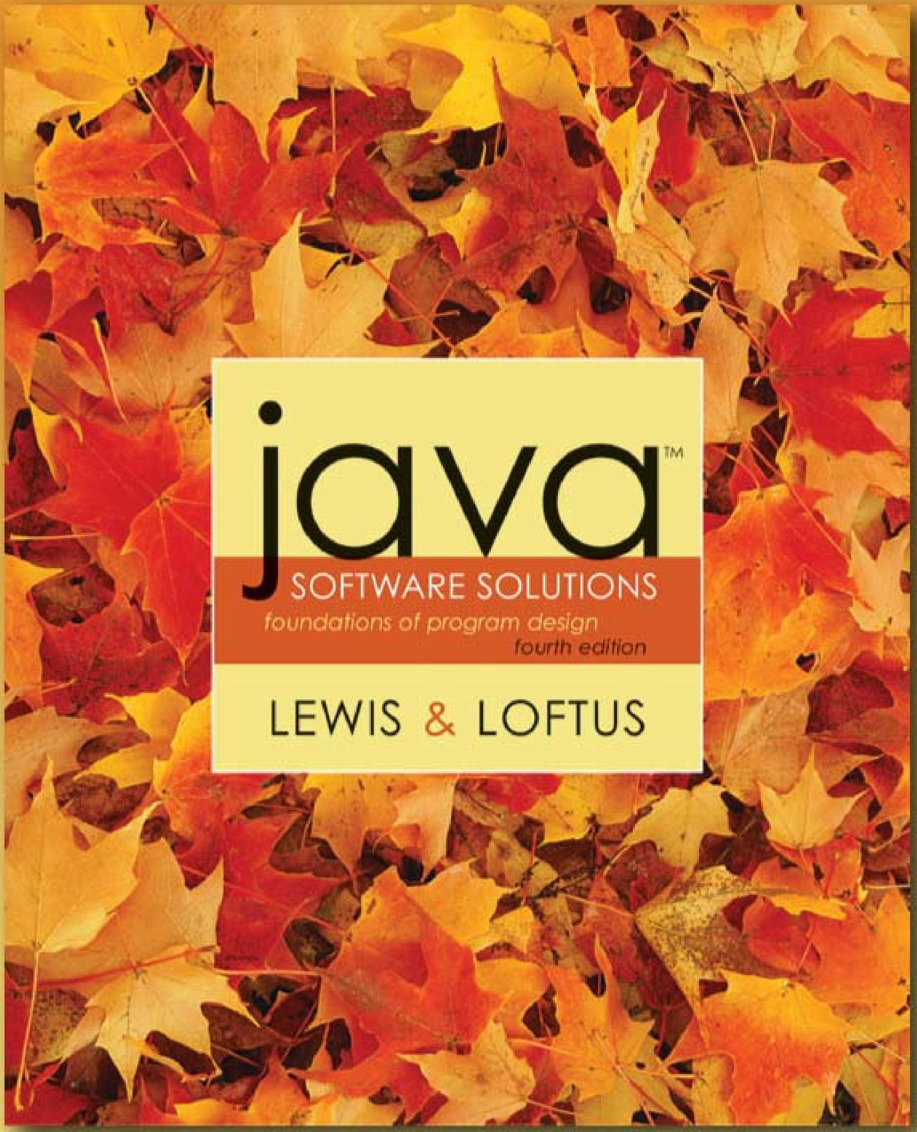
Lecture 7

Arrays



Arrays

- Arrays are objects that help us organize large amounts of information

- Lecture 7 focuses on:
  - array declaration and use
  - bounds checking and capacity
  - arrays that store object references
  - variable length parameter lists
  - multidimensional arrays
  - the `ArrayList` class

Outline

➡ Declaring and Using Arrays

Arrays of Objects

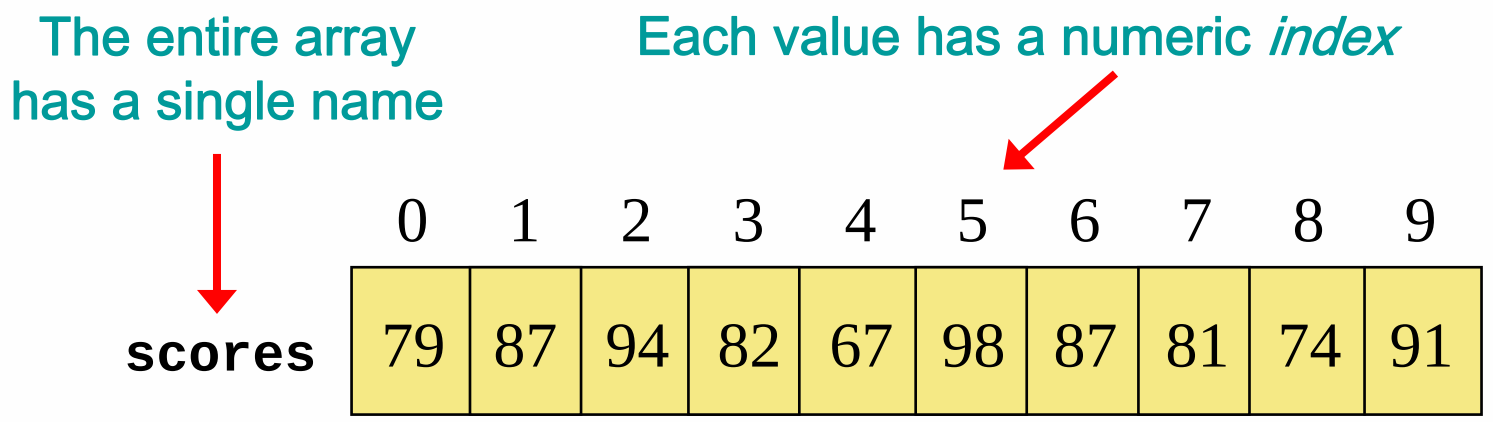
Variable Length Parameter Lists

Two-Dimensional Arrays

The `ArrayList` Class

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 :

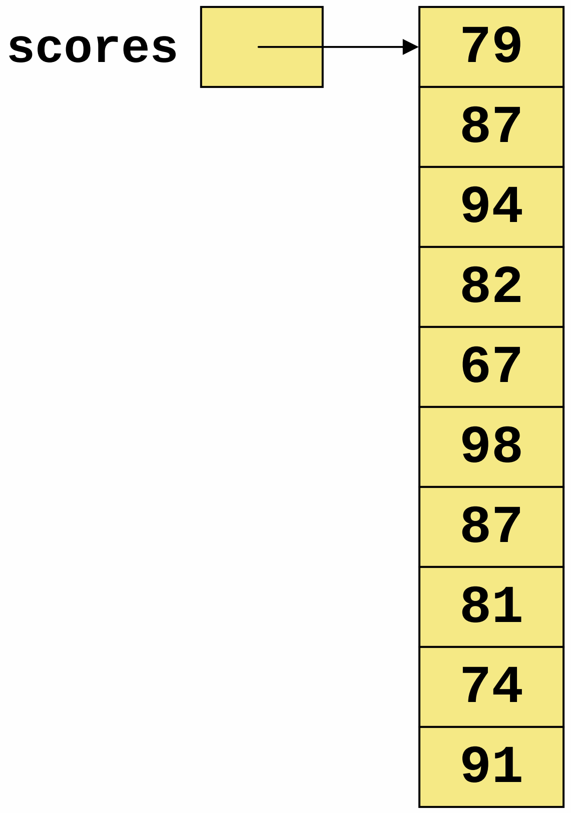
```
scores[2] = 89;

scores[first] = scores[first] + 2;

mean = (scores[0] + scores[1])/2;

System.out.println ("Top = " + scores[5]);
```

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.
- In Java, the array itself is an object that must be instantiated

Arrays

- 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:**

```
float[] prices = new float[500];

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

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

Using Arrays

- The iterator 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 from top (lowest index) to bottom (highest index)

- See `BasicArray.java` (page 372)

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 using only the numbers 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` (page 375)
- See `LetterCount.java` (page 376)

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:

```
float[] prices;

float 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[] letterGrades = {'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 initializer list
- An initializer list can be used only in the array declaration
- See `Primes.java` (page 381)

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

Outline

Declaring and Using Arrays

➡ Arrays of Objects

Variable Length Parameter Lists

Two-Dimensional Arrays

The `ArrayList` Class

Arrays of Objects

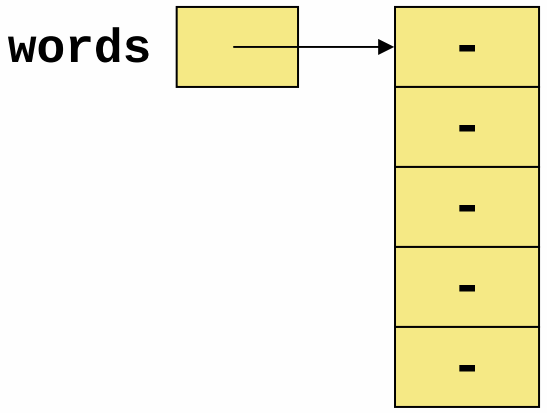
- The elements of an array can be object references
- The following declaration reserves space to store 5 references to `String` objects

```
String[] words = new String[5];
```

- It does NOT create the `String` objects themselves
- Initially an array of objects holds `null` references
- Each object stored in an array must be instantiated separately

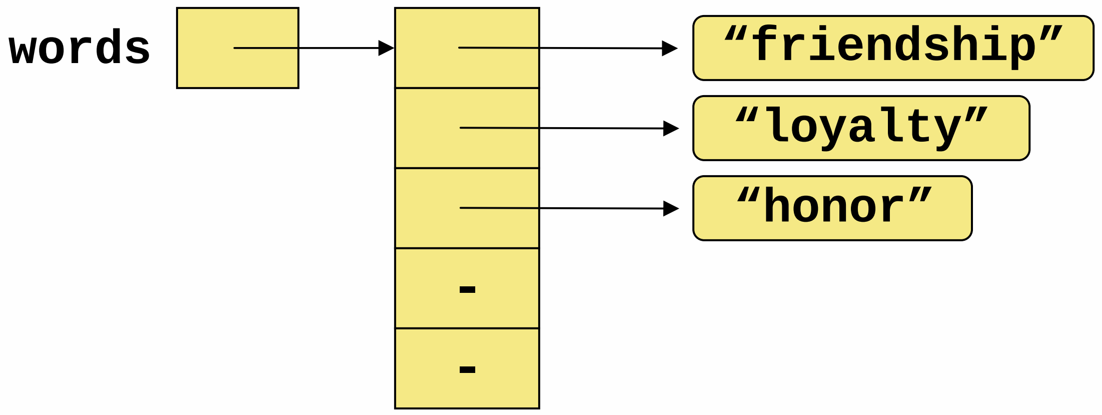
Arrays of Objects

- The `words` array when initially declared:



Arrays of Objects

- After some `String` objects are created and stored in the array:



Arrays of Objects

- Keep in mind that `String` objects can be created using literals

- The following declaration creates an array object called `verbs` and fills it with four `String` objects created using string literals

```
String[] verbs = {"play", "work", "eat", "sleep"};
```

Arrays of Objects

- The following example creates an array of `Grade` objects, each with a string representation and a numeric lower bound

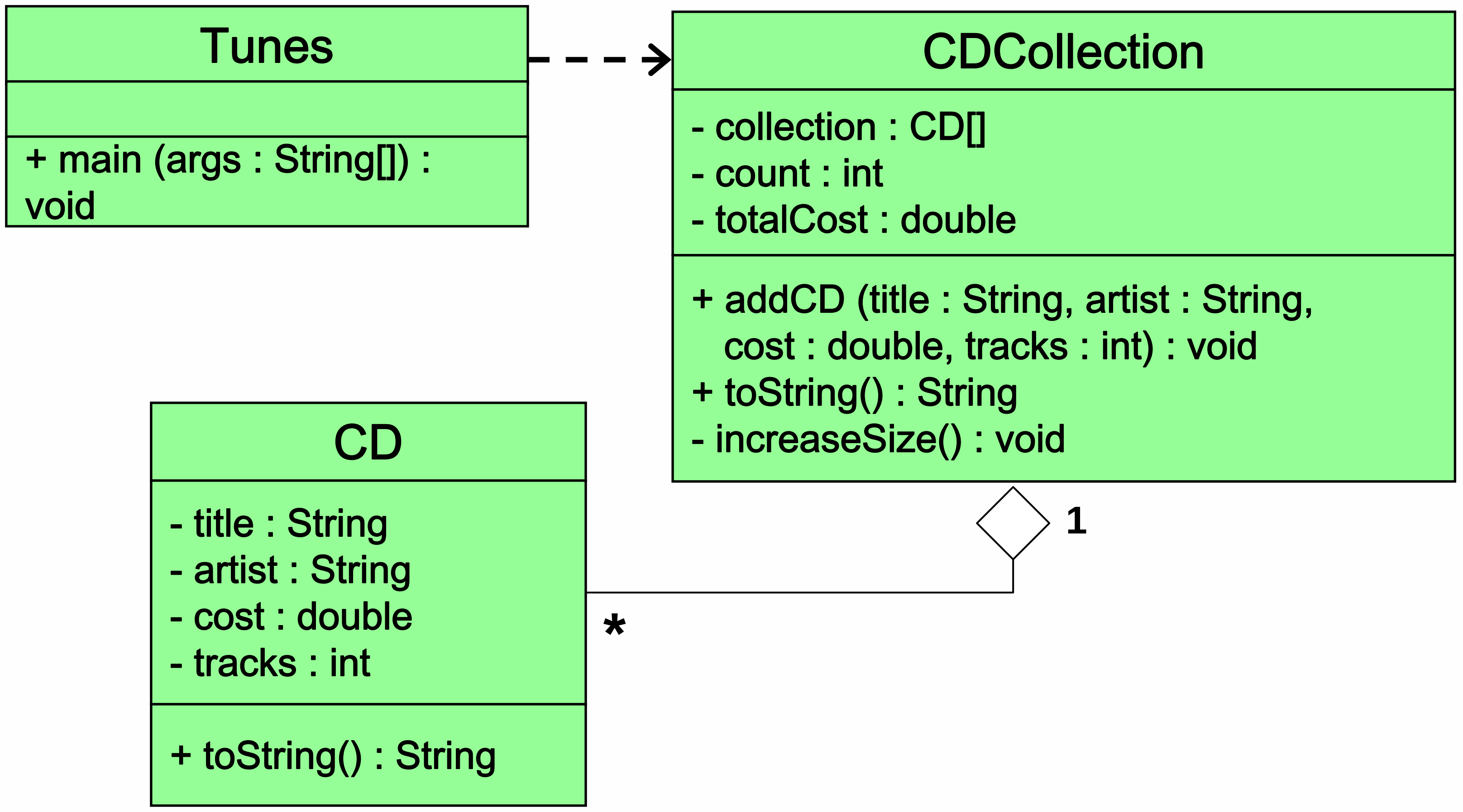
- See `GradeRange.java` (page 384)
- See `Grade.java` (page 385)

- Now let's look at an example that manages a collection of `CD` objects

- See `Tunes.java` (page 387)
- See `CDCollection.java` (page 388)
- See `CD.java` (page 391)

Arrays of Objects

- A UML diagram for the Tunes program:



Command-Line Arguments

- The signature of the `main` method indicates that it takes an array of `String` objects as a parameter
- These values come from *command-line arguments* that are provided when the interpreter is invoked
- For example, the following invocation of the interpreter passes three `String` objects into `main`:

```
> java StateEval pennsylvania texas arizona
```

- These strings are stored at indexes 0-2 of the array parameter of the `main` method
- See `NameTag.java` (page 393)

Outline

Variable Length Parameter Lists

- Suppose we wanted to create a method that processed a different amount of data from one invocation to the next
- For example, let's define a method called `average` that returns the average of a set of integer parameters

```
// one call to average three values
mean1 = average (42, 69, 37);

// another call to average seven values
mean2 = average (35, 43, 93, 23, 40, 21, 75);
```

Variable Length Parameter Lists

- **We could define overloaded versions of the `average` method**
  - **Downside: we'd need a separate version of the method for each parameter count**
- **We could define the method to accept an array of integers**
  - **Downside: we'd have to create the array and store the integers prior to calling the method each time**
- **Instead, Java provides a convenient way to create *variable length parameter lists***

Variable Length Parameter Lists

- Using special syntax in the formal parameter list, we can define a method to accept any number of parameters of the same type
- For each call, the parameters are automatically put into an array for easy processing in the method

Indicates a variable length parameter list

```
public double average (int ... list)
{
   // whatever
}
```

element type

array name

Variable Length Parameter Lists

```
public double average (int ... list)
{
   double result = 0.0;

   if (list.length != 0)
   {
      int sum = 0;
      for (int num : list)
         sum += num;
      result = (double)num / list.length;
   }

   return result;
}
```

Variable Length Parameter Lists

- The type of the parameter can be any primitive or object type

```
public void printGrades (Grade ... grades)
{
   for (Grade letterGrade : grades)
      System.out.println (letterGrade);
}
```

Variable Length Parameter Lists

- A method that accepts a variable number of parameters can also accept other parameters
- The following method accepts an `int`, a `String` object, and a variable number of `double` values into an array called nums

```
public void test (int count, String name,
                  double ... nums)
{
   // whatever
}
```

Variable Length Parameter Lists

- The varying number of parameters must come last in the formal arguments
- A single method cannot accept two sets of varying parameters
- Constructors can also be set up to accept a variable number of parameters
- See `VariableParameters.java` (page 396)
- See `Family.java` (page 397)

Outline

Declaring and Using Arrays

Arrays of Objects

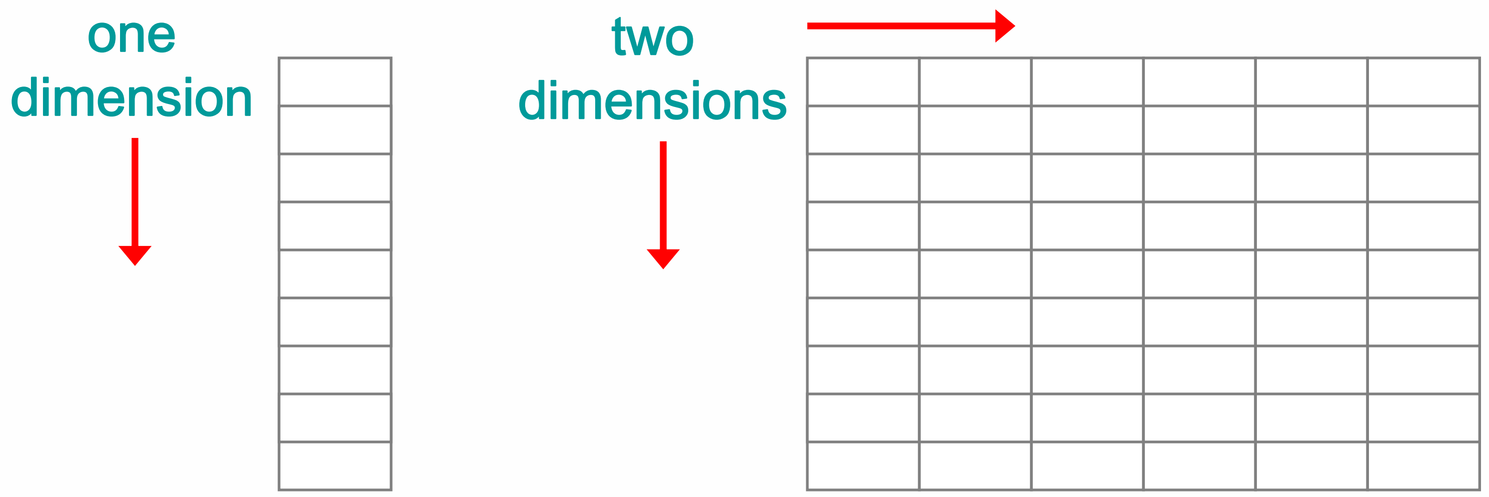
Variable Length Parameter Lists

→ Two-Dimensional Arrays

The `ArrayList` Class

Two-Dimensional Arrays

- A *one-dimensional array* stores a list of elements
- A *two-dimensional array* can be thought of as a table of elements, with rows and columns



Two-Dimensional Arrays

- **To be precise, in Java a two-dimensional array is an array of arrays**
- **A two-dimensional array is declared by specifying the size of each dimension separately:**

```
int[][] scores = new int[12][50];
```

- **A array element is referenced using two index values:**

```
value = scores[3][6]
```

- **The array stored in one row can be specified using one index**

Two-Dimensional Arrays

Expression	Type	Description
`table`	`int[][]`	2D array of integers, or array of integer arrays
`table[5]`	`int[]`	array of integers
`table[5][12]`	`int`	integer

- See `TwoDArray.java` (page 399)
- See `SodaSurvey.java` (page 400)

Multidimensional Arrays

- **An array can have many dimensions – if it has more than one dimension, it is called a *multidimensional array***
- **Each dimension subdivides the previous one into the specified number of elements**
- **Each dimension has its own `length` constant**
- **Because each dimension is an array of array references, the arrays within one dimension can be of different lengths**
  - **these are sometimes called *ragged arrays***

Outline

Declaring and Using Arrays

Arrays of Objects

Variable Length Parameter Lists

Two-Dimensional Arrays

➡ The `ArrayList` Class

The ArrayList Class

- **The `ArrayList` class is part of the `java.util` package**
- **Like an array, it can store a list of values and reference each one using a numeric index**
- **However, you cannot use the bracket syntax with an `ArrayList` object**
- **Furthermore, an `ArrayList` object grows and shrinks as needed, adjusting its capacity as necessary**

The ArrayList Class

- Elements can be inserted or removed with a single method invocation
- When an element is inserted, the other elements "move aside" to make room
- Likewise, when an element is removed, the list "collapses" to close the gap
- The indexes of the elements adjust accordingly

The ArrayList Class

- An `ArrayList` stores references to the `Object` class, which allows it to store any kind of object
- See `Beatles.java` (page 405)
- We can also define an `ArrayList` object to accept a particular type of object
- The following declaration creates an `ArrayList` object that only stores `Family` objects

```
ArrayList<Family> reunion = new ArrayList<Family>
```

- This is an example of *generics*, which are discussed further in Chapter 12

ArrayList Efficiency

- The `ArrayList` class is implemented using an underlying array
- The array is manipulated so that indexes remain continuous as elements are added or removed
- If elements are added to and removed from the end of the list, this processing is fairly efficient
- But as elements are inserted and removed from the front or middle of the list, the remaining elements are shifted

Summary

- **Lecture 7 has focused on:**
  - **array declaration and use**
  - **bounds checking and capacity**
  - **arrays that store object references**
  - **variable length parameter lists**
  - **multidimensional arrays**
  - **the `ArrayList` class**