used as regular variables

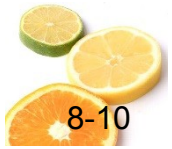



```
tests[0] = 79;
cout << tests[0];
cin  >> tests[1];
tests[4] = tests[0] + tests[1];
cout << tests; // illegal due to
               // missing subscript
```

8.3 Inputting and Displaying Array Contents

cout and **cin** can be used to display values from and store values into an array

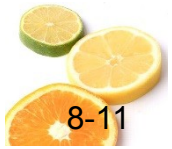
```
const int ISIZE = 5;

int tests[ISIZE]; // Define 5-elt. array
cout << "Enter first test score ";
cin  >>  tests[0];
```



Array Subscripts

- Array subscript can be an integer constant, integer variable, or integer expression
- Examples:

	Subscript is
`cin >> tests[3];`	int constant
`cout << tests[i];`	int variable
`cout << tests[i+j];`	int expression

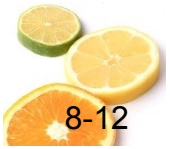


Accessing All Array Elements

To access each element of an array

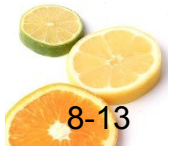
- Use a loop
- Let the loop control variable be the array subscript
- A different array element will be referenced each time through the loop

```
for (i = 0; i < 5; i++)
    cout << tests[i] << endl;
```



Getting Array Data from a File

```
const int ISIZE = 5;
int sales[ISIZE];
ifstream dataFile;
dataFile.open("sales.dat");
if (!dataFile)
   cout << "Error opening data file\n";
else  // Input daily sales
{  for (int day = 0; day < ISIZE; day++)
      dataFile >> sales[day];
   dataFile.close();
}
```



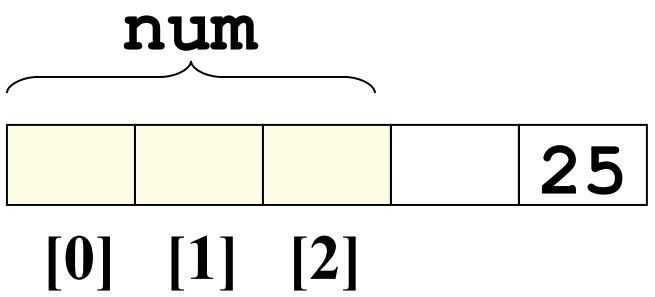
Sending Array Data to a File

- Open the file using an **`ofstream`** object
- Use a loop to write each array element to the file
- Close the file

No Bounds Checking

- There are no checks in C++ that an array subscript is in range
- An invalid array subscript can cause the program to overwrite other memory
- Example:

```
const int ISIZE = 3;
int i = 4;
int num[ISIZE];
num[i] = 25;
```



Off-By-One Errors

- These most often occur when a program accesses data one position beyond the end of an array, or misses the first or last element of an array.

- If an array has size **`n`**, then the subscripts range from `0` to **`n-1`**

8.4 Array Initialization

- An array can be initialized during program execution with assignment statements

```
tests[0] = 79;
tests[1] = 82; // etc.
```

- It can be initialized at array definition with an initialization list

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

Start at element 0 or 1?

- You may choose to declare arrays to be one larger than needed. This allows you to use the element with subscript 1 as the 'first' element, etc., and may minimize off-by-one errors.
- The element with subscript 0 is not used.
- This is most often done when working with ordered data, *e.g.*, months of the year or days of the week

Partial Array Initialization

- If array is initialized at definition with fewer values than the size declarator of the array, the remaining elements will be set to 0 or the empty string

```
int tests[ISIZE] = {79, 82};
```

79	82	0	0	0

- Initial values are used in order; you cannot skip over elements to initialize a noncontiguous range
- You cannot have more values in the initialization list than the declared size of the array

Implicit Array Sizing

- C++ can determine the array size by the size of the initialization list

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

12	17	15	11

- You must use either array size declarator or an initialization list when the array is defined

Alternate Ways to Initialize Variables

- You can initialize a variable at definition time using a functional notation

```
int length(12);  // same result as
                 // int length = 12;
```

- In C++ 11 and higher, you can also do this:

```
int length{12};
```

- The second approach checks the argument to ensure that it matches the data type of the variable, and will generate a compiler error if not

8.5 The Range-Based `for` Loop

- NOTE: This is a C++ 11 feature
- This is a loop that can simplify array processing.
- It uses a variable that will hold a different array element for each iteration
- Format:

```
for (data_type var : array)
  statement;
```

- **`data_type`** : the type of the variable
- **`var`**: the variable
- **`statement;`** : the loop body

Range-Based `for` Loop - Details

- **`data_type`** must be the type of the array elements, or a type that the array elements can be automatically converted to
- **`var`** will hold the value of successive array elements as the loop iterates. Each array element is processed in the loop
- **`statement;`** can be a single statement or a block of statements enclosed in { }

Range-Based `for` Loop - Example

```
// sum the elements of an array
int [] grades = {68,84,75};
int sum = 0;
for (int score : grades)
   sum += score;
```

Range-Based `for` Loop - Example

```
// modify the contents of an array
const int ISIZE = 3;
int [ISIZE] grades;
for (int &score : grades)
{
   cout << "Enter a score: ";
   cin >> score;
}
```

Comparison: Range-Based `for` Loop vs. Regular `for` Loop

- The range-based `for` loop provides a simple notation to use to process all of the elements of an array.
- However, it does not give you access to the subscripts of the array elements.
- If you need to know the element locations as well as the element values, then use a regular `for` loop.

8.6 Processing Array Contents

- Array elements can be
  - treated as ordinary variables of the same type as the array
  - used in arithmetic operations, in relational expressions, etc.
- Example:

```
if (principalAmt[3] >= 10000)
  interest = principalAmt[3] * intRate1;
else
  interest = principalAmt[3] * intRate2;
```

Using Increment and Decrement Operators with Array Elements

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

```
tests[i]++;  // adds 1 to tests[i]
tests[i++];  // increments i, but has
             // no effect on tests
```

Copying One Array to Another

- You cannot copy with an assignment statement:

```
tests2 = tests;  //won't work
```

- You must instead use a loop to copy element-by-element:

```
for (int indx=0; indx < ISIZE; indx++)
   tests2[indx] = tests[indx];
```

Are Two Arrays Equal?

- Like copying, you cannot compare two arrays in a single expression:

```
if (tests2 == tests)
```

- You can use a while loop with a **bool** variable:

```
bool areEqual=true;
int indx=0;
while (areEqual && indx < ISIZE)
{
   if(tests[indx] != tests2[indx]
      areEqual = false;
   indx++;
}
```

Find the Sum, Average of Array Elements

- Use a simple loop to add together array elements

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

- Or use C++ 11 range-based **`for`** loop:

```
for (int num : tests)
    sum += num;
```

- Once summed, average can be computed

```
average = sum/ISIZE;
```

Find the Largest Array Element

- Use a loop to examine each element and find the largest element (*i.e.*, one with the largest value)

```
int largest = tests[0];
for (int tnum = 1; tnum < ISIZE; tnum++)
{  if (tests[tnum] > largest)
      largest = tests[tnum];
}
cout << "Highest score is " << largest;
```

- A similar algorithm exists to find the smallest element

Using Arrays vs. Using Simple Variables

- An array is probably not needed if the input data is only processed once:
  - Find the sum or average of a set of numbers
  - Find the largest or smallest of a set of values
- If the input data must be processed more than once, an array is probably a good idea:
  - Calculate the average, then determine and display which values are above the average, at the average, and below the average

Partially-Filled Arrays

- The exact amount of data (and, therefore, the array size) may not be known when a program is written.
- The programmer makes a best estimate for the maximum amount of data, then sizes arrays accordingly. A sentinel value can be used to indicate end-of-data.
- The programmer must also keep track of how many array elements are actually used

C-Strings and `string` Objects

They can be processed using the array name

- Entire string at once, or
- One element at a time by using a subscript

```
string city;
cout << "Enter city name: ";
cin  >> city;
```

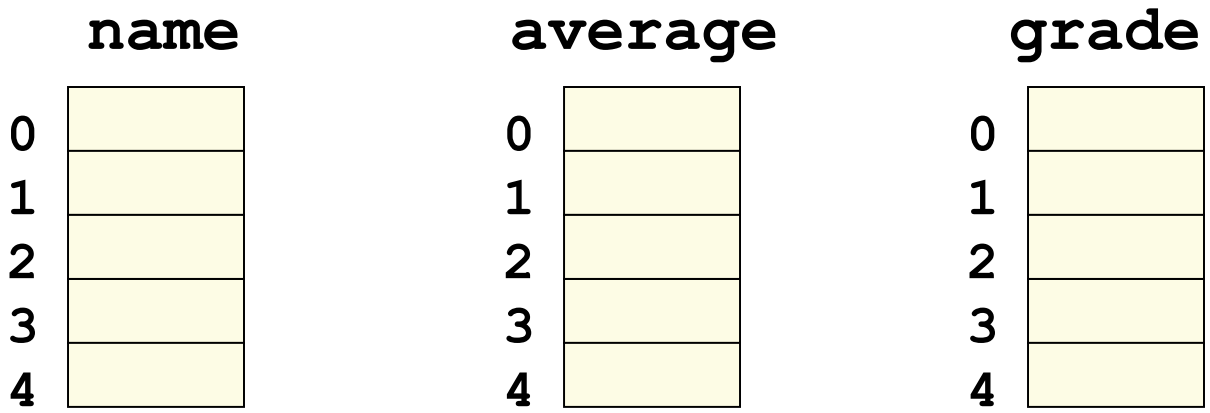
'S'	'a'	'l'	'e'	'm'
city[0]	city[1]	city[2]	city[3]	city[4]

8.7 Using Parallel Arrays

- Parallel arrays: two or more arrays that contain related data
- The subscript is used to relate arrays
  - elements at same subscript are related
- The arrays do not have to hold data of the same type

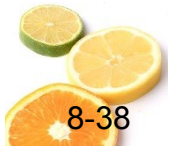
Parallel Array Example

```
const int ISIZE = 5;
string name[ISIZE];   // student name
float average[ISIZE]; // course average
char grade[ISIZE];    // course grade
```



Parallel Array Processing

```
const int ISIZE = 5;
string name[ISIZE];   // student name
float average[ISIZE]; // course average
char grade[ISIZE];    // course grade
...
for (int i = 0; i < ISIZE; i++)
     cout << " Student: " << name[i]
          << " Average: " << average[i]
          << " Grade: "   << grade[i]
          << endl;
```

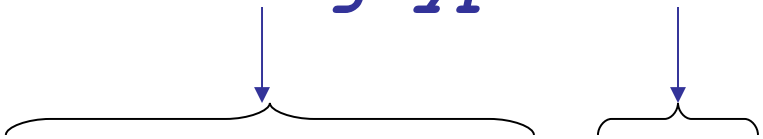


8.8 The `typedef` Statement

- Creates an alias for a simple or structured data type
- Format:

```
typedef existingType newName;
```

- Example:



```
typedef unsigned int Uint;
Uint tests[ISIZE]; // array of
                   // unsigned ints
```

Uses of `typedef`

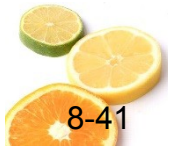
- It can be used to make code more readable
- Can be used to create an alias for an array of a particular type

```
// Define yearArray as a data type
// that is an array of 12 ints
typedef int yearArray[MONTHS];

// Create two of these arrays
yearArray highTemps, lowTemps;
```

8.9 Arrays as Function Arguments

- Passing a single array element to a function is no different than passing a regular variable of that data type
- The function does not need to know that the value it receives is coming from an array

```
displayValue(score[i]);      // call
void displayValue(int item) // header
{  cout << item << endl;
}
```



Passing an Entire Array

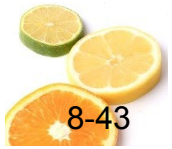
- To define a function that has an array parameter, use empty `[]` to indicate the array in the prototype and header
- To pass an array to a function, just use the array name

```
// Function prototype
void showScores(int []);

// Function header
void showScores(int tests[])

// Function call
showScores(tests);
```

Passing an Entire Array

- Use the array name, without any brackets, as the argument
- You can also pass the array size as a separate parameter so the function knows how many elements to process

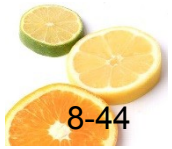
```
showScores(tests, 5);          // call
void showScores(int[], int); // prototype
void showScores(int A[],
                int size) // header
```



Using `typedef` with a Passed Array

You can use **`typedef`** to simplify function prototype and header

```
// Make intArray an integer array
// of unspecified size
typedef int intArray[];

// Function prototype
void showScores(intArray, int);

// Function header
void showScores(intArray tests,
                int size)
```



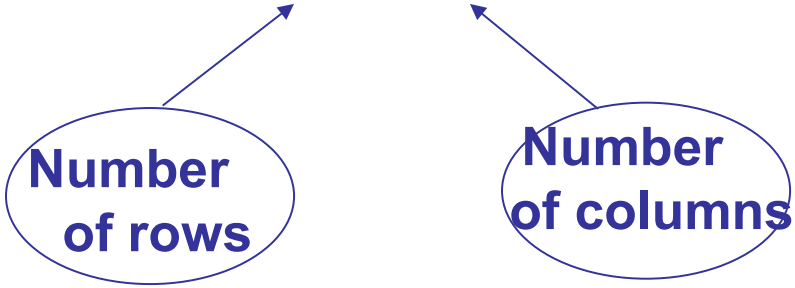
Modifying Arrays in Functions

- Array parameters in functions are similar to reference variables
- Changes made to array passed to a function are made to the actual array in the calling function
- The programmer must be careful that an array is not inadvertently changed by a function
- The `const` keyword can be used in prototype and header to prevent changes

8.10 Two-Dimensional Arrays

- You can define one array for multiple sets of data
- It is like a table in a spreadsheet
- Use two size declarators in definition

```
int exams[4][3];
```



Two-Dimensional Array Representation

```
int exams[4][3];
```

	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][1] = 86;
```

Two-Dimensional Array Access

When you use access an element of a two-dimensional array

```
exams[2][1] = 86;
```

- The first subscript, `[2]`, indicates the row in the array
- The second subscript, `[1]`, indicates the column in the array

Initialization at Definition

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

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

84	78
92	97

- Can omit inner `{ }`

Passing a Two-Dimensional Array to a Function

- Use the array name and the number of columns as arguments in the function call

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

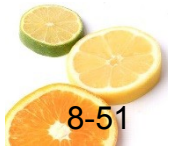
- Use empty `[]` for row and a size declarator for the number of columns in the prototype and header

```
// Prototype, where NUM_COLS is 2
void getExams(int[][NUM_COLS], int);

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

Using `typedef` with a Two-Dimensional Array

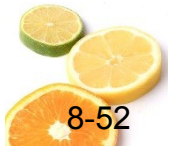
Can use `typedef` for simpler notation

```
typedef int intExams[][2];
   ...
// Function prototype
void getExams(intExams, int);

// Function header
void getExams(intExams exams, int rows)
```



Two-Dimensional Array Traversal

- Use nested loops, one for the row and one for the column, to visit each array element.
- Accumulators can be used to calculate the sum the elements row-by-row, column-by-column, or over the entire array.



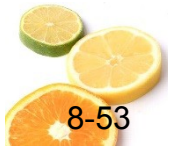
8.11 Arrays with Three or More Dimensions

- You can define arrays that have any number of dimensions

```
short rectSolid(2,3,5);
double timeGrid(3,4,3,4);
```

- When this type of array is used as a parameter, specify the size of all but the 1st dimension

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



8.12 Vectors

- A vector holds a set of elements, like a one-dimensional array
- It has a flexible number of elements. It can grow and shrink
  - There is no need to specify the size when defined
  - Space is automatically added as needed
- Defined in the Standard Template Library (STL)
  - Covered in a later chapter
- Must include **`vector`** header file to use vectors

```
#include <vector>
```

Vectors

- It can hold values of any data type, specified when the vector is defined

```
vector<int> scores;
vector<double> volumes;
```

- You can specify initial size if desired

```
vector<int> scores(24);
```

- Use `[]` to access individual elements

Defining Vectors

- Define a vector of integers (starts with 0 elements)

```
vector<int> scores;
```

- Define **int** vector with initial size 30 elements

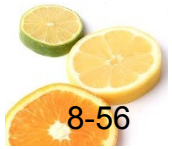
```
vector<int> scores(30);
```

- Define 20-element **int** vector and initialize all elements to 0

```
vector<int> scores(20, 0);
```

- Define **int** vector initialized to size and contents of vector **finals**

```
vector<int> scores(finals);
```



C++ 11 Features for Vectors

- C++ 11 supports vector definitions that use an initialization list

```
vector<int> scores {88, 67, 79, 84};
```

- Note: no = operator between the vector name and the initialization list
- A range-based for loop can be used to access the elements of a vector

```
for (int test : scores)
    cout << test << " ";
```

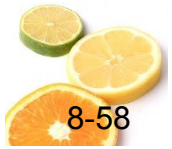
Growing a Vector's Size

- Use the **push_back** member function to add an element to a full vector or to a vector that had no defined size

```
// Add a new element holding a 75
scores.push_back(75);
```

- Use the **size** member function to determine the number of elements currently in a vector

```
howbig = scores.size();
```



Removing Vector Elements

- Use the **pop_back** member function to remove the last element from a vector

```
scores.pop_back();
```

- Note: **pop_back** removes the last element but does not return it
- To remove all of the elements from a vector, use the **clear** member function

```
scores.clear();
```

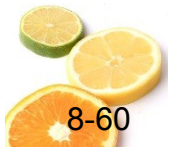
- To determine if a vector is empty, use **empty** member function

```
while (!scores.empty()) ...
```

8.13 Arrays of Objects

- Objects can be used as array elements

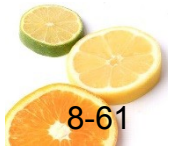
```
class Square
{ private:
     int side;
  public:
     Square(int s = 1)
     { side = s; }
     int getSide()
     { return side; }
};
Square shapes[10];  // Create array of 10
                    // Square objects
```



Arrays of Objects

- Use the array subscript to access a specific object in the array
- Then use dot operator to access the member methods of that object

```
for (i = 0; i < 10; i++)
  cout << shapes[i].getSide() << endl;
```



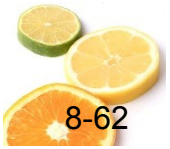
Initializing Arrays of Objects

- You can use the default constructor to perform the same initialization for all objects
- You can use an initialization list to supply specific initial values for each object

```
Square shapes[5] = {1,2,3,4,5};
```

- The default constructor is used for the remaining objects if initialization list is too short

```
Square boxes[5] = {1,2,3};
```

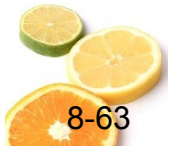


Initializing Arrays of Objects

- If an object is initialized with a constructor that takes > 1 argument, the initialization list must include a call to the constructor for that object

```
Rectangle spaces[3]={ Rectangle(2,5),
                      Rectangle(1,3),
                      Rectangle(7,7)
                    };
```

- The same constructor does not have to be used for every object that is being initialized

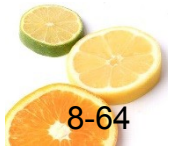


Arrays of Structures

- Structures can be used as array elements

```
struct Student
{
      int studentID;
      string name;
   short year;
      double gpa;
};
const int CSIZE = 30;
Student class[CSIZE]; // Holds 30
                      // Student structures
```

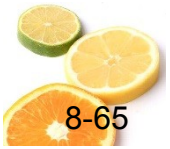
- An array of structures can be used as an alternative to parallel arrays



Arrays of Structures

- Use the array subscript to access a specific structure in the array
- Then use the dot operator to access members of that structure

```
cin  >> class[25].studentID;

cout << class[i].name << " has GPA "
     << class[i].gpa << endl;
```



Chapter 8: Arrays

Starting Out with C++
Early Objects
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by Tony Gaddis, Judy Walters,
and Godfrey Muganda