Chapter 8

Arrays and Strings

Objectives (1 of 3)

- In this chapter, you will:
  - Learn the reasons for arrays
  - Explore how to declare and manipulate data into arrays
  - Understand the meaning of ‘‘array index out of bounds’’
  - Learn how to declare and initialize arrays
  - Become familiar with the restrictions on array processing

Objectives (2 of 3)

- Discover how to pass an array as a parameter to a function
- Learn how to search an array
- Learn how to sort an array
- Become aware of **`auto`** declarations
- Learn about range-based **`for`** loops
- Learn about **`C`**-strings

Objectives (3 of 3)

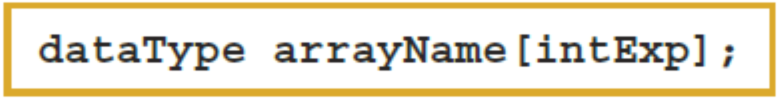
- Examine the use of string functions to process **C**-strings
- Discover how to input data into—and output data from—a **C**-string
- Learn about parallel arrays
- Discover how to manipulate data in a two-dimensional array
- Learn about multidimensional arrays

Introduction

- Simple data type: variables of these types can store only one value at a time
- Structured data type: a data type in which each data item is a collection of other data items

Arrays

- Array: a collection of a fixed number of components, all of the same data type
- One-dimensional array: components are arranged in a list form
- Syntax for declaring a one-dimensional array

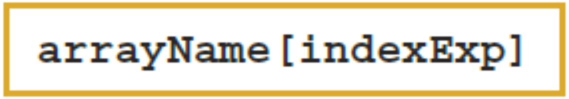


```
dataType arrayName[intExp];
```

- **`intExp`**: any constant expression that evaluates to a positive integer

Accessing Array Components (1 of 3)

- General syntax



```
arrayName[indexExp]
```

- **`indexExp`**: called the index
  - An expression with a nonnegative integer value
- Value of the index is the position of the item in the array
- `[]`: array subscripting operator
  - Array index always starts at **0**

Accessing Array Components (2 of 3)

This statement declares an array of 10 components:

```
int list[10];
```

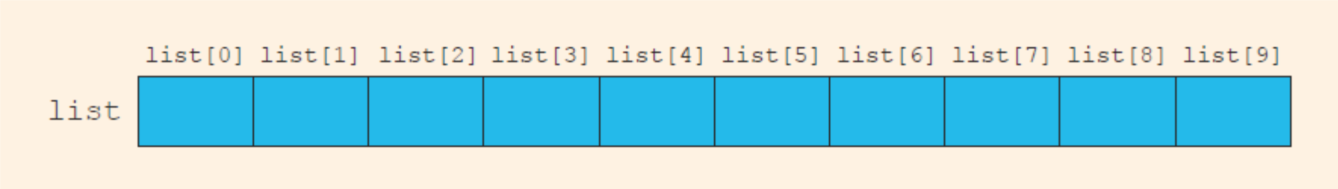


FIGURE 8-3 Array `list`

list[5] = 34;

stores **`34`** in **`list[5]`**, the *sixth* component of the array **`list`**

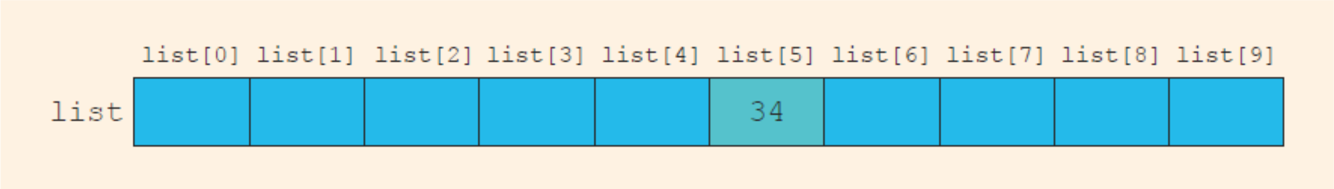


FIGURE 8-4 Array `list` after execution of the statement `list[5]= 34;`

Accessing Array Components (3 of 3)

```
list[3] = 10;
list[6] = 35;
list[5] = list[3] + list[6];
```

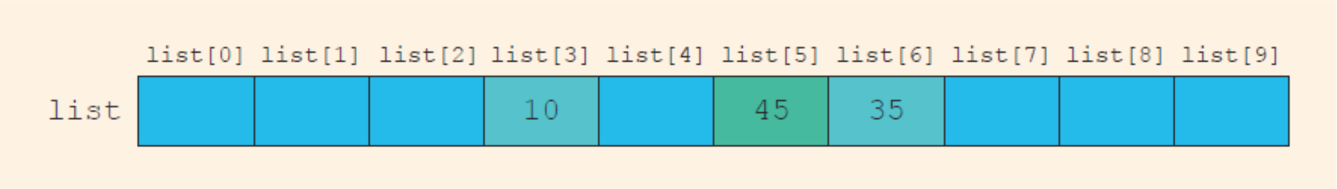


FIGURE 8-5 Array `list` after execution of the statements `list[3]= 10;`, `list[6]= 35;`, and `list[5] = list[3] + list[6];`

Processing One-Dimensional Arrays (1 of 3)

- Basic operations on a one-dimensional array include:
  - Initializing
  - Inputting data
  - Outputting data stored in an array
  - Finding the largest and/or smallest element
- Each operation requires ability to step through elements of the array
  - Easily accomplished using a loop

Processing One-Dimensional Arrays (2 of 3)

- Given the declaration:

```
int list[100];  //array of size 100
int i;
```

- Use a **for** loop to access array elements:

```
for (i = 0; i < 100; i++)       //Line 1
      cin >> list[i];           //Line 2
```

Processing One-Dimensional Arrays (3 of 3)

- Refer to Example 8-3 in the text, which shows how loops are used to process arrays
  - Initializing an array
  - Reading data into an array
  - Printing an array
  - Finding the sum and average of an array
  - Finding the largest element in an array

Array Index Out of Bounds

- The index of an array is in bounds if the index is between `0` and `ARRAY_SIZE - 1`
  - Otherwise, the index is out of bounds
- In C++, there is no guard against indices that are out of bounds
  - This check is solely the programmer's responsibility

Array Initialization During Declaration

- Arrays can be initialized during declaration
  - Values are placed between curly braces
- Example 1

```
double sales[5] = {12.25, 32.50, 16.90, 23, 45.68}
```

- Example 2: the array size is determined by the number of initial values in the braces if the array is declared without size specified

```
double sales[] = {12.25, 32.50, 16.90, 23, 45.68}
```

Partial Initialization of Arrays During Declaration

- The statement:

```
int list[10] = {0};
```

  - Declares an array of **10** components and initializes all of them to zero

- The statement (an example of partial initialization of an array during declaration):

```
int list[10] = {8, 5, 12};
```

  - Declares an array of **10** components and initializes **list[0]** to **8**, **list[1]** to **5**, **list[2]** to **12**
  - All other components are initialized to **0**

Some Restrictions on Array Processing

- Aggregate operation: any operation that manipulates the entire array as a single unit
  - Not allowed on arrays in C++
- Example

```
int myList[5] = {0, 4, 8, 12, 16};  //Line 1
int yourList[5];  //Line 2
yourList = myList;  //illegal
```

- Solution

```
for (int index = 0; index < 5; index++)
    yourList[index] = myList[index];
```

Arrays as Parameters to Functions

- Arrays are passed by reference only
- Do not use symbol **&** when declaring an array as a formal parameter
- The size of the array is usually omitted in the array parameter
  - If provided, it is ignored by the compiler
- The following example illustrates a function header, which includes an array parameter and a parameter specifying the number of elements in the array:

```
void initialize(int list[], int listSize)
```

Constant Arrays as Formal Parameters

- Can prevent a function from changing the actual parameter when passed by reference
  - Use `const` in the declaration of the formal parameter
- Example

```
void example(int x[], const int y[], int sizeX, int sizeY)
```

Base Address of an Array and Array in Computer Memory

- The base address of an array is the address (memory location) of the first array component
  - If `list` is a one-dimensional array, its base address is the address of `list[0]`
- When an array is passed as a parameter, the base address of the actual array is passed to the formal parameter

Functions Cannot Return a Value of the Type Array

- C++ does not allow functions to return a value of type array
- Refer to Example 8-6 in the text
  - Functions **`sumArray`** and **`indexLargestElement`**

Integral Data Type and Array Indices

- C++ allows any integral type to be used as an array index
  - Improves code readability
- The following code illustrates improved readability:

```
enum paintType {GREEN, RED, BLUE, BROWN, WHITE, ORANGE,
                YELLOW};
double paintSale[7];
paintType paint;

for (paint = GREEN; paint <= YELLOW;
                  paint = static_cast<paintType>(paint + 1))
    paintSale[paint] = 0.0;

paintSale[RED] = paintSale[RED] + 75.69;
```

Other Ways to Declare Arrays

- Example 1

```
const int NO_OF_STUDENTS = 20;
int testScores[NO_OF_STUDENTS];
```

- Example 2

```
const int SIZE = 50;             //Line 1
typedef double list[SIZE];       //Line 2

list yourList;                   //Line 3
list myList;                     //Line 4
```

Searching an Array for a Specific Item

- Sequential search (or linear search)
  - Searching a list for a given item, starting from the first array element
  - Compare each element in the array with value that is being searched
  - Continue the search until item is found or no more data is left in the list

Sorting

- Selection sort: rearrange the list by selecting an element and moving it to its proper position
- Steps for a selection sort:
  - Find the smallest element in the unsorted portion of the list
  - Move it to the top of the unsorted portion by swapping with the element currently there
  - Start again with the rest of the list

Selection Sort

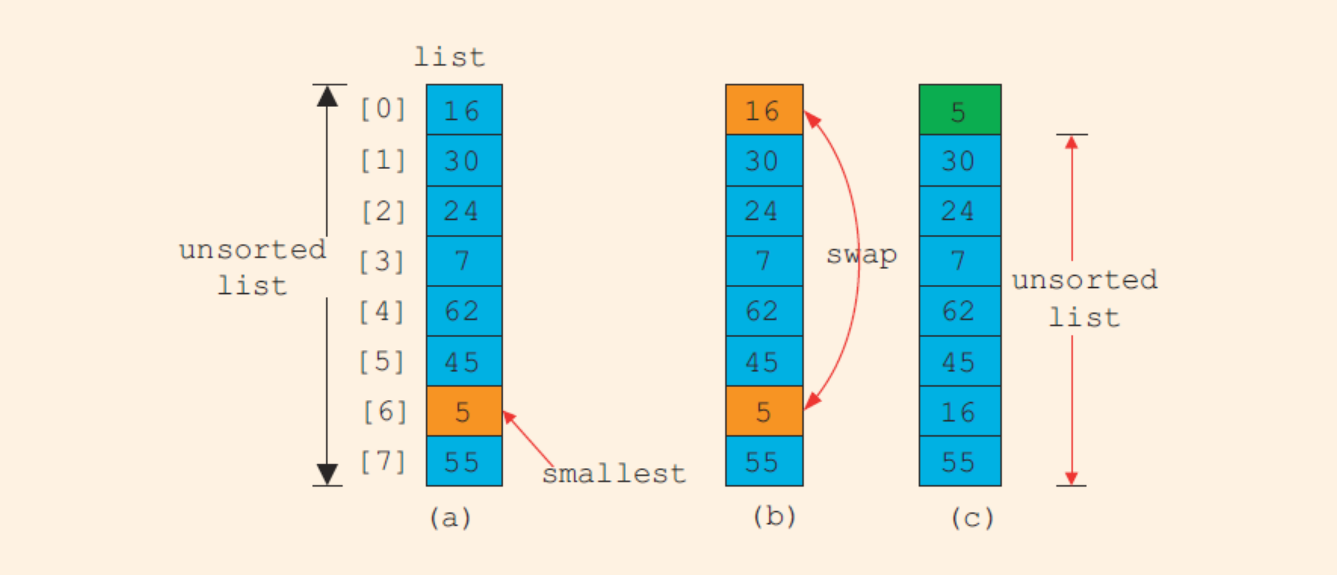


FIGURE 8-10 Elements of `list` during the first iteration

Auto Declaration and Range-Based `for` Loops

- C++11 allows auto declaration of variables
  - Data type does not need to be specified

    ```
    auto num = 15;
    ```

    The type of **`num`** will be **`int`**

- Range-based **`for`** loop

```
double list[25];
double sum;

sum = 0;
for (double num : list) // read as “for each num in list”
    sum = sum + num;
```

C-Strings (Character Arrays) (1 of 3)

- A character array is an array whose components are of type `char`
- **C**-strings are null-terminated (`'\0'`) character arrays
- Examples
  - `'A'` is the character **A**
  - `"A"` is the **C**-string **A**
  - Note: `"A"` represents two characters, `'A'` and `'\0'`

C-Strings (Character Arrays) (2 of 3)

- This is an example of a **C**-string declaration:

```
char name[16];
```

- Since **C**-strings are null terminated and `name` has `16` components, the largest string it can store has `15` characters
- If you store a string whose length is less than the array size, the last components are unused

C-Strings (Character Arrays) (3 of 3)

- The size of an array can be omitted if the array is initialized during declaration

```
char name[] = "John";
```

  - Declares an array of length **5** and stores the **C**-string **"John"** in the array

- Useful string manipulation functions include:
  - **strcpy**
  - **strncpy**
  - **strcmp**
  - **strlen**

String Comparison

- C-strings are compared character by character using the collating sequence of the system
  - Use the function `strcmp`
- If using the ASCII character set:
  - `"Air" < "Boat"`
  - `"Air" < "An"`
  - `"Bill" < "Billy"`
  - `"Hello" < "hello"`

Reading and Writing Strings

- Most rules for arrays also apply to **C**-strings (which are character arrays)
- Aggregate operations, such as assignment and comparison, are not allowed on arrays
- C++ does allow aggregate operations for the input and output of **C**-strings

String Input

- This is an example of string input:

```
cin >> name;
```

  - Stores the next input **C**-string into name
- To read strings with blanks, use the function **`get`**:

```
cin.get(str, m+1);
```

  - When executed , the statement stores the next **`m`** characters into **`str`**, but the newline character is not stored in **`str`**
  - If input string has fewer than **`m`** characters, reading stops at the newline character

String Output

- Example

  ```
  cout << name;
  ```

  - Outputs the content of **`name`** on the screen
  - **`<<`** continues to write the contents of name until it finds the null character
  - If **`name`** does not contain the null character, then strange output may occur since **`<<`** continues to output data from memory adjacent to **`name`** until a `'\0'` is found

Specifying Input/Output Files at Execution Time

- User can specify the name of an input and/or output file at execution time

```
cout << "Enter the input file name: ";
cin >> fileName;
infile.open(fileName); //open the input file
.
.
.
cout << "Enter the output file name: ";
cin >> fileName;
outfile.open(fileName); //open the output file
```

string Type and Input/Output Files

- Argument to the **open** function must be a null-terminated string (a **C**-string)
  - If using a **string** variable for the name of an I/O file, the value must first be converted to a **C**-string before calling **open**
    - Use the **c_str** function to convert
- The syntax to use the function **c_str** is:

```
strVar.c_str()
```

  - Where **strVar** is a variable of type **string**

Parallel Arrays

- Two (or more) arrays are called parallel if their corresponding components hold related information
- The following example illustrates two parallel arrays:

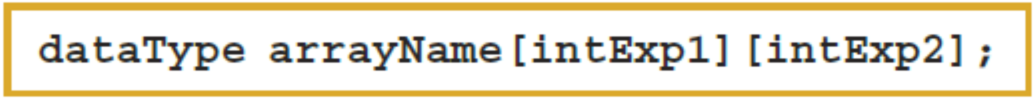
```
int studentId[50];
char courseGrade[50];
```

With the following sample data to enter into the arrays:

```
studentId courseGrade
23456 A
86723 B
22356 C
92733 B
11892 D
.
.
.
```

Two- and Multidimensional Arrays

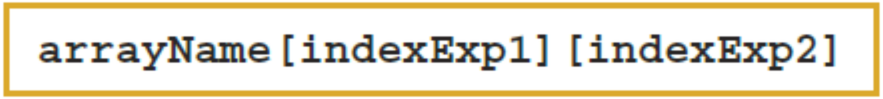
- Two-dimensional array: a collection of a fixed number of components (of the same type) arranged in two dimensions
  - Sometimes called matrices or tables
- Declaration syntax
  - **`intExp1`** and **`intExp2`** are expressions with positive integer values specifying the number of rows and columns in the array



```
dataType arrayName[intExp1][intExp2];
```

Accessing Array Components (1 of 2)

- Syntax to access a component in a two-dimensional array



```
arrayName[indexExp1][indexExp2]
```

  - Where **indexExp1** and **indexExp2** are expressions with positive integer values, and specify the row and column position
  - Example: `sales[5][3] = 25.75;`

Accessing Array Components (2 of 2)

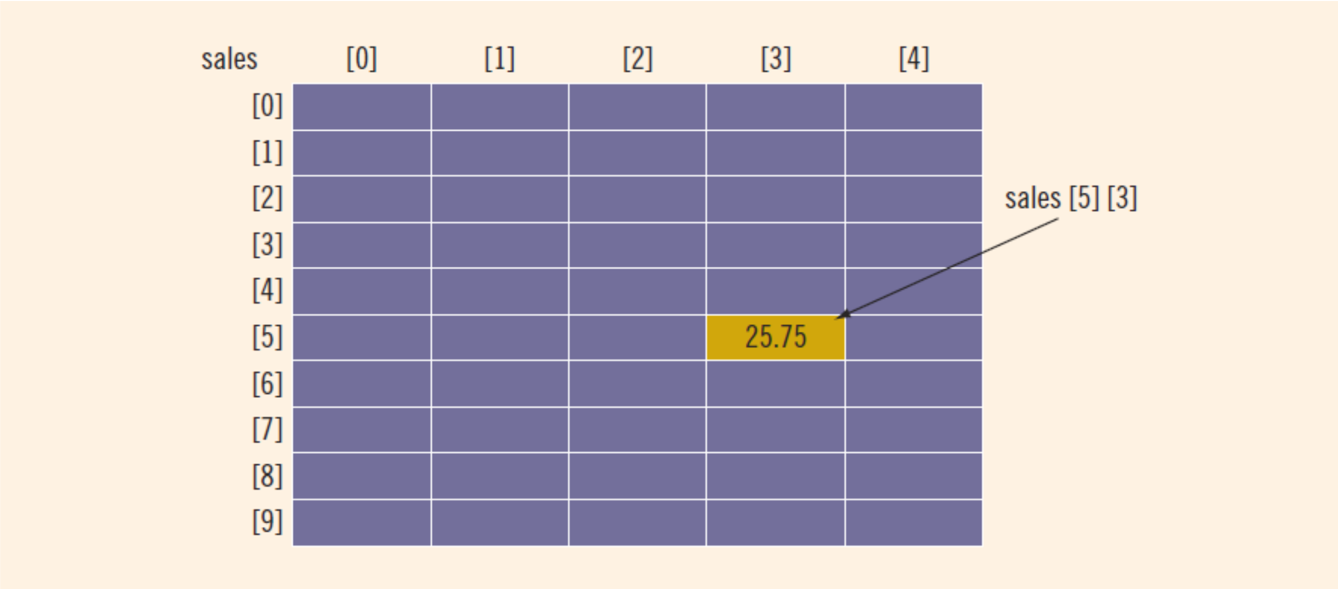


FIGURE 8-14 `sales[5][3]`

Two-Dimensional Array Initialization During Declaration

- Two-dimensional arrays can be initialized when they are declared
  - Elements of each row are enclosed within braces and separated by commas
  - All rows are enclosed within braces
  - For number arrays, unspecified elements are set to 0
- An example of two-dimensional array initialization is shown below:

```
int board[4][3] = {{2, 3, 1},
                   {15, 25, 13},
                   {20, 4, 7},
                   {11, 18, 14}};
```

Two-Dimensional Arrays and Enumeration Types

- Enumeration types can be used for array indices

```
const int NUMBER_OF_ROWS = 6;
const int NUMBER_OF_COLUMNS = 5;
enum carType {GM, FORD, TOYOTA, BMW, NISSAN, VOLVO};
enum colorType {RED, BROWN, BLACK, WHITE, GRAY};
int inStock[NUMBER_OF_ROWS][NUMBER_OF_COLUMNS];
```

Processing Two-Dimensional Arrays

- Ways to process a two-dimensional array:
  - Process a single element
  - Process the entire array
  - Process a single row at a time, called row processing
  - Process a single column at a time, called column processing
- Each row and each column of a two-dimensional array is a one-dimensional array
  - To process, use algorithms similar to processing one-dimensional arrays

Initialization

- An example initializing row number **4** (fifth row) to **0**:

```
row = 4;
for (col = 0; col < NUMBER_OF_COLUMNS; col++)
    matrix[row][col] = 0;
```

- An example initializing the entire matrix to **0**

```
for (row = 0; row < NUMBER_OF_ROWS; row++)
    for (col = 0; col < NUMBER_OF_COLUMNS; col++)
        matrix[row][col] = 0;
```

Print

- Use a nested loop to output the components of a two dimensional array

```
for (row = 0; row < NUMBER_OF_ROWS; row++)
    for (col = 0; col < NUMBER_OF_COLUMNS; col++)
        cout << setw(5) << matrix[row][col] << " ";
    cout << endl;
```

Input

- An example of adding input to row number **4** (fifth row):

```
row = 4;
for (col = 0; col < NUMBER_OF_COLUMNS; col++)
    cin >> matrix[row][col];
```

- An example of adding input to each component of matrix:

```
for (row = 0; row < NUMBER_OF_ROWS; row++)
    for (col = 0; col < NUMBER_OF_COLUMNS; col++)
        cin >> matrix[row][col];
```

Sum by Row

- The following example shows how to find the sum of row number **4**:

```
sum = 0;
row = 4;
for (col = 0; col < NUMBER_OF_COLUMNS; col++)
    sum = sum + matrix[row][col];
```

Sum by Column

- The following example illustrates finding the sum of each individual column:

```
   //Sum of each individual row
for (row = 0; row < NUMBER_OF_ROWS; row++)
{
    sum = 0;
    for (col = 0; col < NUMBER_OF_COLUMNS; col++)
        sum = sum + matrix[row][col];

    cout << "Sum of row " << row + 1 << " = " << sum << endl;
}
```

Largest Element in Each Row and Each Column

- The following example finds the largest element in each row:

```
 //Largest element in each row
for (row = 0; row < NUMBER_OF_ROWS; row++)
{
    largest = matrix[row][0]; //Assume the first element
                              //of the row is the largest.
    for (col = 1; col < NUMBER_OF_COLUMNS; col++)
        if (matrix[row][col] > largest)
            largest = matrix[row][col];

    cout << "The largest element in row " << row + 1
         << " = " << largest << endl;
}
```

Passing Two-Dimensional Arrays as Parameters to Functions

- Two-dimensional arrays are passed by reference as parameters to a function
  - The base address is passed to the formal parameter
- Two-dimensional arrays are stored in row order form
- When declaring a two-dimensional array as a formal parameter, you can omit the size of the first dimension, but not the second

Arrays of Strings

- Strings in C++ can be manipulated using either the data type `string` or character arrays (`C`-strings)

Arrays of Strings and the `string` Type

- The example below declares an array of **`100`** components of type **`string`**:

```
string list[100];
```

- Basic operations, such as assignment, comparison, and input/output, can be performed on values of the **`string`** type
- The data in list can be processed just like any one-dimensional array

Arrays of Strings and C-Strings (Character Arrays)

```
strcpy(list[1], "Snow White");
```

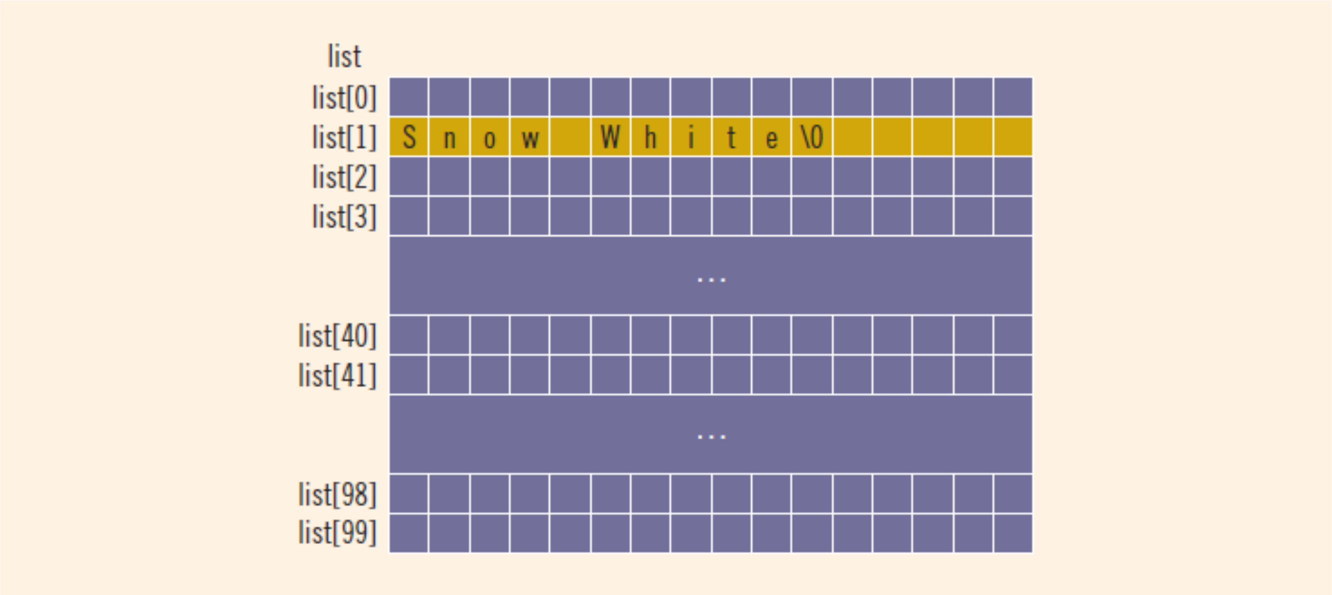


FIGURE 8-20 Array `list`, showing `list[1]`

Another Way to Declare a Two-Dimensional Array

- Can use `typedef` to define a two-dimensional array data type:

```
const int NUMBER_OF_ROWS = 20;
const int NUMBER_OF_COLUMNS = 10;
typedef int tableType[NUMBER_OF_ROWS][NUMBER_OF_COLUMNS];
```

- This statement declares an array of `20` rows and `10` columns:

```
tableType matrix;
```

Multidimensional Arrays

- *n*-dimensional array: a collection of a fixed number of elements arranged in *n* dimensions (*n* >= 1)
- Declaration syntax

```
dataType arrayName[intExp1][intExp2] ... [intExpn];
```

- Code to access a component

```
arrayName[indexExp1][indexExp2] ... [indexExpn]
```

Quick Review (1 of 4)

- An array is a structured data type with a fixed number of components of the same type
  - Components are accessed using their relative positions in the array
- Elements of a one-dimensional array are arranged in the form of a list
- An array index can be any expression that evaluates to a nonnegative integer
  - Must always be less than the size of the array

Quick Review (2 of 4)

- The base address of an array is the address of the first array component
- When passing an array as an actual parameter, use only its name
  - Passed by reference only
- A function cannot return an array type value
- Individual array components can be passed as parameters to functions

Quick Review (3 of 4)

- In C++, **C**-strings are null terminated and are stored in character arrays
- Commonly used **C**-string manipulation functions include: **`strcpy`**, **`strncpy`**, **`strcmp`**, **`strncmp`**, and **`strlen`**
- Parallel arrays hold related information
- In a two-dimensional array, the elements are arranged in a table form

Quick Review (4 of 4)

- To access an element of a two-dimensional array, you need a pair of indices: one for row position, one for column position
- In row processing, a two-dimensional array is processed one row at a time
- In column processing, a two-dimensional array is processed one column at a time