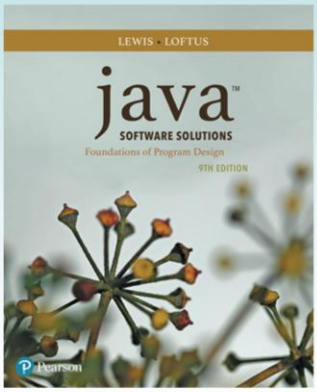
Chapter 8
Arrays



Java Software Solutions
Foundations of Program Design
9th Edition

John Lewis
William Loftus

Arrays

- Arrays are objects that help us organize large amounts of information
- Chapter 8 focuses on:
  - array declaration and use
  - bounds checking and capacity
  - arrays that store object references
  - variable length parameter lists
  - multidimensional arrays

Outline

- **Declaring and Using Arrays**
- **Arrays of Objects**
- **Variable Length Parameter Lists**
- **Two-Dimensional Arrays**

Arrays

- The `ArrayList` class, introduced in Chapter 5, is used to organize a list of objects
- It is a class in the Java API
- An *array* is a programming language construct used to organize a list of objects
- It has special syntax to access elements
- As its name implies, the `ArrayList` class uses an array internally to manage the list of objects

Arrays

- An array is an ordered list of values:

The entire array has a single name

Each value has a numeric *index*

	0	1	2	3	4	5	6	7	8	9
`scores`	79	87	94	82	67	98	87	81	74	91

An array of size N is indexed from zero to N-1

This array holds 10 values that are indexed from 0 to 9

Arrays

- A particular value in an array is referenced using the array name followed by the index in brackets
- For example, the expression

```
scores[2]
```

  refers to the value `94` (the 3rd value in the array)

- That expression represents a place to store a single integer and can be used wherever an integer variable can be used

Arrays

- For example, an array element can be assigned a value, printed, or used in a calculation:

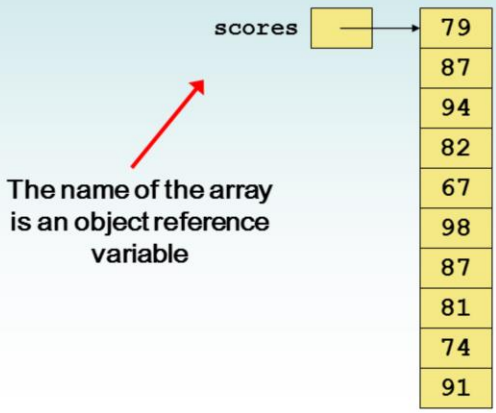
```
scores[2] = 89;
scores[first] = scores[first] + 2;
mean = (scores[0] + scores[1])/2;
System.out.println ("Top = " + scores[5]);
pick = scores[rand.nextInt(11)];
```

Arrays

- The values held in an array are called *array elements*
- An array stores multiple values of the same type – the *element type*
- The element type can be a primitive type or an object reference
- Therefore, we can create an array of integers, an array of characters, an array of `String` objects, an array of `Coin` objects, etc.

Arrays

- In Java, the array itself is an object that must be instantiated
- Another way to depict the `scores` array:



Declaring Arrays

- The `scores` array could be declared as follows:

```
int[] scores = new int[10];
```

- The type of the variable `scores` is `int[]` (an array of integers)
- Note that the array type does not specify its size, but each object of that type has a specific size
- The reference variable `scores` is set to a new array object that can hold 10 integers

Declaring Arrays

- Some other examples of array declarations:

```
int[] weights = new int[2000];

double[] prices = new double[500];

boolean[] flags;
flags = new boolean[20];

char[] codes = new char[1750];
```

Using Arrays

- The for-each version of the `for` loop can be used when processing array elements:

```
for (int score : scores)
   System.out.println (score);
```

- This is only appropriate when processing all array elements starting at index 0
- It can't be used to set the array values
- See `BasicArray.java`

```java
//*******************************************************************
//  BasicArray.java       Author: Lewis/Loftus
//
//  Demonstrates basic array declaration and use.
//*******************************************************************

public class BasicArray
{
   //-----------------------------------------------------------------
   //  Creates an array, fills it with various integer values,
   //  modifies one value, then prints them out.
   //-----------------------------------------------------------------
   public static void main (String[] args)
   {
      final int LIMIT = 15, MULTIPLE = 10;

      int[] list = new int[LIMIT];

      //  Initialize the array values
      for (int index = 0; index < LIMIT; index++)
         list[index] = index * MULTIPLE;

      list[5] = 999;  // change one array value

      //  Print the array values
      for (int value : list)
         System.out.print (value + "  ");
   }
}
```

Inc.

Output

```
0   10   20   30   40   999   60   70   80   90   100   110   120   130   140
```

```java
//********************************************************************

public class BasicArray
{
   //-----------------------------------------------------------------
   //  Creates an array, fills it with various integer values,
   //  modifies one value, then prints them out.
   //-----------------------------------------------------------------
   public static void main (String[] args)
   {
      final int LIMIT = 15, MULTIPLE = 10;

      int[] list = new int[LIMIT];

      //  Initialize the array values
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      list[5] = 999;  // change one array value

      //  Print the array values
      for (int value : list)
         System.out.print (value + "  ");
   }
}
```
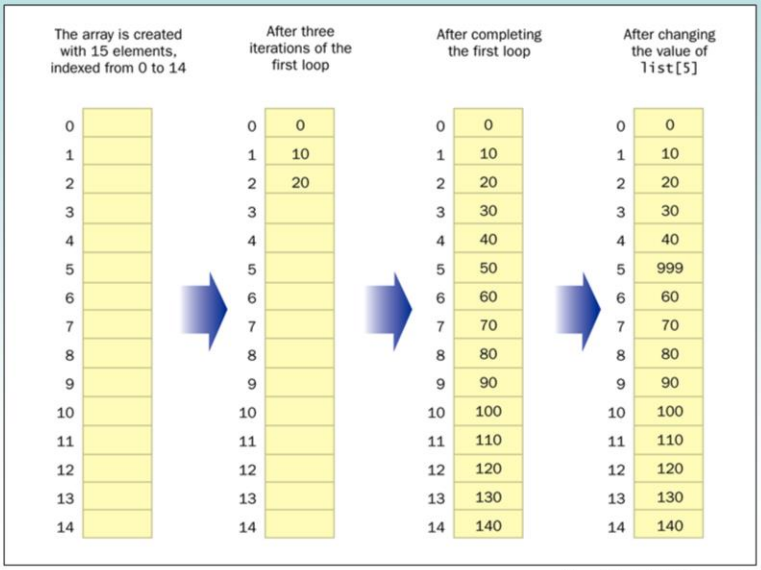

Inc.

Basic Array Example



Quick Check

Write an array declaration to represent the ages of 100 children.

Write code that prints each value in an array of integers named `values`.

Quick Check

Write an array declaration to represent the ages of 100 children.

```
int[] ages = new int[100];
```

Write code that prints each value in an array of integers named `values`.

```
for (int value : values)
   System.out.println(value);
```

Bounds Checking

- Once an array is created, it has a fixed size
- An index used in an array reference must specify a valid element
- That is, the index value must be in range 0 to N-1
- The Java interpreter throws an `ArrayIndexOutOfBoundsException` if an array index is out of bounds
- This is called automatic *bounds checking*

Bounds Checking

- For example, if the array `codes` can hold 100 values, it can be indexed from 0 to 99
- If the value of `count` is 100, then the following reference will cause an exception to be thrown:

```
System.out.println(codes[count]);
```

- It's common to introduce *off-by-one errors* when using arrays:

problem

```
for (int index=0; index <= 100; index++)
   codes[index] = index*50 + epsilon;
```

Bounds Checking

- Each array object has a public constant called `length` that stores the size of the array
- It is referenced using the array name:

```
scores.length
```

- Note that `length` holds the number of elements, not the largest index
- See `ReverseOrder.java`
- See `LetterCount.java`

```java
//********************************************************************
//  ReverseOrder.java       Author: Lewis/Loftus
//
//  Demonstrates array index processing.
//********************************************************************

import java.util.Scanner;

public class ReverseOrder
{
   //-----------------------------------------------------------------
   //  Reads a list of numbers from the user, storing them in an
   //  array, then prints them in the opposite order.
   //-----------------------------------------------------------------
   public static void main (String[] args)
   {
      Scanner scan = new Scanner (System.in);

      double[] numbers = new double[10];

      System.out.println ("The size of the array: " + numbers.length);
```

continue

continue

```
      for (int index = 0; index < numbers.length; index++)
      {
         System.out.print ("Enter number " + (index+1) + ": ");
         numbers[index] = scan.nextDouble();
      }

      System.out.println ("The numbers in reverse order:");

      for (int index = numbers.length-1; index >= 0; index--)
         System.out.print (numbers[index] + "  ");
   }
}
```

Sample Run

```
The size of the array: 10
Enter number 1: 18.36
Enter number 2: 48.9
Enter number 3: 53.5
Enter number 4: 29.06
Enter number 5: 72.404
Enter number 6: 34.8
Enter number 7: 63.41
Enter number 8: 45.55
Enter number 9: 69.0
Enter number 10: 99.18
The numbers in reverse order:
99.18  69.0  45.55  63.41  34.8  72.404  29.06  53.5  48.9  18.36
```

```java
//*****************************************************************
//  LetterCount.java       Author: Lewis/Loftus
//
//  Demonstrates the relationship between arrays and strings.
//*****************************************************************

import java.util.Scanner;

public class LetterCount
{
   //-----------------------------------------------------------------
   //  Reads a sentence from the user and counts the number of
   //  uppercase and lowercase letters contained in it.
   //-----------------------------------------------------------------
   public static void main (String[] args)
   {
      final int NUMCHARS = 26;

      Scanner scan = new Scanner (System.in);

      int[] upper = new int[NUMCHARS];
      int[] lower = new int[NUMCHARS];

      char current;   // the current character being processed
      int other = 0;  // counter for non-alphabetics
```

continue

continue

```
System.out.println ("Enter a sentence:");
String line = scan.nextLine();

//  Count the number of each letter occurence
for (int ch = 0; ch < line.length(); ch++)
{
   current = line.charAt(ch);
   if (current >= 'A' && current <= 'Z')
      upper[current-'A']++;
   else
      if (current >= 'a' && current <= 'z')
         lower[current-'a']++;
      else
         other++;
}
```

continue

continue

```
      //  Print the results
      System.out.println ();
      for (int letter=0; letter < upper.length; letter++)
      {
         System.out.print ( (char) (letter + 'A') );
         System.out.print (": " + upper[letter]);
         System.out.print ("\t\t" + (char) (letter + 'a') );
         System.out.println (": " + lower[letter]);
      }

      System.out.println ();
      System.out.println ("Non-alphabetic characters: " + other);
   }
}
```

Sample Run

```
Enter a sentence:
In Casablanca, Humphrey Bogart never says "Play it again, Sam."

A: 0          a: 10
B: 1          b: 1
C: 1          c: 1
D: 0          d: 0
E: 0          e: 3
F: 0          f: 0
G: 0          g: 2
H: 1          h: 1
I: 1          i: 2
J: 0          j: 0
K: 0          k: 0
L: 0          l: 2
M: 0          m: 2
N: 0          n: 4
O: 0          o: 1
P: 1          p: 1
Q: 0          q: 0
```

continue

Sample Run (continued)

```
R: 0          r: 3
S: 1          s: 3
T: 0          t: 2
U: 0          u: 1
V: 0          v: 1
W: 0          w: 0
X: 0          x: 0
Y: 0          y: 3
Z: 0          z: 0

Non-alphabetic characters: 14
```

Alternate Array Syntax

- The brackets of the array type can be associated with the element type or with the name of the array
- Therefore the following two declarations are equivalent:

```
double[] prices;
double prices[];
```

- The first format generally is more readable and should be used

Initializer Lists

- An *initializer list* can be used to instantiate and fill an array in one step
- The values are delimited by braces and separated by commas
- Examples:

```
int[] units = {147, 323, 89, 933, 540,
               269, 97, 114, 298, 476};

char[] grades = {'A', 'B', 'C', 'D', 'F'};
```

Initializer Lists

- Note that when an initializer list is used:
  - the `new` operator is not used
  - no size value is specified
- The size of the array is determined by the number of items in the list
- An initializer list can be used only in the array declaration
- See `Primes.java`

```java
//*********************************************************************
//  Primes.java       Author: Lewis/Loftus
//
//  Demonstrates the use of an initializer list for an array.
//*********************************************************************

public class Primes
{
   //-----------------------------------------------------------------
   //  Stores some prime numbers in an array and prints them.
   //-----------------------------------------------------------------
   public static void main (String[] args)
   {
      int[] primeNums = {2, 3, 5, 7, 11, 13, 17, 19};

      System.out.println ("Array length: " + primeNums.length);

      System.out.println ("The first few prime numbers are:");

      for (int prime : primeNums)
         System.out.print (prime + "  ");
   }
}
```

```
//*************                                                    ***************
//  Primes.java
//
//  Demonstrate                                                    array.
//*************                                                    ***************

public class Primes
{
   //-----------------------------------------------------------------
   //  Stores some prime numbers in an array and prints them.
   //-----------------------------------------------------------------
   public static void main (String[] args)
   {
      int[] primeNums = {2, 3, 5, 7, 11, 13, 17, 19};

      System.out.println ("Array length: " + primeNums.length);

      System.out.println ("The first few prime numbers are:");

      for (int prime : primeNums)
         System.out.print (prime + "  ");
   }
}
```

Output

```
Array length: 8
The first few prime numbers are:
2  3  5  7  11  13  17  19
```

Arrays as Parameters

- An entire array can be passed as a parameter to a method
- Like any other object, the reference to the array is passed, making the formal and actual parameters aliases of each other
- Therefore, changing an array element within the method changes the original
- An individual array element can be passed to a method as well, in which case the type of the formal parameter is the same as the element type