Arrays
Static Arrays

Learning Objectives

- Static Arrays
  - Introduction to Arrays
  - Arrays in Functions
  - Programming with Arrays
  - Multidimensional Arrays
- Pointers
  - Pointer variables
  - Memory management
- Dynamic Arrays
  - Creating and using
  - Pointer arithmetic

Introduction to Arrays

- Array definition:
  - A collection of data of same type
- First "aggregate" data type
  - Means "grouping"
  - int, float, double, char are simple data types
- Used for lists of like items
  - Test scores, temperatures, names, etc.
  - Avoids declaring multiple simple variables
  - Can manipulate "list" as one entity

Declaring Arrays

- Declare the array → allocates memory
  int score[5];
  - Declares array of 5 integers named "score"
  - Similar to declaring five variables:
    int score_0, score_1, score_2, score_3, score_4
- Individual parts called many things:
  - Indexed or subscripted variables
  - "Elements" of the array
  - Value in brackets called index or subscript
    - Numbered from 0 to size - 1

Accessing Arrays

- Access using index/subscript
  - cout << score[3];
- Note two uses of brackets:
  - In declaration, specifies SIZE of array
  - Anywhere else, specifies a subscript
- Size, subscript need not be literal
  - int score[MAX_SCORES];
  - score[n+1] = 99;
    - If n is 2, identical to: score[3]

Array Usage

- Powerful storage mechanism
- Can issue command like:
  - "Do this to i^{th} indexed variable"
    where i is computed by program
  - "Display all elements of array score"
  - "Fill elements of array score from user input"
  - "Find highest value in array score"
  - "Find lowest value in array score"

Array Program Example:
Display 5.1 Program Using an Array (1 of 2)

Display 5.1 Program Using an Array

```
1  //Reads in five scores and shows how much each
2  //score differs from the highest score.
3  #include <iostream>
4  using namespace std;
5  int main( )
6  {
7      int i, score[5], max;
8      cout << "Enter 5 scores:\n";
9      cin >> score[0];
10     max = score[0];
11     for (i = 1; i < 5; i++)
12     {
13         cin >> score[i];
14         if (score[i] > max)
15             max = score[i];
16         //max is the largest of the values score[0],..., score[i].
17     }
```

Array Program Example:
Display 5.1 Program Using an Array (2 of 2)

```
18        cout << "The highest score is " << max << endl
19             << "The scores and their\n"
20             << "differences from the highest are:\n";
21        for (i = 0; i < 5; i++)
22            cout << score[i] << " off by "
23                 << (max - score[i]) << endl;
24        return 0;
25    }
```

SAMPLE DIALOGUE

Enter 5 scores:
5 9 2 10 6
The highest score is 10
The scores and their
differences from the highest are:
5 off by 5
9 off by 1
2 off by 8
10 off by 0
6 off by 4

for-loops with Arrays

- Natural counting loop
  - Naturally works well "counting through" elements of an array
- Example:

```
for (int idx = 0; idx<5; idx++)
{
   cout << score[idx] << "off by "
        << max - score[idx] << endl;
}
```

  - Loop control variable (idx) counts from 0 – 5

Major Array Pitfall

- Array indexes always start with zero!
- Zero is "first" number to computer scientists
- C++ will "let" you go beyond range
  - Unpredictable results
  - Compiler will not detect these errors!
- Up to programmer to "stay in range"

Best Practice
Defined Constant as Array Size

- Always use defined/named constant for array size
- Example:
  const int NUMBER_OF_STUDENTS = 5;
  int score[NUMBER_OF_STUDENTS];
- Improves readability
- Improves versatility
- Improves maintainability

Uses of Defined Constant

- Use everywhere size of array is needed
  - In for-loop for traversal:

```
for (int idx = 0; idx < NUMBER_OF_STUDENTS; idx++)

    // Manipulate array
}
```

  - In calculations involving size:

```
lastIndex = (NUMBER_OF_STUDENTS – 1);
```

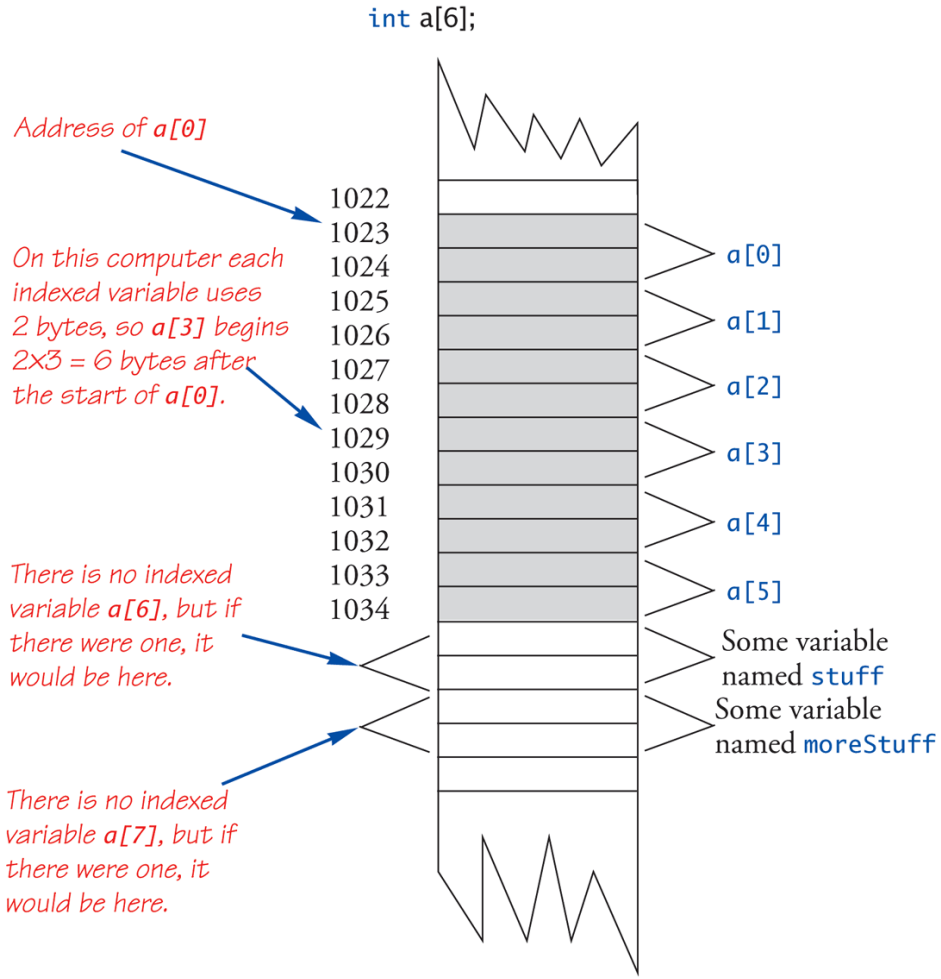
  - When passing array to functions (later)
- If size changes → requires only ONE change in program!

Arrays in Memory

- Recall simple variables:
  - Allocated memory in an "address"
- Array declarations allocate memory for entire array
- Sequentially-allocated
  - Means addresses allocated "back-to-back"
  - Allows indexing calculations
    - Simple "addition" from array beginning (index 0)

An Array in Memory

Display 5.2 **An Array in Memory**



Initializing Arrays

- As simple variables can be initialized at declaration:

```
int price = 0;        // 0 is initial value
```

- Arrays can as well:

```
int children[3] = {2, 12, 1};
```

  - Equivalent to following:

```
int children[3];
children[0] = 2;
children[1] = 12;
children[2] = 1;
```

Auto-Initializing Arrays

- If fewer values than size supplied:
  - Fills from beginning
  - Fills "rest" with zero of array base type
  - int b[4] = {5, 12, 11};
    - Whats stored in b[3] ?
- If array-size is left out
  - Declares array with size required based on number of initialization values
  - Example:
    int b[] = {5, 12, 11};
    - Allocates array b to size 3

Arrays in Functions

- As arguments to functions
  - Indexed variables
    - An individual "element" of an array can be function parameter
  - Entire arrays
    - All array elements can be passed as "one entity"
- As return value from function
  - Can be done

Indexed Variables as Arguments

- Indexed variable handled same as simple variable of array base type
- Given this function declaration:
  void myFunction(double par1);
- And these declarations:
  int i; double n, a[10];
- Can make these function calls:
  myFunction(i); // i is converted to double
  myFunction(a[3]); // a[3] is double
  myFunction(n); // n is double

Entire Arrays as Arguments

- Formal parameter can be entire array
  - Argument then passed in function call is array name
  - Called "array parameter"
- Send size of array as well
  - Typically done as second parameter
  - Simple int type formal parameter
- Given this function declaration:
  void myFunction(double par1[ ], int size_par1);
- And these declarations:
  double a[10]; int n=10;
- Can make these function calls:

  myFunction(a, n);

Entire Array as Argument Example: **Display 5.3** Function with an Array Parameter

Display 5.3 Function with an Array Parameter

SAMPLE DIALOGUEFUNCTION DECLARATION

```
void fillUp(int a[], int size);
//Precondition: size is the declared size of the array a.
//The user will type in size integers.
//Postcondition: The array a is filled with size integers
//from the keyboard.
```

SAMPLE DIALOGUEFUNCTION DEFINITION

```
void fillUp(int a[], int size)
{
    cout << "Enter " << size << " numbers:\n";
    for (int i = 0; i < size; i++)
        cin >> a[i];
    cout << "The last array index used is " << (size - 1) << endl;
}
```

Entire Array as Argument Example

- Given previous example:
- In some main() function definition, consider this calls:

```
int score[5], numberOfScores = 5;
fillup(score, numberOfScores);
```

  - 1st argument is entire array
  - 2nd argument is integer value

- Note no brackets in array argument!

Array Parameters

- May seem strange
  - No brackets in array argument
  - Must send size separately
- One nice property:
  - Can use SAME function to fill any size array!
  - Exemplifies "re-use" properties of functions
  - Example:
    int score[5], time[10];
    fillUp(score, 5);
    fillUp(time, 10);

Functions that Return an Array

- Functions cannot return arrays same way simple types are returned
- Requires use of a "pointer"
- Will be discussed later

Programming with Arrays

- Plenty of uses
  - Partially-filled arrays
    - Must be declared some "max size"
  - Sorting
  - Searching

Multidimensional Arrays

- Arrays with more than one index
  - char page[30][100];
    - Two indexes: An "array of arrays"
    - Visualize as:
      page[0][0], page[0][1], …, page[0][99]
      page[1][0], page[1][1], …, page[1][99]
      …
      page[29][0], page[29][1], …, page[29][99]
- C++ allows any number of indexes
  - Usually no more than two indexes

Multidimensional Array as Function Parameters

- Similar to one-dimensional array
  - 1st dimension size not given
    - Provided as second parameter
  - 2nd dimension size IS given
- Example:

```
void DisplayPage(const char p[][100], int sizeDimension1)
{
        for (int index1=0; index1<sizeDimension1; index1++)
        {
                for (int index2=0; index2 < 100; index2++)
                        cout << p[index1][index2];
                cout << endl;
        }
}
```

Arrays Example: arrayExample.cpp

```
#include  <iostream>
using namespace  std;
int main()
{
      int i;
      int age[4];
      age[0]=23;
      age[1]=34;
      age[2]=65;
      age[3]=74;
      for(i=0; i<4; i++)
      {
            cout  <<"Element: "<< i <<" Value of  age:  "<< age[i] <<"\n";
      }
       return 0;
}
```

declare an integer array containing 4 elements

Note: The number in the square brackets [] is the position number of a particular array element. The position numbers begins at 0

Output:

Element: 0 Value of age: 23

Element: 1 Value of age: 34

Element: 2 Value of age: 65

Element: 3 Value of age: 74